MAS6505

Piezoresistive Sensor Signal Interface IC

- **Optimized for Piezoresistive Pressure Sensors**
- **Very Low Power Consumption**
- **1.71V Supply Voltage Operation**
- **Very Low Noise Analog Front-End**
- **Ratiometric ΔΣ ADC**
- **SPI and I2C Serial Buses**
- **512 Bit EEPROM Calibration Memory**

DESCRIPTION

MAS6505 is a piezoresistive sensor signal interface IC with a low noise analog front-end (AFE) and an Analog-to-Digital Converter (ADC). The AFE comprises of a low noise chopper amplifier with 32 selectable gain options from 1x up to 55.8x and an input signal polarity selection. The ADC employs delta-sigma (ΔΣ) A/D conversion technique with seven oversampling ratio (OSR) options for optimization between speed, power consumption and resolution. The ADC's 1-sigma noise resolution is up to 17.9 bits in the 1400 mV input signal range (ISR) of the ADC. Additionally the ADC has eight input offset options with both polarities to match input signal range with different sensor signals. The sensor input 1-sigma noise resolution is down to 0.27 µVrms which can be further reduced with four digital low pass filtering options.

MAS6505 has one input channel suitable for a piezoresistive pressure sensor. In addition to pressure measurement the device can be configured for temperature measurement. The temperature can be measured either by sensing temperature dependence of the sensor bridge resistance or using an external temperature sensing diode. The gain and offset settings can be configured independently for the both measurements.

MAS6505 is designed especially to meet the requirement for low power consumption, thus making it an ideal choice for battery powered systems. Overall current consumption values from 1.2 µA up to 22 µA (one pressure and temperature A/D conversion in a second) can be achieved depending on selected resolution setting.

A serial bus compatible with 4-wire or 3-wire SPI bus or 2-wire I2C bus is used for configuring and starting measurements and reading out the results.

The measurements can be run either at forced mode (single command based measurement) or at normal mode (automated measurements) at eight different output rates with selectable delays between measurement from 0.5ms up to 4000ms. An internal clock oscillator makes external clock unnecessary.

The 512-bit EEPROM memory is available for storing trimming and sensor calibration data on chip. MAS6505 outputs raw measurement results and calibrated and temperature compensated results need to be calculated in the application host system using the sensor calibration data.

FEATURES

- Supply Voltage 1.71 V…5.5 V
- Low Sleep Current Consumption 42nA Typ
- Very Low Operating Current 1.2 µA…22 µA Typ
- Very Low Noise Analog Front-End 0.27 µVrms
- Ratiometric ΔΣ A/D Conversion
- A/D Conversion Time 1.04 ms…33.3 ms Typ
- Sensor Resistance Range 3 kΩ ... 6 kΩ
- Seven Resolution Options by OSR Selection
- Internal Clock Oscillator
- 2-Wire Serial Data Interface (I2C Bus)
- 4- and 3-Wire Serial Peripheral Interface Bus
- 512 Bit EEPROM Memory

APPLICATIONS

- Digital Piezoresistive Pressure Modules
- Altimeter and Barometer
- Temperature measurement
- Battery Powered Systems
- Navigation systems
- Industrial and Process Control Applications

BLOCK DIAGRAM

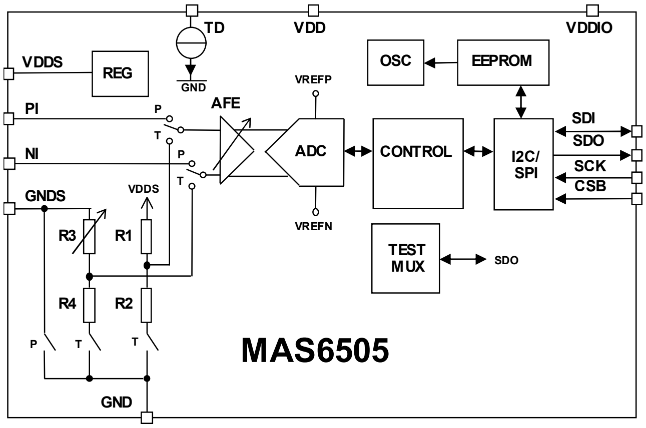


Figure 1. MAS6505 block diagram

ABSOLUTE MAXIMUM RATINGS

All Voltages with Respect to Ground (GND)

Parameter	Symbol	Conditions	Min	Max	Unit
Supply Voltage	V_{DD}		-0.3	7.0	V
Serial Bus Voltage	V_{DDIO}		-0.3	7.0	V
Serial Bus Pins		SDI, SDO, SCK, CSB	-0.3	V_{DDIO} + 0.3 or 7.0V whichever is smaller	V
Sensor Pins		VDDS, PI, NI, GNDS, TD, Note 1.	-0.3	2.3V	V
Latchup Current Limit	I_{LUT}	For all pins, test according to JESD78A.	-100	+100	mA
Junction Temperature	T_{Jmax}			+ 150	°C
Storage Temperature	T_S	Note 2	- 50	+125	°C
ESD Rating	V_{HBM}	Note 3	±2000		V
	V_{CDM}	Note 4	±500V		V

Note: The absolute maximum rating values are stress ratings only. Functional operation of the device at conditions between maximum operating conditions and absolute maximum ratings is not implied and EEPROM contents may be corrupted. Exposure to these conditions for extended periods may affect device reliability (e.g. hot carrier degradation, oxide breakdown). Applying conditions above absolute maximum ratings may be destructive to the devices.
Note: This is a CMOS device and therefore it should be handled carefully to avoid any damage by static voltages (ESD).
Note 1: Voltage rating applies to TD pin when an external temperature sensing diode or test mode STEST=1001 is selected. In other operating modes the TD pin voltage rating is 7.0V.
Note 2: See EEPROM memory data retention at hot temperature. Storage or bake at hot temperatures will reduce wafer level trimming and calibration data retention time.
Note 3: JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
Note 4: JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

RECOMMENDED OPERATION CONDITIONS

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Supply Voltage	V_{DD}	A/D conversions EEPROM read EEPROM write, Note 1	1.71 1.71 4.5	1.8 1.8 5.0	5.5 5.5 5.5	V
Serial Bus Voltage	V_{DDIO}		1.2	1.8	5.5	V
Operating Temperature	T_A		-40	+25	+90	°C
EEPROM Write Temperature	T_A	Note 1	+10	+25	+40	°C

Note 1: EEPROM write operation requires typical 5.0V supply voltage but EEPROM read operation has wide supply voltage range from 1.71V to 5.5V. EEPROM write operation is recommended to be done at room temperature.

ELECTRICAL CHARACTERISTICS

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = VDDIO = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Regulated Sensor Bridge Supply Voltage	V_{DDS}		1.62	1.68	1.74	V
Sleep current	I_{DD_SLEEP}	All inputs at VDD, no load. T=25°C. Note 1.		0.024	0.15	µA
Standby current	I_{DD_STB}	All inputs at VDD, no load. T=25°C. Note 2.		4.1	10	µA
EEPROM Activated (Regulator ON)	I_{DD_EON}	EON=010 or 101 T=25°C. Note 3.		71	130	µA
A/D Conversion Current Consumption (excluding sensor current)	$I_{DD\_CONV\_P}$ $I_{DD\_CONV\_TR}$ $I_{DD\_CONV\_TD}$	Pressure mode Temperature bridge mode Temperature diode mode T=25°C		280 350 220	420 520 330	µA
External Temperature Sensing Diode Bias Current	I_{TD}	T=25°C	7	10	13	µA
Peak Supply Current During Pressure Measurement	$I_{DD\_PEAK\_P}$	R_{SENSOR} = 6 kΩ		0.6		mA
Peak Supply Current During Temperature Measurement	$I_{DD\_PEAK\_TR}$ $I_{DD\_PEAK\_TD}$	Bridge sensing (R_{SENSOR} = 6kΩ) External diode sensing		0.53 0.26		mA
Average Current in Pressure Measurement (incl. sensor current)	$I_{DD\_AVG\_P}$	GAINP<>1 OSRP = ¼ OSRP = ½ OSRP = 1 OSRP = 2 OSRP = 4 OSRP = 8 OSRP = 16, note 4		 0.6 0.9 1.5 2.8 5.2 10 20		µA
Average Current in Temperature Measurement (incl. sensor current)	$I_{DD\_AVG\_TR}$	Bridge temperature sensing GAINT<>1 OSRP = ¼ OSRP = ½ OSRT = 1 OSRT = 2 OSRT = 4 OSRT = 8 OSRT = 16, note 4		 0.55 0.59 1.4 2.0 3.9 7.7 15		µA
	$I_{DD\_AVG\_TD}$	Diode temperature sensing GAINT=1, SGNGAINT=1, OFST=-28% OSRP = ¼ OSRP = ½ OSRT = 1 OSRT = 2 OSRT = 4 OSRT = 8 OSRT = 16, note 4		 0.27 0.40 0.67 1.2 2.3 4.4 8.7		µA

Note 1. Leakage current may increase if digital input voltages are not close to VDD (logic high) or GND (logic low).

Note 2. Standby current is an extra current that is drawn only in the normal mode (MODE=11)

Note 3. Activating EEPROM (EON=010 or 101) turns on internal regulator. To minimize current consumption the EEPROM should be kept inactive (EON=000) in any other time when not used.

Note 4. Current consumption values are from forced mode at measurement rate 1Hz.

ELECTRICAL CHARACTERISTICS

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = VDDIO = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Average Current in Temperature + Pressure Measurement (incl. sensor current)	$I_{DD\_AVG\_P\&TR}$	Bridge temperature sensing, GAINP<>1, GAINT<>1, note 1 OSRP = ¼, OSRT= ¼ OSRP = ½, OSRT= ½ OSRP = 1, OSRT = 1 OSRP = 2, OSRT = 1 OSRP = 4, OSRT = 1 OSRP = 8, OSRT = 1 OSRP = 16, OSRT = 2		1.2 1.5 2.9 4.1 6.6 12 22		µA
	$I_{DD\_AVG\_P\&TD}$	Diode temperature sensing GAINP<>1, GAINT=1, note 1 OSRP = ¼, OSRT= ¼ OSRP = ½, OSRT= ½ OSRP = 1, OSRT = 1 OSRP = 2, OSRT = 1 OSRP = 4, OSRT = 1 OSRP = 8, OSRT = 1 OSRP = 16, OSRT = 2		0.9 1.3 2.2 3.4 5.9 11 21		µA
Internal Clock Oscillator Frequency	f_{OSC}		240	250	260	kHz
Internal System Clock Frequency	f_{MCLK}		120	125	130	kHz
Single A/D Conversion Time	t_{CONV_X}	OSRx = ¼ OSRx = ½ OSRx = 1 OSRx = 2 OSRx = 4 OSRx = 8 OSRx = 16, x = P or T	0.96 1.45 2.44 4.41 8.35 16.22 31.98	1.04 1.55 2.58 4.62 8.72 16.91 33.3	1.16 1.70 2.76 4.90 9.16 17.7 34.76	ms
Single Temperature and Pressure A/D Conversion Time	$t_{CONV\_T\&P}$	OSRP = ¼, OSRT= ¼ OSRP = ½, OSRT= ½ OSRP = 1, OSRT = 1 OSRP = 2, OSRT = 1 OSRP = 4, OSRT = 1 OSRP = 8, OSRT = 1 OSRP = 16, OSRT = 2	1.96 2.95 4.91 6.88 10.82 18.7 36.42	2.11 3.13 5.18 7.23 11.32 19.51 37.95	2.25 3.31 5.45 7.58 11.85 20.38 39.58	ms
ADC Noise Resolution	V_{N_ADC}	V_{IN}=0V, GAINx=1 OSRx = ¼ OSRx = ½ OSRx = 1 OSRx = 2 OSRx = 4 OSRx = 8 OSR_x = 16 x = P or T, notes 2 and 3		43 (15) 31 (15.5) 22 (15.9) 15 (16.5) 11 (16.9) 7.9 (17.4) 5.7 (17.9)		μV_{RMS} (bit)

Note 1. Current consumption values are from forced mode at measurement rate 1Hz.

Note 2. GAINx=1 (x=P or T) setting bypasses the AFE amplifier and connects input signal directly to the ADC input.

Note 3. ADC resolution in bits is calculated as follows: V_N[bit] = log(1400mV / V_N)/log(2) when V_N is the RMS noise voltage at the input.

ELECTRICAL CHARACTERISTICS

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = VDDIO = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Sensor Input Noise Resolution in Pressure Measurement	$V_{N\_IN\_P}$	V_{IN}=0V GAINP=14.9 (23.5dB) OSRP = ¼ OSRP = ½ OSRP = 1 OSRP = 2 OSRP = 4 OSRP = 8 OSRP = 16, note 1		 3.7 (14.6) 2.6 (15.1) 1.8 (15.7) 1.2 (16.3) 0.84 (16.8) 0.63 (17.2) 0.44 (17.7)		μV_{RMS} (bit)
		V_{IN}=0V GAINP=55.8 (34.9dB) OSRP = ¼ OSRP = ½ OSRP = 1 OSRP = 2 OSRP = 4 OSRP = 8 OSRP = 16, note 1		 2.3 (13.4) 1.5 (14) 0.98 (14.6) 0.72 (15.1) 0.52 (15.6) 0.36 (16.1) 0.27 (16.5)		μV_{RMS} (bit)
Sensor Input Noise Resolution in Sensor Bridge Temperature Measurement	$V_{N\_IN\_TR}$	GAINT=14.9 (23.5dB) OSRT = ¼ OSRT = ½ OSRT = 1 OSRT = 2 OSRT = 4 OSRT = 8 OSRT = 16, note 1		 6.3 (13.9) 5.3 (14.1) 4.4 (14.4) 3.6 (14.7) 3 (14.9) 2.5 (15.2) 2.1 (15.4)		μV_{RMS} (bit)
Sensor Input Noise Resolution in External Diode Temperature Measurement	$V_{N\_IN\_TD}$	GAINT=1 (0dB), SGNGAINT=1 OSRT%= -28% OSRT = ¼ OSRT = ½ OSRT = 1 OSRT = 2 OSRT = 4 OSRT = 8 OSRT = 16, notes 1 and 2		 46 (14.9) 35.2 (15.3) 26.9 (15.7) 20.5 (16.1) 15.6 (16.5) 11.9 (16.8) 9.1 (17.2)		μV_{RMS} (bit)

Note 1. Resolution in bits is calculated as follows: V_N_[bit] = log(1400mV / GAINx / V_N)/log(2) when V_N is the RMS noise voltage at the input and x=P or T.

Note 2. To avoid signal clipping GAINT=1, SGNGAINT=1 and OFST%= -28% settings must be used in external diode temperature measurement

.

ELECTRICAL CHARACTERISTICS

T_A = -40°C to +90°C, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = VDDIO = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
ADC Linearity	INL_{ADC}	GAINx=1 OSRx = ¼ OSRx = ½ OSRx = 1 OSRx = 2 OSRx = 4 OSRx = 8 OSRx = 16 x = P or T, note 1		 3700 (11.2) 760 (13.5) 260 (15.1) 310 (14.8) 360 (14.6) 330 (14.7) 260 (15.1)		LSB (bit)
Sensor Input Linearity	INL_{AFE}	GAINx=4.7 V_{IN}=$V_{IN\_LIN\_MIN}$...$V_{IN\_LIN\_MAX}$ OSRx = ¼ OSRx = ½ OSRx = 1 OSRx = 2 OSRx = 4 OSRx = 8 OSRx = 16 x = P or T, note 1		 3800 (11.2) 610 (13.8) 340 (14.7) 470 (14.2) 510 (14.1) 460 (14.3) 430 (14.4)		LSB (bit)
ADC VDD Sensitivity	$VDD_{SENSADC}$	GAINx=1, OSRx = 16, V_{IN}=$V_{IN\_LIN\_MIN}$...$V_{IN\_LIN\_MAX}$ Note 2		±0.0008		%FS/V
ADC Input Signal Range	ISRADC	VDDS=1.68V		1400		mVpp
ADC Linear Input Signal Range	ISRLINADC	VDDS=1.68V 10%...90% (80%) of ISRADC		1120		mVpp
Full Scale Output Code Range Values	CODEFS		0		11184810	-
Linear Range Output Code Values (10%...90% of Full Scale Code Range)	CODELIN		1118481		10066329	-
EEPROM size		Note 3		512		bit
EEPROM data write time		Note 4			13	ms
EEPROM data retention		T_A = +125 °C, AEC-Q100-005, Note 5	20			years

Note 1. Linearity in bits is calculated from output code as follows: INL [bit] = log(80%*$CODEFS_{MAX}$ / INL)/log(2) when integral nonlinearity (INL) is calculated from best fit line to linear input signal range containing 21 pcs analysis points.

Note 2. VDD is stepped from 1.8V to 3.6V and VDD sensitivity in %FS/V calculated as

VDD_{SENS} =100%*(CODE(VDD=3.6V) –CODE(VDD=1.8V))/CODEFS/(3.6V-1.8V)

Note 3. 48 bits out of 512 bits are reserved for internal EEPROM oscillator and clock oscillator trim values, temperature and pressure measurement gain and offset configurations and sensor resistance trim values. The remaining 464 bits can be freely used for storing calibration coefficients and other data.

Note 4. There should be at least a 13ms delay after each EEPROM write since EEPROM programming can take up to 13ms.

Note 5. Data retention values apply when extended EEPROM tests are done. Please contact Micro Analog Systems Oy if the data retention values here need to be guaranteed by comprehensive EEPROM testing.

ELECTRICAL CHARACTERISTICS

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = VDDIO = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Temperature Measurement Resistors	R_1 R_2 R_4	T=+25°C	-30%	12000 12000 12000	+30%	Ω
	R_3	RSENSOR=0000 RSENSOR=0001 RSENSOR=0010 RSENSOR=0011 RSENSOR=0100 RSENSOR=0101 RSENSOR=0110 RSENSOR=0111 RSENSOR=1000 RSENSOR=1001 RSENSOR=1010 RSENSOR=1011 RSENSOR=1100 RSENSOR=1101 RSENSOR=1110 RSENSOR=1111	-30%	10110 9890 9644 9370 9064 8722 8340 7914 7438 6907 6314 5652 4912 4087 3166 2137	+30%	Ω
Temperature Coefficient of Temperature Measurement Resistors	TC_R			-70		ppm/°C

Digital inputs

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Input High Voltage	V_{IH}		80% VDD		100% VDD	V
Input Low Voltage	V_{IL}		0% VDD		20% VDD	V
Pull Up Current	I_{IL_CSB}	CSB pin, VDD=1.8V		-6.3		µA
Serial Bus Clock Frequency	f_{SCK}	I2C bus SPI bus			400 2	kHz MHz

Digital outputs

T_A = -40ºC to +90ºC, VDD = 1.71V to 5.5V, Typ T_A = 25°C, Typ VDD = 1.8 V, Typ VDDS = 1.68 V, R_{SENSOR} = 6kΩ unless otherwise noted

Parameter	Symbol	Conditions	Min	Typ	Max	Unit
Output high voltage	V_{OH}	I_{Source}=0.6mA	80% VDD		100% VDD	V
Output low voltage	V_{OL}	I_{Sink}=0.6mA	0% VDD		20% VDD	V
Signal rise time (from 10% to 90%)	t_r	SDI pin, C_B=50pF		550		ns
Signal fall time (from 90% to 10%)	t_f	SDI pin, C_B=50pF		11		ns

FUNCTIONAL DESCRIPTION

♦ Power on reset

The MAS6505 has power on reset (POR) circuitry which resets the device into standby mode after both power supplies VDD and VDDIO have risen to sufficient levels. The VDD is supply voltage for analog and digital blocks and the VDDIO is supply voltage for the digital I2C and SPI serial bus interface. There are no limitations for the slope and sequence of raising of the VDD and VDDIO supplies.

However it is recommended to reset the device manually after every power up to make sure it is reset properly. This is accomplished via serial bus by writing any data byte to the Reset register ($EC/6C_{HEX}$). See table 1 for MAS6505 memory addresses. The POR or writing to the Reset register will reset all registers from $ED/6D_{HEX}$ to $FF/7F_{HEX}$ to a zero (00_{HEX}) value.

♦ Digital interface selection

The MAS605 supports I2C and SPI digital interfaces. The I2C interface is a 2-wire serial bus which is selected by leaving the CSB pin unconnected (floating) or by connecting it to VDDIO. The CSB pin has internal 250 kΩ pull-up resistor to VDDIO. Note: The 2-wire I2C bus of MAS6505 supports only basic I2C bus communication protocol but not for example 10-bit addressing, arbitration and clock stretching features of the I2C bus specification.

The SPI interface supports 3-wire and 4- wire serial bus communication. Selection between 3- and 4-wire SPI bus modes is done by WIRE bit in the Configuration register ($EE/6E_{HEX}$). See table 3. After power up the WIRE=0 which selects the 4-wire SPI bus mode. To select 3-wire SPI bus mode it is necessary to first set WIRE=1 by writing to the Configuration register.

The SPI communication is selected by pulling the CSB pin low. It has an additional SPI mode lock in feature. By pulling CSB low and giving at least four SCK clock pulses makes the digital interface to lock into SPI communication mode. This is done in order to avoid inadvertently decoding SPI traffic to another slave device as I2C data. After entering SPI lock mode the I2C communication is possible only after applying power on reset.

FUNCTIONAL DESCRIPTION (continued)

♦ Operating modes

Only two registers are needed for configuring and running the measurements. The Configuration register ($EE/6E_{HEX}$) contains only measurement configuration settings. See table 3. The Control register ($EF/6F_{HEX}$) contains measurement and operating mode selection settings. Writing to Control register starts the selected measurements. See table 4.

MAS6505 has three selectable operating modes; sleep mode, forced mode (single command based measurement) and normal mode (automated measurements). The operating mode is selected by MODE bits in the Control register ($EF/6F_{HEX}$).

In the sleep mode (MODE=00) the device does not perform any measurements and only a very small sleep current is drawn from the supplies.

In the forced mode (MODE=01, 10) selected measurements are run only once after which the device returns automatically to the sleep mode. Every new measurement requires writing a new forced mode command into the Control register. In the forced mode an internal clock oscillator is turned on only during the measurement. The forced mode is recommended in applications that use low measurement rate or require host based synchronization of measurements.

In the normal mode (MODE=11) selected measurements are performed automatically in a loop at a selected rate until the sleep mode (MODE=00) is selected. Normal mode measurement cycle comprises of a measurement and a standby period. Selected measurements are performed during the measurement period. To minimize current consumption the device enters standby mode for the time between measurements during which only the internal clock oscillator is running. The standby mode time is defined by a DELAY bit setting in the Configuration register ($EE/6E_{HEX}$). There are eight delay settings available; 0.5ms, 62.5ms, 125ms, 250ms, 500ms, 1000ms, 2000ms and 4000ms. The normal mode measurement cycle is a sum of selected measurements' A/D conversion time and the delay setting. See figure 2 for normal mode measurement cycle illustration. The normal mode is recommended in applications where IIR filter is used like for filtering short-term sensor signal disturbances.

Selection of temperature and pressure measurements and their resolution can be done independently using OSRT and OSRP oversampling ratio settings in the Control register ($EF/6F_{HEX}$). Each oversampling ratio has seven settings 1/4x, 1/2x, 1x, 2x, 4x, 8x and 16x in addition to no measurement setting. The highest value setting gives highest resolution but it has the longest A/D conversion time and the highest power consumption. Similar way the lowest value setting gives the lowest resolution but it has the shortest A/D conversion time and the lowest power consumption. Thus the multiple oversampling ratio settings allow optimizing measurements between speed, power consumption and resolution. See ELECTRICAL CHARACTERISTICS on pages 3-7.

♦ Digital IIR low pass filter

The Configuration register ($EE/6E_{HEX}$) has additionally selection for a digital infinite impulse response (IIR) type low pass filter option with four different filter coefficients 2, 4, 8 and 16. See table 3. The IIR low pass filter can be used to damp sudden variations in the sensor signal and to further improve noise resolution by an additional filtering of the noise. The filter does not affect output data rate but step response delay. When selected the filtering is applied to both temperature and pressure signals. The filtered temperature and pressure conversion results are stored into the Temperature result registers ($F4/74…F6/76_{HEX}$) and the Pressure result registers ($F1/71…F3/73_{HEX}$) respectively. The IIR filter can be applied to both forced and normal modes.

FUNCTIONAL DESCRIPTION (continued)

♦ Reading measurement results

MAS6505 pressure and temperature measurement results are 24-bit unsigned numbers each of which are stored into three 8-bit result registers. The pressure result addresses are MSB byte ($F1_{HEX}$), LSB byte ($F2_{HEX}$) and XLSB byte ($F3_{HEX}$). The temperature result addresses are MSB byte ($F4_{HEX}$), LSB byte ($F5_{HEX}$) and XLSB byte ($F6_{HEX}$).
MAS6505 A/D conversion and result status can be monitored from Status register ($F0_{HEX}$) which contains RDYT and RDYP flags to indicate when there are unread temperature (T) and/or pressure (P) measurement results available in the pressure and temperature result registers. See figure 2 and table 7. The corresponding RDYx (x=T or P) flag is set (1) when a new measurement is ready for a read. Reading the measurement result will clear (0) the corresponding RDYx (x=T or P) flag.

The decision when to read measurement results can be made by polling the Status register and waiting until the flag(s) of selected measurement(s) (RDYT and/or RDYP flags) have been set high. This method can be used in both forced and normal modes. In forced mode an another choice is to wait at least maximum A/D conversion time before reading the result. See also figure 3 for Calibrated MAS6505 sensor system measurement flow. In normal mode it is also possible to read results at a rate when new results are expected to be ready. This is possible since MAS6505 has internal A/D conversion result memory buffer. If new result is finished during read of result registers the new value is updated result registers only after the serial bus communication has been released. **Important note: In normal mode the results must be always read using incremental read** (all three bytes of each result or all six bytes of both results at single read sequence) to maintain A/D conversion data consistency. See table 15 example of the incremental read in chapter 2-wire serial data interface (I2C bus). The incremental read is recommended to be used also in the forced mode.

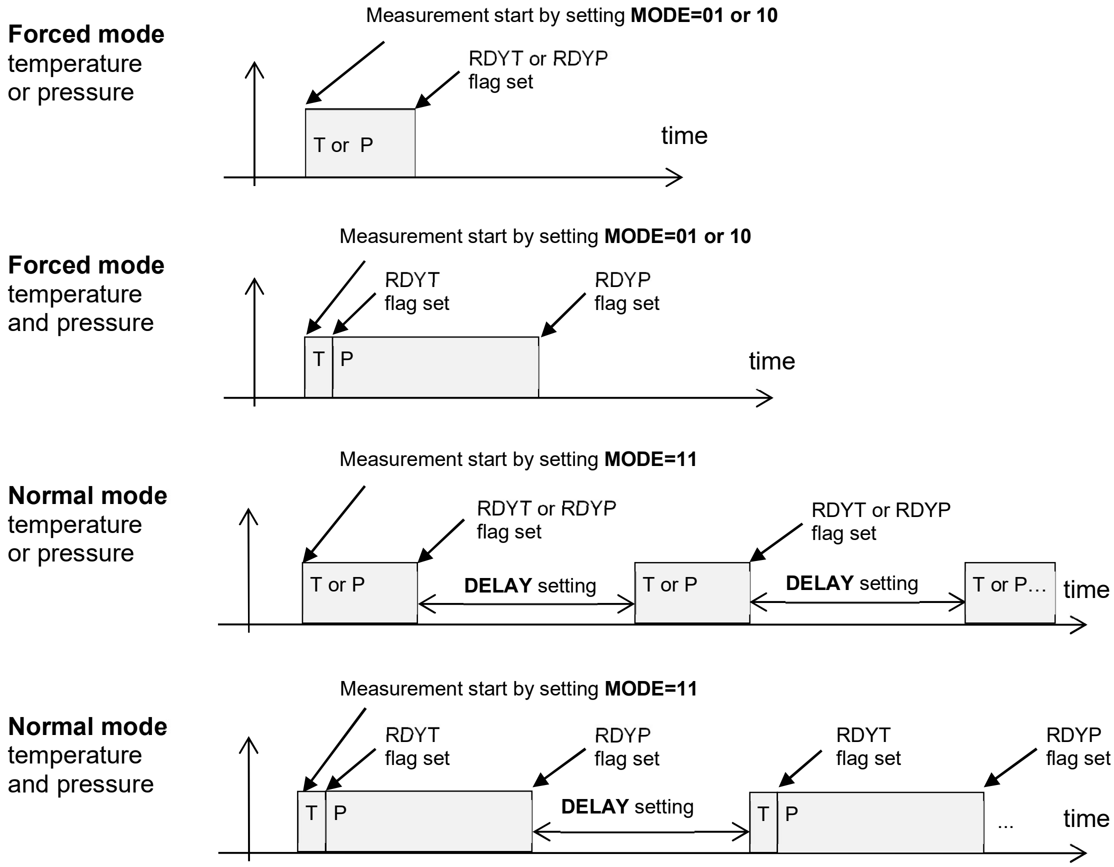


Figure 2. Forced and normal mode measurement and status register RDYT and RDYP flag update timing (T=temperature, P=pressure)

FUNCTIONAL DESCRIPTION (continued)

♦ Trimming operating modes

MAS6505 has trimming settings for the internal clock oscillator, temperature sensing, AFE and ADC. These are needed for example to fit sensors' signals with the input range of MAS6505 and to maximize the noise performance.

There are five trimming setting registers and corresponding EEPROM addresses. See table 1. Four of these are for the AFE, ADC and temperature sensor trimming settings. See tables 7-10. The fifth is for internal clock oscillator which should be left untouched since it is factory trimmed. See table 11. The corresponding EEPROM trimming setting addresses are for storing the trimming settings to the non-volatile memory.

MAS6505 has three trimming setting operating modes which are selected by TRIM bits in the Trim and test register ($FA/7A_{HEX}$). See table 6. By default the TRIM=00 which is the normal trimming operating mode in which all the trimming settings will be automatically read to registers from the EEPROM memory in the beginning of each measurement. This guarantees that the internal clock oscillator, temperature sensing, AFE and ADC have the right trimming settings during each measurement. Thus the end user of a trimmed sensor system only needs to start measurement(s) at the selected configuration settings and read the result(s).

The other two trimming setting operating modes are only for search of the optimal trimming values. In the TRIM=01 or 10 setting only internal clock oscillator trimming setting is read from the EEPROM but the temperature sensing, AFE and ADC trimming settings are taken from the registers. This allows fast search of trimming settings via registers since the slower EEPROM write procedure is not necessary until only when the final trimming values are found. The third TRIM=11 trimming setting operating mode should not be used since it is only for factory trimming of the internal clock oscillator.

The Trim and test register ($FA/7A_{HEX}$) contains also SOSC, STEST and SCALC bit settings. These are only for testing purposes and default zero bit values should be always used (SOSC=0, STEST=0000, SCALC=0).

♦ Temperature sensing

MAS6505 supports two different temperature sensing methods. The first method is based on sensing sensor bridge resistance which changes in temperature. Nominal sensor bridge resistance values from 3 kΩ up to 6 kΩ including typical resistance tolerances are supported. However other sensor resistance values may also be possible just by choosing low or unity gain amplification at the analog front end (AFE) amplifier but at cost of reduced measurement resolution.

The second temperature sensing method is using an external temperature sensing diode. When selected the MAS6505 sinks a constant 10 µA bias current from the temperature sensing diode during the temperature measurement. The external temperature diode is connected between VDDS pin (diode anode) and TD pin (diode cathode). To avoid signal clipping GAINT=1, SGNGAINT=1 and OFST%= -28% settings must be used in external diode temperature measurement.

The temperature sensing method selection and sensor bridge resistance trimming is done using Temperature sensor configuration register ($FB/7B_{HEX}$). See table 7. The trimming value is stored into EEPROM address ($BB/3B_{HEX}$). See also chapter Sensor bridge resistance temperature sensing.

FUNCTIONAL DESCRIPTION (continued)

♦ Analog front-end and ADC trimming

The pressure and temperature sensors are interfaced with analog front-end (AFE) which comprises of a low noise chopper amplifier with 32 selectable gain options from 1x up to 55.8x and an input signal polarity selection. The amplified sensor signal is then fed to input of the delta-sigma (ΔΣ) analog-to-digital converter (ADC). The input signal range of the ratiometric ADC is ISRADC=1400 mV at the nominal sensor supply voltage VDDS=1.68 V. This corresponds to differential signal ranging from -700mV to +700mV. The ADC offers eight input offset options with both polarities to adjust to different sensor signals.

For the best resolution and to avoid signal clipping the amplifier gain and the ADC offset settings need to be trimmed optimally for both the temperature and the pressure sensor signals. In optimal cases the signal ranges of amplified sensor signals cover maximally the linear input signal range (ISRLIN) of the ADC. The ISRLIN is 10%...90% of the ISR i.e. ISRLIN = 80%*ISR = 1120 mV at VDDS=1.68 V. See further details in chapters AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS and AFE GAIN AND ADC OFFSET SELECTIONS.

MAS6505 has individual AFE and ADC trimming settings for both pressure and temperature measurement. The AFE gain and polarity for pressure is trimmed using Pressure gain trim register ($FC/7C_{HEX}$). See table 8. The corresponding EEPROM storage address is ($BC/3C_{HEX}$). The AFE gain and polarity for temperature is trimmed using Temperature gain trim register ($FD/7D_{HEX}$). See table 9. The corresponding EEPROM storage address is ($BD/3D_{HEX}$). The ADC offsets and polarities for pressure and temperature are trimmed using Temperature and pressure offset trim register ($FE/7E_{HEX}$). See table 10. The corresponding EEPROM storage address is ($BE/3E_{HEX}$).

♦ Internal clock oscillator

MAS6505 has an internal clock oscillator making external clock unnecessary. In the forced mode it is turned on only during the A/D conversions and turned off when the sleep mode is entered. In the normal mode the internal clock oscillator is turned on continuously to run selected measurements periodically.

The internal oscillator frequency is factory trimmed to 250 kHz using a 7-bit register. See table 11 for Clock oscillator frequency trim register ($FF/7F_{HEX}$). The factory trimming value has been stored into EEPROM address ($BF/3F_{HEX}$). Note: it is recommended to not touch the factory trimming value of the internal clock oscillator. The converter runs from a divided system clock which is 125 kHz.

♦ EEPROM memory

The 512-bit (64 byte) EEPROM memory is available for storing trimming and calibration data on chip. Six of the EEPROM bytes are reserved for trimming purposes. One byte is for selecting temperature sensor and trimming sensor bridge resistance that is used in sensor bridge resistance based temperature measurements. Three bytes are for trimming AFE gain and ADC offset in the pressure and temperature measurements. Two EEPROM addresses are reserved for storing factory trim values of EEPROM oscillator and internal clock oscillator. These EEPROM addresses must be left untouched. The remaining 464 bits (58 bytes) in addresses $80/00_{HEX}$ … $B9/39_{HEX}$ are free for other use such as storing sensor calibration coefficients. See table 1.

After power on reset the EEPROM is by default inactive. To use EEPROM (read or write) it needs to be first activated. To prevent accidental overwriting or erasing of the trimming and calibration memory the EEPROM write requires an additional enable setting. These EEPROM functions are controlled using EEPROM control register ($ED/6D_{HEX}$). See table 2 for EON and EWE bit settings. When activated the EEPROM draws typically 60µA current. To save current the EEPROM should be always disabled after use.

See also chapters EEPROM WRITE PROCEDURE and EEPROM READ ONLY PROCEDURE.

♦ Calibration

MAS6505 performs pressure and temperature measurements resulting raw measurement values. Thus calibrated temperature and pressure reading calculations need to be done outside in the host system by utilizing calibration coefficients that are stored into the EEPROM during sensor calibration procedure. See additional DAE6505 document regarding sensor system calibration.

CALIBRATED SENSOR SYSTEM MEASUREMENT FLOW

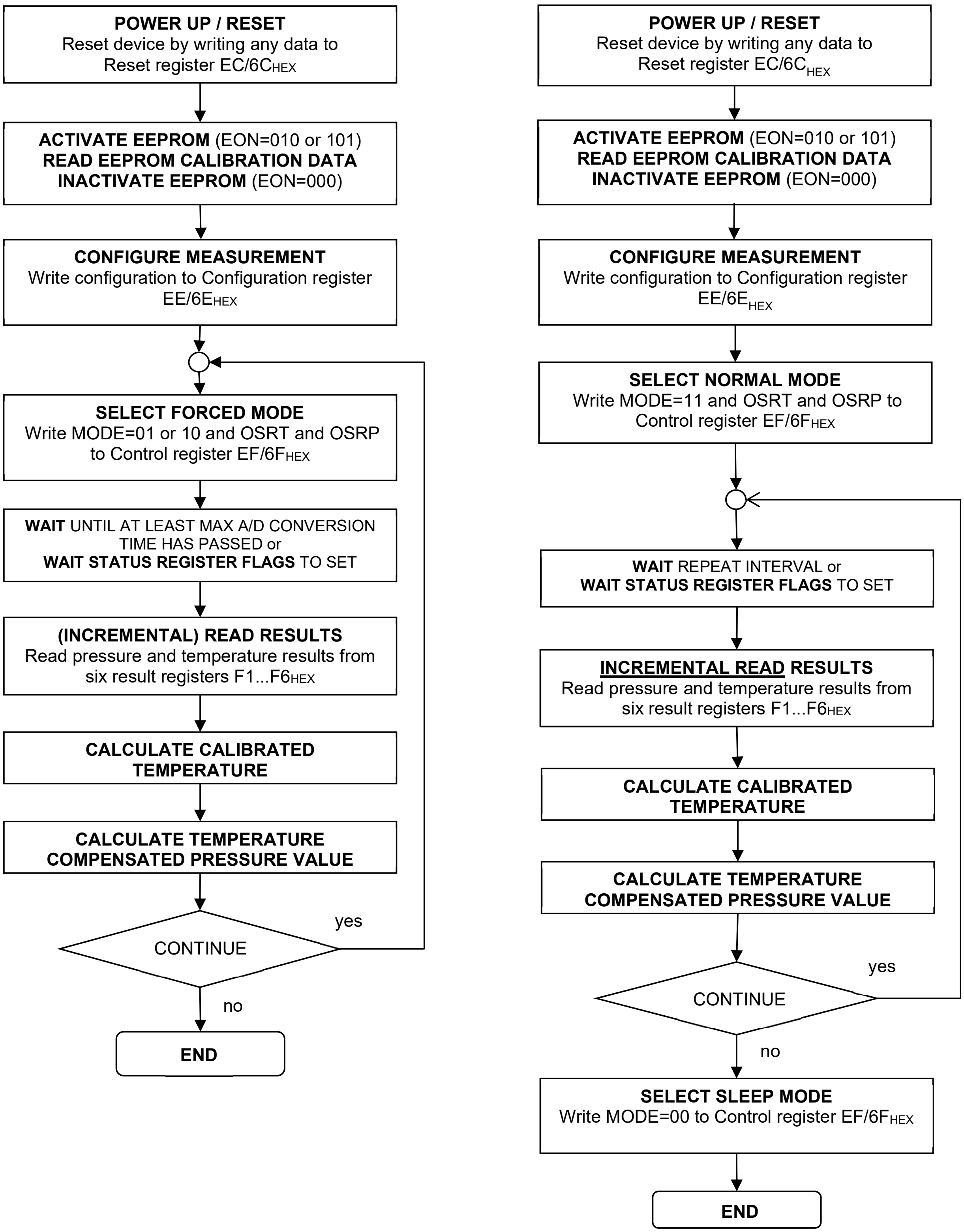


Figure 3. Flow charts for measurement flow of a calibrated MAS6505 sensor system

Figure 3 present flow charts for measurement flow of calibrated MAS6505 sensor system in both forced mode (single command based measurement) and normal mode (automated measurements).

REGISTER AND EEPROM DATA ADDRESSES

Table 1. Register and EEPROM data addresses

A7	A6	A5	A4	A3	A2	A1	A0	I2C BUS (HEX)	SPI BUS (HEX) W=write (A7=0) R=read (A7=1)	Description	Type
A7	0 … 0	0 … 1	0 … 1	0 … 1	0 … 0	0 … 0	0 … 1	80 … B9	W: 00…39 R: 80…B9	EEPROM; free for any data	E
A7	0	1	1	1	0	1	0	BA	W: 3A, R: BA	EEPROM oscillator frequency trim (factory trimmed)	E+T
A7	0	1	1	1	0	1	1	BB	W: 3B, R: BB	Temperature sensor configuration	E+T
A7	0	1	1	1	1	0	0	BC	W: 3C, R: BC	Pressure gain trim	E+T
A7	0	1	1	1	1	0	1	BD	W: 3D, R: BD	Temperature gain trim	E+T
A7	0	1	1	1	1	1	0	BE	W: 3E, R: BE	Temperature and pressure offset trim	E+T
A7	0	1	1	1	1	1	1	BF	W: 3F, R: BF	Clock oscillator frequency trim (factory trimmed)	E+T
A7	1	1	0	1	1	0	0	EC	W: 6C	Reset register; write any data for a device reset	R
A7	1	1	0	1	1	0	1	ED	W: 6D, R: ED	EEPROM control register	R
A7	1	1	0	1	1	1	0	EE	W: 6E, R: EE	Configuration register	R
A7	1	1	0	1	1	1	1	EF	W: 6F, R: EF	Control register	R
A7	1	1	1	0	0	0	0	F0	R: F0	Status register	R
A7	1	1	1	0	0	0	1	F1	R: F1	Pressure MSB byte result	R
A7	1	1	1	0	0	1	0	F2	R: F2	Pressure LSB byte result	R
A7	1	1	1	0	0	1	1	F3	R: F3	Pressure XLSB byte result	R
A7	1	1	1	0	1	0	0	F4	R: F4	Temperature MSB byte result	R
A7	1	1	1	0	1	0	1	F5	R: F5	Temperature LSB byte result	R
A7	1	1	1	0	1	1	0	F6	R: F6	Temperature XLSB byte result	R
A7	1	1	1	0	1	1	1	F7	W: 77, R: F7	Test input data MSB byte	R
A7	1	1	1	1	0	0	0	F8	W: 78, R: F8	Test input data LSB byte	R
A7	1	1	1	1	0	0	1	F9	W: 79, R: F9	Test input data XLSB byte	R
A7	1	1	1	1	0	1	0	FA	W: 7A, R: FA	Trim and test register	R
A7	1	1	1	1	0	1	1	FB	W: 7B, R: FB	Temperature sensor configuration	R+T
A7	1	1	1	1	1	0	0	FC	W: 7C, R: FC	Pressure gain trim	R+T
A7	1	1	1	1	1	0	1	FD	W: 7D, R: FD	Temperature gain trim	R+T
A7	1	1	1	1	1	1	0	FE	W: 7E, R: FE	Temperature and pressure offset trim	R+T
A7	1	1	1	1	1	1	1	FF	W: 7F, R: FF	Clock oscillator frequency trim	R+T

Type: E = EEPROM, R= Register, T = Trim data
Note: When using the SPI serial interface the register address bit A7 is also used for selecting write (A7= 0) or read (A7=1) operation. For the I2C interface address bit A7 = 1.

Important note: All addresses presented in this document use 8-bit notation. The I2C bus device address consists of 7 address bits and 8^{th} LSB bit which selects between write (LSB=0) and read (LSB=1) operation. Thus MAS6505 device address for write is EA_{HEX} and for read EB_{HEX}. In the SPI bus the register and EEPROM addresses start with MSB bit (A7) which selects between write (MSB=0) and read (MSB=1) and which is followed by 7 address bits. For example when using 8-bit address notation the Configuration register write and read addresses via SPI bus are then $6E_{HEX}$ and EE_{HEX} respectively. In the I2C the A7 MSB address bit value is always one (A7=1).

REGISTER AND EEPROM DATA ADDRESSES

MAS6505 includes a 64 byte (512 bit) non-volatile EEPROM data memory and twenty registers. See table 1 on the previous page presenting register and EEPROM data addresses of the MAS6505. The address values differ whether I2C or SPI serial bus communication is used.

In the SPI serial bus the address bit A7 selects between write (A7=0) and read (A7=1) operation.

In the I2C serial bus the address bit A7 value is always one (A7=1). Selection between write and read operation is done by the LSB bit of the I2C device address (write LSB=0, read LSB=1) but the register addresses are the same for both write and read operation. The MAS6505 I2C device address is EA/EB_{HEX} for write/read. See also Table 12.

The first 58 bytes (464 bits) of EEPROM memory (addresses $80/00_{HEX}$…$B9/39_{HEX}$) are free for storing sensor calibration and other data. The last six EEPROM memory bytes (48 bits) are reserved for trim data purposes and they are marked with note "E+T" in the Table 1. EEPROM oscillator frequency trim address ($BA/3A_{HEX}$) must be left untouched since it contains factory trimming value of the internal EEPROM oscillator. Temperature sensor configuration EEPROM address ($BB/3B_{HEX}$) is for storing the temperature sensor selection and bridge resistance trim settings. Pressure gain trim EEPROM address ($BC/3C_{HEX}$) is for storing pressure measurement AFE gain trim settings. Similarly Temperature gain trim EEPROM address ($BD/3D_{HEX}$) is for storing the temperature measurement AFE gain trim settings. Temperature and pressure offset trim EEPROM address ($BE/3E_{HEX}$) is for storing the temperature and pressure measurement ADC offset trim settings. The last EEPROM memory byte (8 bits) in the EEPROM address $BF/3F_{HEX}$ is reserved for storing trimming value of factory trimmed internal 250 kHz clock oscillator. Also this EEPROM address must be left untouched to not lose the factory trimming value.

Reset register ($EC/6C_{HEX}$) does not contain any data. Writing any data byte to this register forces a device reset. The reset initializes all control registers (addresses ED_{HEX}…FF_{HEX}) to a default zero value.

EEPROM control register ($ED/6D_{HEX}$) is used for activating EEPROM (EON bits) which is necessary in both EEPROM read and write. Additionally for write operation the EEPROM has to be enabled for write (EWE bits) since by default the EEPROM write is disabled. See table 2.

The Configuration register ($EE/6E_{HEX}$) contains delay and IIR filter measurement configuration settings and also selection between 4- and 3- wire modes of the SPI bus. See table 3.

The Control register ($EF/6F_{HEX}$) contains measurement resolution and operating mode selection settings. Writing to the Control register starts the selected measurements. See table 4.

The Status register ($F0_{HEX}$) contains various status flags. The FIRSTT and FIRSTP flags are for internal use only. When being high (1) they indicate that the running measurement is the first one after starting the normal mode (continuous) measurements. The forced mode measurements (single measurements) are always considered as first measurements so the FIRSTT and FIRSTP are always high (1) for them. They are reset right after the first measurement has ended. The RDYT and RDYP flags indicate when unread temperature and pressure results are available at the result registers. Checking status of these two flags can be used to decide when to read out new measurement results. See table 5.

The 24-bit measurement result of pressure is stored into three registers $F1_{HEX}$ (MSB, most significant byte), $F2_{HEX}$ (LSB, least significant byte), $F3_{HEX}$ (XLSB, extra least significant byte).

The 24-bit measurement result of temperature is stored into three registers $F4_{HEX}$ (MSB, most significant byte), $F5_{HEX}$ (LSB, least significant byte), $F6_{HEX}$ (XLSB, extra least significant byte).

Three Test input data registers ($F7/77$…$F9/79_{HEX}$) are for IIR filter testing purpose only.

Trim and test register ($FA/7A_{HEX}$) is for trimming and testing purposes. The TRIM bits define whether the trim settings are taken from the EEPROM TRIM=00 (default setting) or from the corresponding trim data registers TRIM<>00. See table 6 for details. The Trimming mode (TRIM=01 or 10) is for trimming the temperature sensor and also the AFE gain and the ADC offset in both temperature and pressure measurements. There is also Trim test mode (TRIM=11) but it is for internal clock oscillator trimming and testing purpose only.

There are five trim data registers in addresses $FB/7B_{HEX}$…$FF/7F_{HEX}$. They have equivalent function storage space in the non-volatile EEPROM addresses $BB/3B_{HEX}$… $BF/3F_{HEX}$. When selecting the Trimming mode (TRIM=01 or 10) in the Trim and test register the temperature sensor, AFE gain and ADC offset trimming can be done using fast register write operation instead of using much slower EEPROM write operations. After optimal trim register values are found they can be stored into the corresponding EEPROM trim data addresses. In the default TRIM=00 setting all the stored trimming settings will be automatically read to registers from the EEPROM memory in the beginning of each measurement.

REGISTER AND EEPROM DATA ADDRESSES (continued)

Temperature sensor configuration register ($FB/7B_{HEX}$) is for storing the temperature sensor selection and bridge resistance trim settings. Pressure gain trim register ($FC/7C_{HEX}$) is for storing pressure measurement AFE gain trim settings. Similarly Temperature gain trim register ($FD/7D_{HEX}$) is for storing the temperature measurement AFE gain trim settings. Temperature and pressure offset trim register ($FE/7E_{HEX}$) is for storing the temperature and pressure measurement ADC offset trim settings. The last Clock oscillator frequency trim register ($FF/7F_{HEX}$) is for internal 250 kHz clock oscillator trimming. It is only for testing purpose since the internal clock oscillator is factory trimmed.

Following chapters desribe the twenty registers more detailed.

RESET REGISTER ($EC/6C_{HEX}$)

The Reset register is for resetting the device via serial bus. The reset will take place immediately after any data byte is written to the address $EC/6C_{HEX}$ via the I2C or SPI serial bus interface. The reset initializes internal counters and the serial communication bus and resets all registers from $FF/7F_{HEX}$ to $EC/6C_{HEX}$ to a default zero (00_{HEX}) value. Reading from the reset register is not possible since it does not contain any data.

EEPROM CONTROL REGISTER (ED/6D$_{HEX}$)

EEPROM control register (ED/6D$_{HEX}$) has EON bits for activating the EEPROM and EWE bits for enabling the EEPROM for a write. See table 2. By default the EEPROM is inactive (EON=000) and write protected (EWE=00, EEPROM write disabled).

To read or write EEPROM it needs to be first activated by setting EON=010 or 101. Any other EON bit combination keeps the EEPROM inactive. Note that to minimize current consumption the EEPROM should be activated only during EEPROM read or write operations and kept inactive in other time. This is because an internal regulator is turned on when the EEPROM is active. To read only the EEPROM content the EEPROM control register should be set to value 02$_{HEX}$ or 05$_{HEX}$ prior read. After activating the EEPROM and before starting to read or write the EEPROM there need to be a startup time wait of least 0.2 ms. See also chapter EEPROM READ ONLY PROCEDURE.

To write EEPROM it is necessary to additionally enable the EEPROM for a write by setting EWE=01. Alternatively EEPROM block write can be enabled by setting EWE=10. However the block write is intended only for testing purposes. **Warning: The EEPROM block write should not be used since the given data byte overwrites all EEPROM content including the factory trimming values of the EEPROM oscillator (BA/3A$_{HEX}$) and internal clock oscillator (BF/3F$_{HEX}$).** Any other EWE bit combination keeps the EEPROM write disabled. This write protection feature is for avoiding accidental overwrite of the EEPROM calibration data. To both read and write EEPROM content the EEPROM control register should be set to value 0A$_{HEX}$. See also chapter EEPROM WRITE PROCEDURE.

The EEPROM control register contains also EE_TEST bits which select different EEPROM test modes. By default the EEPROM test mode is disabled (EE_TEST=000). **The EE_TEST bits should be always kept at the default setting since the other settings are only for EEPROM testing purpose.**

Table 2. EEPROM control register (ED/6D$_{HEX}$)

Bit Number	Bit Name	Description	Value	Function
7-5	EE_TEST	EEPROM test modes	000	**EEPROM test mode disabled (default)**
			001	Charge pump verification, ETEST = VNEG
			010	Charge pump verification, ETEST = VPOS
			011	Oscillator verification, SDO = TCLK4M (Note 1)
			100	Parallel endurance test
			101	Read data retention test, NMART = 1 (Note 2)
			110	Read data retention test, PMART = 1 (Note 3)
			111	No test mode
4-3	EWE	Enable EEPROM write	00	**EEPROM write disabled (default)**
			01	EEPROM normal write enabled
			10	EEPROM block write enabled
			11	EEPROM write disabled
2-0	EON	Activate EEPROM for read or write	000	**EEPROM inactive (default)**
			010	EEPROM activated
			101	EEPROM activated
			other	EEPROM inactive

Note 1. To get the EEPROM oscillator output TCLK4M from SDO pin, set the MSB bit ENTP = 1 in the Oscillator frequency trim register (FF/7F$_{HEX}$) and clear (00$_{HEX}$) the Trim and test register (FA/7A$_{HEX}$).
Note 2. VNEG margin voltage can be forced from ETEST pin
Note 3. VPOS margin voltage can be forced from ETEST pin

CONFIGURATION REGISTER (EE/6E$_{HEX}$)

Configuration register (EE/6E$_{HEX}$) contains measurement delay and digital infinite inpulse response (IIR) low pass filter coefficient settings. In addition the register has configuration bit to select between 4-wire and 3-wire SPI bus modes. See table 3.

In normal mode the selected measurements are run automatically in a loop. There are eight delays from 0.5ms up to 4000ms selectable by DELAY bit settings.

By FILTER bit settings it is possible to select optional low pass filtering of the output temperature and pressure results. Filtered temperature and pressure results are stored into the Temperature result registers (F4/74…F6/76$_{HEX}$) and the Pressure result registers (F1/71…F3/73$_{HEX}$) respectively. The low pass filtering can be used to damp sudden variations in the sensor signal and to further improve noise resolution by an additional filtering of the noise. The filter does not affect output data rate but it narrows signal bandwidth and increases step response delay. See also APPLICATION INFORMATION on page 40 regarding IIR filter noise resolution improvement and step response characteristics.

The FILTER=000 selects no filtering. There are four filter coefficient options available; COEFF=2, 4, 8 or 16. The IIR filter is initialized every time the FILTER value is changed. Writing the same FILTER value to the Configuration register which it already contains does not initialize the filter. The filtered digital output code formula is as shown in equation 1 below.

$$\mathbf{CODE_{NEW}} = \frac{\mathbf{CODE_{OLD}}\cdot(\mathbf{COEFF}-\mathbf{1})+\mathbf{CODE_{ADC}}}{\mathbf{COEFF}} \qquad \textbf{Equation 1}$$

where

$CODE_{NEW}$ = new filtered output

$CODE_{OLD}$ = previous filtered output

$CODE_{ADC}$ = latest A/D conversion result

COEFF = IIR filter coefficient (2, 4, 8 or 16)

Table 3. Configuration register (EE/6E$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7-5	DELAY	Delay between measurements	000 001 010 011 100 101 110 111	0.5ms 62.5ms 125ms 250ms 500ms 1000ms 2000ms 4000ms
4-2	FILTER	IIR filter coefficient	000 001 010 011 other	No filtering 2 4 8 16
1	-	-	0 1	**Default** Reserved for testing purpose. See note.
0	WIRE	SPI 3-wire selection	0 1	4-wire in SPI bus mode (default after power up) 3-wire in SPI bus mode

Note: Keep bit [1] always at logic 0. When STEST=1100 is selected in the Trim and test register (FA/7A$_{HEX}$) the bit [1] logic 1 selects external clock for the EEPROM block.

CONTROL REGISTER (EF/6F$_{HEX}$)

The Control register (EF/6F$_{HEX}$) contains measurement and operating mode selection settings. Writing to Control register starts the selected measurements. See table 4.

There are oversampling ratio (OSR) settings for temperature and pressure. The OSRT setting is for temperature and OSRP for pressure measurement. Each of them has seven settings 1/4x, 1/2x, 1x, 2x, 4x, 8x and 16x in addition to no measurement setting. Thus it is possible select only temperature or pressure measurement or both measurements. The oversampling ratio setting affects measurement resolution and speed and power consumption. The highest value setting gives the highest resolution but it has the longest A/D conversion time and the highest power consumption. Similar way the lowest value setting gives the lowest resolution but it has the shortest A/D conversion time and the lowest power consumption. Thus the multiple oversampling ratio settings allow optimizing measurements between speed, power consumption and resolution.

See ELECTRICAL CHARACTERISTICS on pages 3-7.

The MODE bits select from three operating modes. The MODE=00 setting selects sleep mode in which there are no measurements performed and only a very small sleep current is drawn from the supplies.

The MODE=01 or 10 setting selects forced mode which runs selected measurements only once after which the device returns automatically to the sleep mode.

The MODE=11 setting selects normal mode in which selected measurements are performed automatically in a loop. The delay between measurements is configured by DELAY bit setting in the Configuration register (EE/6E$_{HEX}$). To minimize current consumption the device enters standby mode for the time between measurements during which only the internal clock oscillator is running. The automatic measurements are stopped by setting MODE=00 which selects the sleep mode.

Table 4. Control register (EF/6F$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7-5	OSRT	Oversampling ratio for temperature measurement	000 001 010 011 100 101 110 111	No temperature measurement (default) 1/4x Very fast mode 1/2x Fast mode 1x Ultra low power 2x Low power 4x Standard resolution 8x High resolution 16x Ultra high resolution
4-2	OSRP	Oversampling ratio for pressure measurement	000 001 010 011 100 101 110 111	No pressure measurement (default) 1/4x Very fast mode 1/2x Fast mode 1x Ultra low power 2x Low power 4x Standard resolution 8x High resolution 16x Ultra high resolution
1-0	MODE	Operating mode	00 01, 10 11	Sleep mode (default) Forced mode (single command based measurement) Normal mode (automated measurements)

STATUS REGISTER ($F0_{HEX}$)

The Status register ($F0_{HEX}$) contains various status flags. See table 5. The ERDY flag goes low (ERDY=0) during EEPROM read and write operations to indicating EEPROM being busy. After EEPROM operation is finished the ERDY flag returns high (ERDY=1). The FIRSTT and FIRSTP flags are for internal use only. When being high they indicate that the running measurement is the first one after starting the measurements. They are reset right after the first measurement has ended.

The RDYT and RDYP flags indicate when unread temperature and pressure results are available at the result registers. Polling status of these two flags can be used to decide when to read out the new measurement results. Reading data from any of the three Pressure result registers ($F1…F3_{HEX}$) clears the RDYP flag (RDYP=0). Reading data from any of the three Temperature result registers ($F4…F6_{HEX}$) clears the RDYT flag (RDYT=0).

Table 5. Status register ($F0_{HEX}$)

Bit Number	Bit Name	Description	Value	Function
7-5	-	-	000	-
4	ERDY		0 1	EEPROM busy EEPROM ready
3	FIRSTT		0 1	Not first T measurement First run T measurement
2	FIRSTP		0 1	Not first run P measurement First run P measurement
1	RDYT		0 1	No unread T result available Unread T result available
0	RDYP		0 1	No unread P result available Unread P result available

T = temperature, P = pressure

PRESSURE MEASUREMENT RESULT REGISTERS ($F1…F3_{HEX}$)

The measurement result of pressure is stored into three read only type Pressure measurement result registers in addresses $F1…F3_{HEX}$. MSB (most significant byte) is at $F1_{HEX}$, LSB (least significant byte) at $F2_{HEX}$ and XLSB (extra least significant byte) at $F3_{HEX}$. If IIR low pass filtering is selected (FILTER<>000 in the Configuration registers) the pressure measurement result registers contain filtered value of measurement results.

TEMPERATURE MEASUREMENT RESULT REGISTERS ($F4…F6_{HEX}$)

The measurement result of temperature is stored into three read only type Temperature measurement result registers in addresses $F4…F6_{HEX}$. MSB (most significant byte) is at $F4_{HEX}$, LSB (least significant byte) at $F5_{HEX}$ and XLSB (extra least significant byte) at $F6_{HEX}$. If IIR low pass filtering is selected (FILTER<>000 in the Configuration registers) the temperature measurement result registers contain filtered value of measurement results.

TEST INPUT DATA REGISTERS ($F7/77…F9/79_{HEX}$)

The three bytes of Test input data registers ($F7/77…F9/79_{HEX}$) are for testing purpose only. By the Trim and test register ($FA/7A_{HEX}$) setting SCALC=1 it is possible to choose taking data for the temperature and pressure result IIR low pass filters from the Test input data registers. This test mode allows testing temperature and pressure result IIR low pass filters with any 24-bit input data. In normal operation (SCALC=0) the input data for the IIR filters are the latest temperature and pressure conversion results. Filtered temperature and pressure results are stored into the Temperature result registers ($F4/74…F6/76_{HEX}$) and the Pressure result registers ($F1/71…F3/73_{HEX}$) respectively.

TRIM AND TEST REGISTER (FA/7A$_{HEX}$)

Trim and test register (FA/7A$_{HEX}$) is for trimming and testing purposes. In normal operation the Trim and test register default value is 00$_{HEX}$. See table 6.

The SOSC bit selects between internal and external oscillator clock signal. By default the internal clock oscillator is selected (SOSC=0). The external oscillator signal can be also selected (SOSC=1) but this is only for testing purpose.

The STEST bits are for selecting test signals to the SDO pin. In normal operation there is no test output selected (STEST=0000) which is the default setting. Other settings (STEST<>0000) select different signals to the SDO pin and are also only for testing purpose.

The TRIM bits select source of the trim data. By default setting (TRIM=00) all trim data is taken from the EEPROM. This is proper operating mode of a trimmed pressure module.

TRIM=01 or 10 setting selects Trimming mode which is used in the trimming of the temperature sensor, AFE gains and ADC offsets of the temperature and pressure measurements. In this mode only internal factory trimmed clock oscillator trim data is taken from the EEPROM. The rest of the trim data is taken from the four trim registers in addresses FB/7B$_{HEX}$ …FE/7E$_{HEX}$. See tables 7-10. Trimming using registers can be done much faster than when using EEPROM since register write is much faster than the slower EEPROM write. After finding optimal trim values to these four trim registers they need to be stored into the corresponding four EEPROM trim data addresses 3B/3B$_{HEX}$ …3E/3E$_{HEX}$. See table 1. In normal operating mode (TRIM=00) all the stored trimming settings will be automatically read to registers from the EEPROM memory in the beginning of each measurement.

The TRIM=11 setting selects taking all trim data from registers. This is only for internal clock oscillator trimming purpose and not needed since the internal clock oscillator is factory trimmed.

The SCALC bit selects input data source for the IIR low pass filter. By default SCALC=0 which selects data from the A/D conversion results. However SCALC=1 selects to take calculation input data from the Test input data registers (F7/77$_{HEX}$… F9/79$_{HEX}$) instead. This test mode allows testing of the IIR low pass filter with any 24-bit input data.

Table 6. MAS6505 Trim and test register (FA/7A$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7	SOSC	Selection for oscillator clock	0 1	Internal clock oscillator (default) TD = input for external clock signal
6-3	STEST	TEST pin signal selection	0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111	SDO = no test output (default) SDO= output for internal OSC (on all the time) SDO = output for OUT_SDM SDO = output for internal band gap SDO = output for EEPROM VREG voltage SDO = output for EOC signal SDO = output for EEPROM VREG OK SDO = output for EEPROM chip enable SDO = output for internal LVDD SDO = PO, TD = NO, AFE output signals SDO = no test output SDO = input current sink for external chopper bias SDO = input for external clock SDO = input for external clock, internal input short for sensor bridge noise measurement SDO = no test output, internal input short for sensor bridge noise measurement SDO = no test output, internal temperature diode for noise measurement
2-1	TRIM	Selects source of trim data	00 01, 10 11	All trim data from EEPROM (default) Trimming mode (only OSC trim data from EEPROM) Trim test mode (All trim data from registers)
0	SCALC	Selection for input data source of IIR filter	0 1	Normal operation (default) IIR filter test mode

Note: To enable SDO pin operating as test pin set ENTP=1 in the Clock oscillator frequency trim register address FF/7F$_{HEX}$.
Note: If the SOSC=1 the external clock signal is selected and the internal oscillator is disabled independent of STEST selection.
Note: External clock signal at either TD or SDO pin must not exceed VDD voltage.

TEMPERATURE SENSOR CONFRIGURATION REGISTER (FB/7B$_{HEX}$)

Temperature sensor configuration register (FB/7B$_{HEX}$) is for configuring temperature sensing. See table 7.

The TSENSOR bit selects between sensor bridge resistance temperature sensing and external temperature sensing diode.

When using the sensor bridge resistance based temperature sensing (TSENSOR=0) it is necessary to trim sensor bridge resistance setting by the RSENSOR bits. There are sixteen sensor bridge resistance trim values available ranging from 1.89kΩ to 9.86kΩ. These correspond to internal trim resistor R3 values ranging typically from 10.1kΩ down to 2.14kΩ and which are used to balance the formed temperature sensing bridge circuit. For more details see chapter SENSOR BRIDGE RESISTANCE TEMPERATURE SENSING .

When using the external temperature sensing diode (TSENSOR=1) the external temperature diode is connected between VDDS pin (diode anode) and TD pin (diode cathode). During temperature measurement the MAS6505 sinks a constant 10 µA bias current from the temperature sensing diode and the temperature dependent diode forward voltage is measured. To avoid signal clipping GAINT=1, SGNGAINT=1 and OFST%= -28% settings must be used in external diode temperature measurement.

Note that to select trim data from registers there must be also set TRIM=01 or 10 in the Trim and test register (FA/7A$_{HEX}$). After power up the default setting is TRIM=00 which selects all trim data from EEPROM.

The Sensor bridge resistance selection configuration value need to be stored into Sensor bridge resistance selection data EEPROM address (BB/3B$_{HEX}$) since by default (TRIM=00) the trimming value is read from the EEPROM before every temperature measurement.

See also chapters AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS, AFE GAIN AND ADC OFFSET SELECTIONS, EXTERNAL TEMPERATURE DIODE TEMPERATURE SENSING and SENSOR BRIDGE RESISTANCE TEMPERATURE SENSING which describe temperature sensing signals and how the GAIN and OFS settings define the sensor input signal range.

Table 7. Temperature sensor configuration register (FB/7B$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7-5	-	-	X	-
4	TSENSOR	Temperature sensor selection	0 1	Sensor bridge resistance temperature sensing External temperature sensing diode
3-0	RSENSOR	Sensor bridge resistance trim	0000 0001 0010 0011 0100 0101 0110 0111 1000 1001 1010 1011 1100 1101 1110 1111	R3=10110 Ω (Rsensor=1890 Ω) R3=9890 Ω (Rsensor=2110 Ω) R3=9644 Ω (Rsensor=2356 Ω) R3=9370 Ω (Rsensor=2630 Ω) R3=9064 Ω (Rsensor=2936 Ω) R3=8722 Ω (Rsensor=3278 Ω) R3=8340 Ω (Rsensor=3660 Ω) R3=7914 Ω (Rsensor=4086 Ω) R3=7438 Ω (Rsensor=4562 Ω) R3=6907 Ω (Rsensor=5093 Ω) R3=6314 Ω (Rsensor=5686 Ω) R3=5652 Ω (Rsensor=6348 Ω) R3=4912 Ω (Rsensor=7088 Ω) R3=4087 Ω (Rsensor=7913 Ω) R3=3166 Ω (Rsensor=8834 Ω) R3=2137 Ω (Rsensor=9863 Ω)

X = Don't care

PRESSURE GAIN TRIM REGISTER (FC/7C$_{HEX}$)

Pressure gain trim register (FC/7C$_{HEX}$) is for configuring analog front end (AFE) gain (GAINP) setting for the pressure measurement. There are 32 selectable gain options from 1x (0dB) to 55.8x (34.9dB). The gain setting 1x bypasses the AFE and connects the input signal directly to the ADC input. See table 8.

The polarity of pressure measurement gain is selected by additional sign bit (SGNGAINP).

Note that to select trim data from registers there must be also set TRIM=01 or 10 in the Trim and test register (FA/7AHEX). After power up the default setting is TRIM=00 which selects all trim data from EEPROM.

The Pressure gain trim value needs to be stored into Pressure gain trim EEPROM address (BC/3C$_{HEX}$) since by default (TRIM=00) the trimming value is read from the EEPROM before every pressure measurement.

See also chapters AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS and AFE GAIN AND ADC OFFSET SELECTIONS which describes how the GAIN and OFS settings define the sensor input signal range and how to choose optimal values.

Table 8. Pressure gain trim register (FC/7C$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7-6	-	-	X	-
5	SGNGAINP	Pressure Measurement Gain Sign	0 1	Positive Negative
4-0	GAINP	Pressure Measurement Gain	00000 00001 00010 00011 00100 00101 00110 00111 01000 01001 01010 01011 01100 01101 01110 01111 10000 10001 10010 10011 10100 10101 10110 10111 11000 11001 11010 11011 11100 11101 11110 11111	1x (0dB), ISRP=1400mVpp 4.7x (13.4dB), ISRP=298mVpp 5.1x (14.2dB), ISRP=275mVpp 5.6x (15dB), ISRP=250mVpp 6x (15.6dB), ISRP=233mVpp 6.5x (16.3dB), ISRP=215mVpp 7.1x (17dB), ISRP=197mVpp 7.7x (17.7dB), ISRP=182mVpp 8.4x (18.5dB), ISRP=167mVpp 9.1x (19.2dB), ISRP=154mVpp 9.9x (19.9dB), ISRP=141mVpp 10.7x (20.6dB), ISRP=131mVpp 11.6x (21.3dB), ISRP=121mVpp 12.6x (22dB), ISRP=111mVpp 13.8x (22.8dB), ISRP=101mVpp 14.9x (23.5dB), ISRP=94mVpp 16.2x (24.2dB), ISRP=86.4mVpp 17.6x (24.9dB), ISRP=79.5mVpp 19.1x (25.6dB), ISRP=73.3mVpp 20.7x (26.3dB), ISRP=67.6mVpp 22.5x (27dB), ISRP=62.2mVpp 24.5x (27.8dB), ISRP=57.1mVpp 26.6x (28.5dB), ISRP=52.6mVpp 28.8x (29.2dB), ISRP=48.6mVpp 31.3x (29.9dB), ISRP=44.7mVpp 34x (30.6dB), ISRP=41.2mVpp 36.9x (31.3dB), ISRP=37.9mVpp 40.1x (32.1dB), ISRP=34.9mVpp 43.5x (32.8dB), ISRP=32.2mVpp 47.3x (33.5dB), ISRP=29.6mVpp 51.3x (34.2dB), ISRP=27.3mVpp 55.8x (34.9dB), ISRP=25.1mVpp

X = Don't care
Note: Corresponding pressure measurement input signal range at sensor input is ISRP=ISRADC/GAINP=1400mVpp/GAINP @ VDDS=1.68V

TEMPERATURE GAIN TRIM REGISTER (FD/7DHEX)

Temperature gain trim register (FD/7DHEX) is for configuring analog front end (AFE) gain (GAINT) setting for the temperature measurement. There are 32 selectable gain options from 1x (0dB) to 55.8x (34.9dB). The gain setting 1x bypasses the AFE and connects the input signal directly to the ADC input. See table 9.

The polarity of temperature measurement gain is selected by additional sign bit (SGNGAINT).

Note that to select trim data from registers there must be also set TRIM=01 or 10 in the Trim and test register (FA/7AHEX). After power up the default setting is TRIM=00 which selects all trim data from EEPROM.

The Temperature gain trim value needs to be stored into Temperature gain trim data EEPROM address (BD/3DHEX) since by default (TRIM=00) the trimming value is read from the EEPROM before every temperature measurement.

See also chapters AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS and AFE GAIN AND ADC OFFSET SELECTIONS which describes how the GAIN and OFS settings define the sensor input signal range and how to choose optimal values.

Table 9. Temperature gain trim register (FD/7DHEX) description

Bit Number	Bit Name	Description	Value	Function
7-6	-	-	X	-
5	SGNGAINT	Temperature Measurement Gain Sign	0 1	Positive Negative
4-0	GAINT	Temperature Measurement Gain	00000 00001 00010 00011 00100 00101 00110 00111 01000 01001 01010 01011 01100 01101 01110 01111 10000 10001 10010 10011 10100 10101 10110 10111 11000 11001 11010 11011 11100 11101 11110 11111	1x (0dB), ISRT=1400mVpp 4.7x (13.4dB), ISRT=298mVpp 5.1x (14.2dB), ISRT=275mVpp 5.6x (15dB), ISRT=250mVpp 6x (15.6dB), ISRT=233mVpp 6.5x (16.3dB), ISRT=215mVpp 7.1x (17dB), ISRT=197mVpp 7.7x (17.7dB), ISRT=182mVpp 8.4x (18.5dB), ISRT=167mVpp 9.1x (19.2dB), ISRT=154mVpp 9.9x (19.9dB), ISRT=141mVpp 10.7x (20.6dB), ISRT=131mVpp 11.6x (21.3dB), ISRT=121mVpp 12.6x (22dB), ISRT=111mVpp 13.8x (22.8dB), ISRT=101mVpp 14.9x (23.5dB), ISRT=94mVpp 16.2x (24.2dB), ISRT=86.4mVpp 17.6x (24.9dB), ISRT=79.5mVpp 19.1x (25.6dB), ISRT=73.3mVpp 20.7x (26.3dB), ISRT=67.6mVpp 22.5x (27dB), ISRT=62.2mVpp 24.5x (27.8dB), ISRT=57.1mVpp 26.6x (28.5dB), ISRT=52.6mVpp 28.8x (29.2dB), ISRT=48.6mVpp 31.3x (29.9dB), ISRT=44.7mVpp 34x (30.6dB), ISRT=41.2mVpp 36.9x (31.3dB), ISRT=37.9mVpp 40.1x (32.1dB), ISRT=34.9mVpp 43.5x (32.8dB), ISRT=32.2mVpp 47.3x (33.5dB), ISRT=29.6mVpp 51.3x (34.2dB), ISRT=27.3mVpp 55.8x (34.9dB), ISRT=25.1mVpp

X = Don't care
Note: Corresponding temperature measurement input signal range at sensor input is ISRT=ISRADC/GAINT=1400mVpp/GAINT at VDDS=1.68V

TEMPERATURE AND PRESSURE OFFSET TRIM REGISTER (FE/7E$_{HEX}$)

Temperature and pressure offset trim register (FE/7E$_{HEX}$) is for configuring ADC input offset settings for both temperature and pressure measurements. There are eight offset options with polarity available to match input signal range (ISR) with different sensor signals. OFST and SGNOFST bits are for the temperature offset and polarity selection. Similarly OFSP and SGNOFSP are for the pressure offset and polarity selection. See table 10.

The input of the ratiometric ADC is differential with input signal range of ISRADC = ±700mV = 1400mVpp at the nominal sensor supply voltage VDDS=1.68V. The ADC offset options are in 7%*ISRADC steps which corresponds to absolute input offset voltage step of 7%*1400mVpp=98mV.

Note that to select trim data from registers there must be also set TRIM=01 or 10 in the Trim and test register (FA/7AHEX). After power up the default setting is TRIM=00 which selects all trim data from EEPROM.

The Temperature and pressure offset trim value needs to be stored into Temperature and pressure offset trim EEPROM address (BE/3E$_{HEX}$) since by default (TRIM=00) the trimming value is read from the EEPROM before every temperature measurement.

See also chapters AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS and AFE GAIN AND ADC OFFSET SELECTIONS which describes how the GAIN and OFS settings define the sensor input signal range and how to choose optimal values.

Table 10. Temperature and pressure offset trim register (FE/7E$_{HEX}$) description

Bit Number	Bit Name	Description	Value	Function
7	SGNOFST	Temperature Measurement Offset Sign	0 1	Positive Negative
6-4	OFST	Temperature Measurement Offset	000 001 010 011 100 101 110 111	0% ISRADC 7% ISRADC 14% ISRADC 21% ISRADC 28% ISRADC 35% ISRADC 42% ISRADC 49% ISRADC
3	SGNOFSP	Pressure Measurement Offset Sign	0 1	Positive Negative
2-0	OFSP	Pressure Measurement Offset	000 001 010 011 100 101 110 111	0% ISRADC 7% ISRADC 14% ISRADC 21% ISRADC 28% ISRADC 35% ISRADC 42% ISRADC 49% ISRADC

Note: ISRADC=1400 mVpp (differential input signal range ±700 mV) at VDDS=1.68V
Note: Corresponding temperature measurement input signal offset voltage at sensor input is $VOFST=(-1)^{SGNOFST}*OFST/GAINT$
Note: Corresponding pressure measurement input signal offset voltage at sensor input is $VOFSP=(-1)^{SGNOFSP}*OFSP/GAINP$

CLOCK OSCILLATOR FREQUENCY TRIM REGISTER (FF/7F$_{HEX}$)

Note that the internal clock oscillator frequency has been factory trimmed and the trim value has been stored into the EEPROM (BF/3F$_{HEX}$). It is recommended not to change the factory programmed value! See table 11.

The Clock oscillator frequency trim register (FF/7F$_{HEX}$) is for trimming the internal clock oscillator to 250 kHz frequency. By selecting ENTP=1 in the Clock oscillator frequency trim register (FF/7F$_{HEX}$) and STEST=0001 and TRIM=11 in the Trim and test register (FA/7A$_{HEX}$) the internal oscillator is turned on all the time and the 250 kHz oscillator signal can be measured at the SDO pin and also adjusted by the Clock oscillator frequency trim register.

The seven LSB bits adjust the oscillator signal period in 35 ns steps. The signal period decreases and frequency increases when the trim value increases. The seven bits register value is considered as a 2's complement number. Typically the mid value 00$_{HEX}$ corresponds to 212 kHz clock oscillator frequency.

After finding a suitable trim value it can be stored into the EEPROM (BF/3F$_{HEX}$).

Table 11. Clock oscillator frequency trim register (FF/7F$_{HEX}$)

Bit Number	Bit Name	Description	Value (bin)	Value (2's complement)	Value (dec)	Function
7	ENTP	Enable for test pin	0 1			Disable test pin (default) SDO is test pin if STEST<>0
6-0	OSCF	Clock oscillator frequency control	0111111 0111110 ……. 0000001 0000000 1111111 1111110 ……. 1000001 1000000	63 62 … 1 0 -1 -2 … -63 -64	63 62 … 1 0 127 126 … 65 64	Max frequency … … … 212 kHz … … … … Min frequency

EEPROM WRITE PROCEDURE

This chapter gives instructions for writing data to the EEPROM memory.

The 512-bit (64 byte) EEPROM memory is available for storing trimming and calibration data on chip. The first 464-bits (58 bytes) in addresses $80/00_{HEX}$ … $B9/39_{HEX}$ are free for any use such as storing sensor calibration coefficients. The last six EEPROM bytes in addresses $BA/3A_{HEX}$ … $BF/3F_{HEX}$ are reserved for trimming purposes. See table 1 describing register and EEPROM data addresses.

Writing to the non-volatile EEPROM memory requires supply voltage of 5.0V (VDD=4.5V…5.5V). See write/read application figure 4 below. However note that the EEPROM read is possible at wide supply voltage range VDD=1.71V…5.5V.

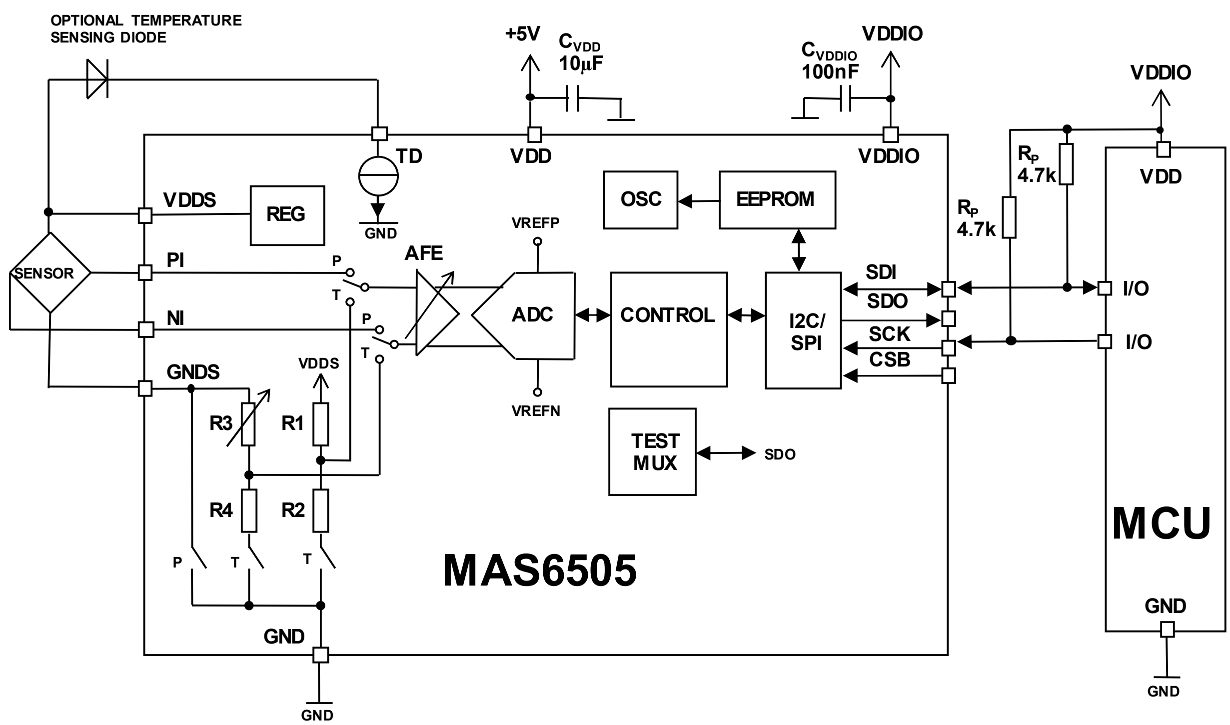
The EEPROM write procedure is shown on the next page figure 5.

In the beginning of the EEPROM write procedure the initial conditions need to be reset. Connecting VDD triggers power-on-reset (POR) but to make sure the device is reset it is recommended to give an additional reset by writing any data byte on the reset register ($EC/6C_{HEX}$) via the serial bus.

The EEPROM is activated and write enabled by writing value $0A_{HEX}$ to the EEPROM control register ($ED/6D_{HEX}$). After activating EEPROM there need to be a wait of at least 0.2 ms before reading from or writing to EEPROM.

Next the data can be written to the EEPROM memory addresses one byte (8-bit) at a time. It is necessary to have a delay of minimum 13ms after programming each byte (8-bit). The success of each write can be verified by reading back the data byte (8-bit) and comparing it to the original byte (8-bit).

After all data bytes are written the EEPROM memory is inactivated and protected from write by writing 00_{HEX} to the EEPROM control register ($ED/6D_{HEX}$).



NOTE: In I2C bus communication the CSB pin is unused and left unconnected (floating). It has an internal pull up to VDDIO.

Figure 4. Typical EEPROM write/read application circuit (VDD=+5V) in I2C bus communication

EEPROM WRITE PROCEDURE (continued)

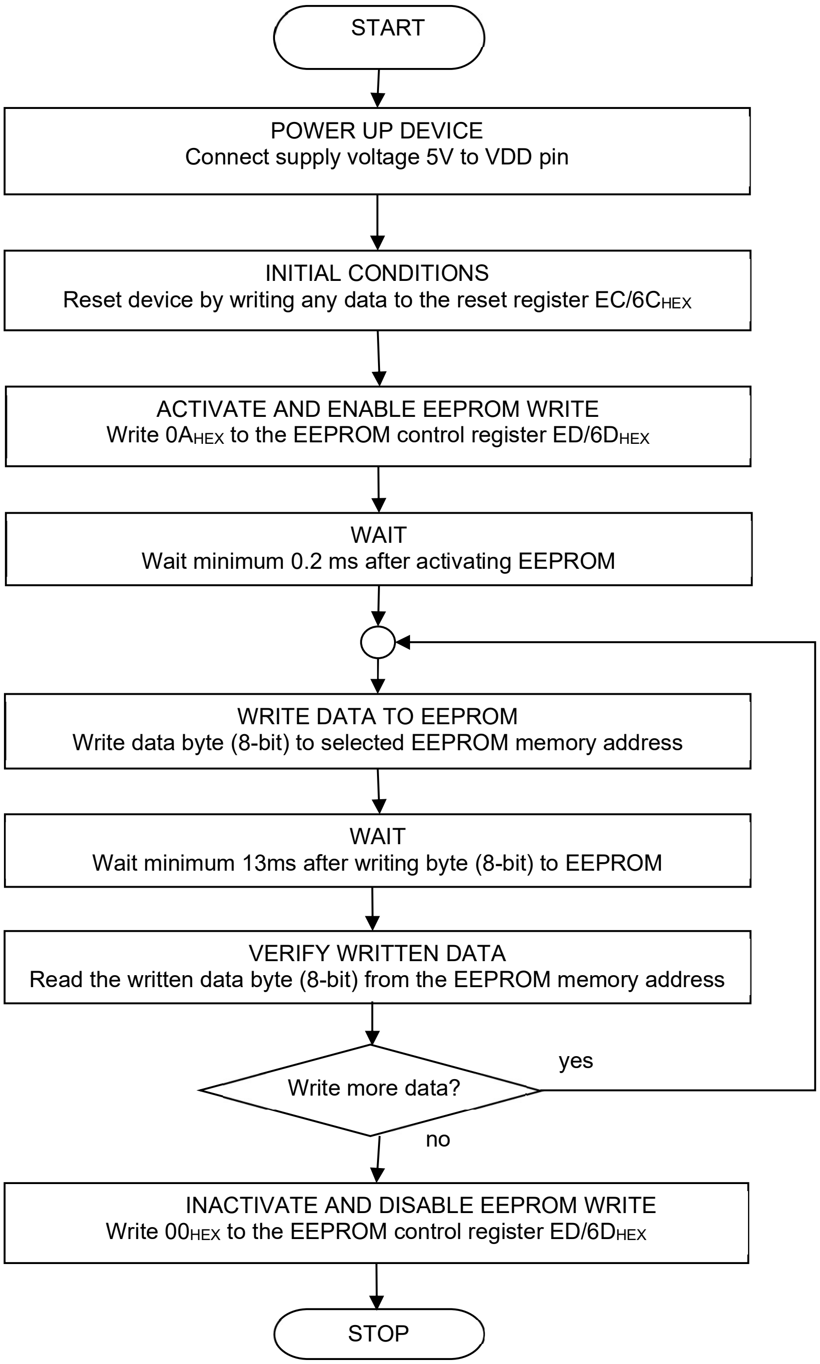


Figure 5. Flow chart for MAS6505 EEPROM write

EEPROM READ ONLY PROCEDURE

This chapter gives instructions for only reading data from the EEPROM memory.

In read only application (using readily programmed MAS6505 sensor module) the EEPROM can be read at wide supply voltage range VDD=1.71V…5.5V.

In the beginning of the EEPROM read only procedure the initial conditions are reset. Connecting VDD triggers power-on-reset (POR) but to make sure the device is reset an additional reset should be given by writing any data byte to the reset register ($EC/6C_{HEX}$) via the serial bus.

The EEPROM is activated and kept write protected by writing value 02_{HEX} (or alternatively 05_{HEX}) to the EEPROM control register ($ED/6D_{HEX}$). After activating EEPROM there need to be wait at least 0.2 ms before reading from or writing to EEPROM.

In read there is no need for extra delay between reads of each byte like in write and incremental read can be used (after each read byte the read address is automatically incremented to a next address if read is continued).

After all data bytes are read the EEPROM memory is inactivated by writing 00_{HEX} to the EEPROM control register ($ED/6D_{HEX}$).

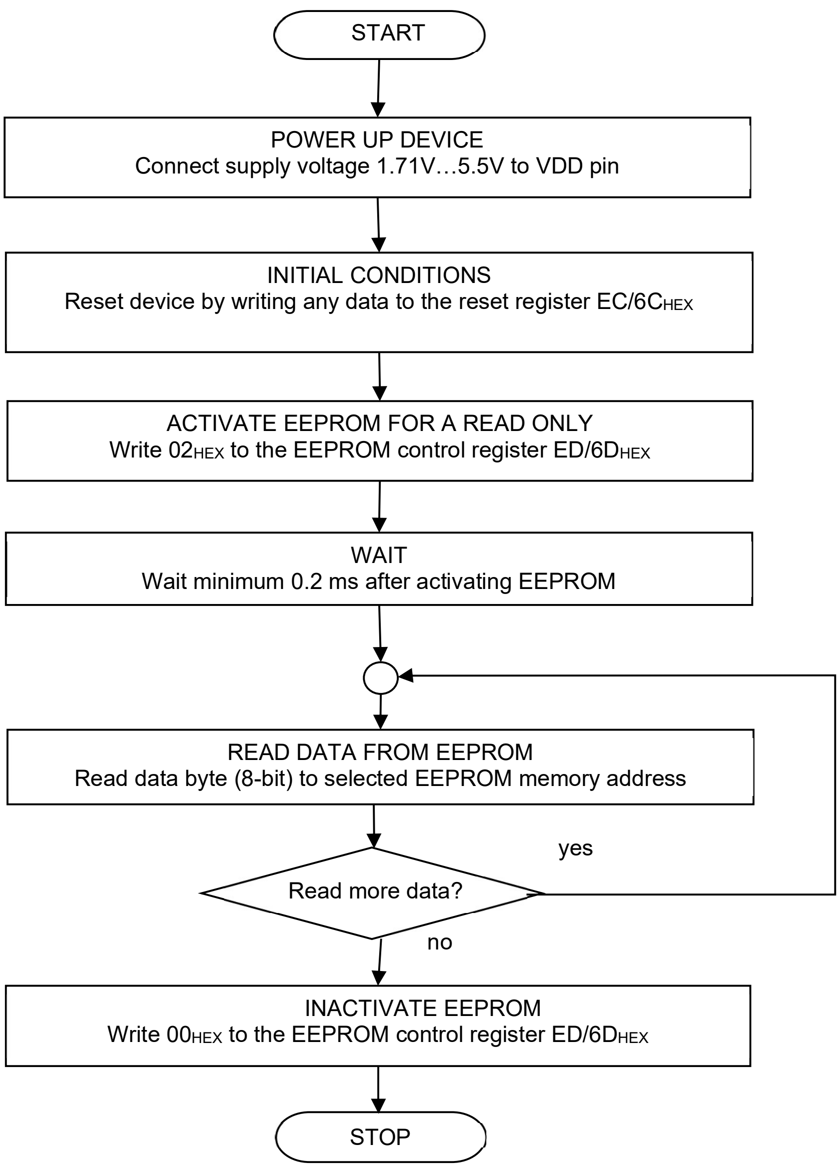


Figure 6. Flow chart for MAS6505 EEPROM read only

SERIAL DATA INTERFACE CONTROL

Serial Interface

MAS6505 is operated via serial bus communication. The MAS6505 acts as slave device and communication is initiated only by an external master device that is connected to the serial bus.

The MAS6505 supports 2-wire serial I2C bus and 4- and 3-wire serial SPI bus. Selection between I2C and SPI communication is done by CSB chip select pin. The CSB=high selects I2C and CSB=low activates SPI communication. In I2C communication the CSB pin can be either connected to VDDIO or left unconnected (floating) since the CSB pin has internal 250 kΩ pull-up resistor to VDDIO. The 2-wire serial I2C bus type interface comprises of serial clock input (SCK) and bi-directional serial data (SDI) input/output. The I2C bus is used to write configuration data to sensor interface IC and read the measurement result when measurement has been finished. The interface is also used for reading the calibration data from the non-volatile EEPROM memory.

Note: The 2-wire I2C bus of MAS6505 supports only basic I2C bus communication protocol but not for example 10-bit addressing, arbitration and clock stretching features of the I2C bus specification.

The alternative 4-wire serial SPI bus type interface comprises of serial clock input (SCK), serial data input (SDI), serial data output (SDO) and chip select input (CSB). In the 3-wire mode the SDI pin operates as both data input and data output. The SPI bus wire selection is done by WIRE bit in the Configuration register ($EE/6E_{HEX}$). By default the SPI bus is in the 4-wire mode (WIRE=0). The 3-wire mode can be selected by setting WIRE=1.

The serial bus has an additional SPI mode lock in feature. By pulling CSB low and giving at least four SCK clock pulses makes the digital interface to lock into SPI communication mode. This is done in order to avoid inadvertently decoding SPI traffic to another slave device as I2C data. After entering SPI lock mode the I2C communication is possible only after applying power on reset.

MAS6505 has Reset register ($EC/6C_{HEX}$) which allows resetting the device via serial interface. Writing any data byte to the Reset register ($EC/6C_{HEX}$). Reset initializes counters and the serial communication bus and resets all registers from $FF/7F_{HEX}$ to $EC/6C_{HEX}$ to a default zero (00_{HEX}) value. Reading from the reset register is not possible.

I2C Bus Communication

The I2C bus communication is selected by connecting the CSB pin to VDDIO or leaving it unconnected (floating).

The I2C bus standard makes it possible to connect several different devices on same bus. The devices are distinguished from each other by unique device addresses. The MAS6505 device address is shown in the following Table 12Table . The LSB bit of the device address (using 8-bit address notation) defines whether the bus is configured to Read (1) or Write (0) operation. See Figures 4 and 15 showing MAS6505 configured for I2C bus communication.

Table 12. MAS6505 I2C bus hard wired device address (EA/EB_{HEX} for Write/Read)

A7	A6	A5	A4	A3	A2	A1	W/R
1	1	1	0	1	0	1	0/1

I2C Bus Protocol Definitions

Data transfer is initiated by master with a Start bit (S) when SDI is pulled low while SCK stays high. Then, SDI sets the transferred bit while SCK is low and the data is sampled (received) when SCK rises. When the transfer is complete, a Stop bit (P) is sent by releasing the data line to allow it to be pulled up while SCK is constantly high.

Figure 7 on next page shows the start (S) and stop (P) bits and a data bit. Data must be held stable at the SDI pin when SCK is high. Data at the SDI pin can change value only when SCK is low.

Each SDI line byte transfer must contain 8-bits where the most significant bit (MSB) always comes first. Each byte has to be followed by an acknowledge bit (see further below). The number of bytes transmitted per transfer is unrestricted.

2-WIRE SERIAL DATA INTERFACE (I2C BUS)

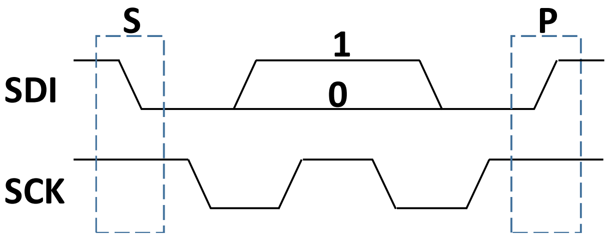


Figure 7. I2C bus protocol definitions

Bus communication includes Acknowledge (A) and not Acknowledge (N) messages. To send an acknowledge the receiver device pulls the SDI low for one SCK clock cycle. For not acknowledge (N) the receiver device leaves the SDI high for one SCK clock cycle in which case the master can then generate either a Stop (P) bit to abort the transfer, or a repeated Start (Sr) bit to start a new transfer.

Abbreviations:
A= Acknowledge
N = Not Acknowledge
S = Start
Sr = Repeated Start
P = Stop
(shaded box) = from Master (MCU) to Slave (MAS6505)
(white box) = from Slave (MAS6505) to Master (MCU)

Measurement Configuration and Starting – Write Sequence

Prior starting measurements a suitable configuration setup should be written to the Configuration register (EE/6E$_{HEX}$). Actual A/D conversion is started by writing measurement setup into the Control register (EF$_{HEX}$). The Control register write sequence is illustrated in Table 13. Since Configuration and control register addresses are consecutive it is also possible to write both registers in the same write sequence by utilizing the incremental write feature of MAS6505. This is illustrated in the table 14.
.

Table 13. MAS6505 I2C bus write sequence of Control register

S	AW	A	ACT	A	DCT	A	P

Table 14. MAS6505 I2C bus incremental write sequence of both Configuration and Control registers

S	AW	A	ACF	A	DCF	A	DCT	A	P

Abbreviations:
AW = Device write address EA$_{HEX}$ (%1110 1010)
AR = Device read address EB$_{HEX}$ (%1110 1011)
ACF = Configuration reg. addr. EE$_{HEX}$ (%1110 1110)
ACT = Control reg. addr. EF$_{HEX}$ (%1110 1111)
DCF=Data of Configuration register
DCT=Data of Control register
Ax = Address of non-specified register
Dx = Data of non-specified register
AP = MSB register address of pressure result (F1$_{HEX}$, %1111 0001)
AT = MSB register address of temperature result (F4$_{HEX}$, %1111 0100)
Dxy = Data of measurement result register; temperature (x=T), pressure (x=P), MSB (y=M), LSB (y=L) or XLSB (y=X)

Each serial bus operation, like write, starts with the start (S) bit (see Figure 7). After start (S) the MAS6505 device address with write bit (AW*Table*) is sent followed by an Acknowledge (A). Next the target register address is sent and followed by an Acknowledge (A). Then the data is written one byte at a time. Each byte is followed by an Acknowledge (A). The serial bus operation is ended with stop (P) command (see Figure 7). The MAS6505 starts configured measurement right after receiving the Configuration register (EE$_{HEX}$) bits.

2-WIRE SERIAL DATA INTERFACE (I2C BUS)

Conversion Result – Read Sequence

Table 15 presents a general control sequence for a single register data (Dx) read from register address (Ax).

Table 15. MAS6505 I2C bus single register (address Ax) data byte (Dx) read sequence

S	AW	A	Ax	A	Sr	AR	A	Dx	N	P

Table 16 shows an incremental read sequence for reading the 24-bit measurement results of both temperature and pressure. All the six result bytes can be read in a single read sequence. This is possible because of MAS6505 auto increment function and since pressure and temperature result register addresses are consecutive. The auto increment function increments register address automatically to the next register address when either read or write sequence is continued (not ended by a Stop bit P) after each data byte. The read command is ended by the Stop bit P only after all the six bytes have been read. The first the three pressure result registers are read in order MSB (DPM), LSB (DPL) and XLSB (DPX) and this is followed by three temperature result registers in the same order MSB (DTM), LSB (DTL) and XLSB (DTX).

Table 16. MAS6505 I2C bus incremental read sequence for six measurement result bytes

S	AW	A	AP	A	Sr	AR	A	DPM	A	DPL	A	DPX	A	DTM	A	DTL	A	DTX	N	P

4-WIRE OR 3-WIRE SERIAL DATA INTERFACE (SPI BUS)

The 4-wire serial SPI bus type interface comprises of serial clock input (SCK), serial data input (SDI), serial data output (SDO) and chip select input (CSB). In 3-wire mode the SDO pin is not used and the SDI pin operates as both data input and data output. The SPI bus wire selection is done by WIRE bit in the Configuration register (EE/6E$_{HEX}$). By default the SPI bus is in the 4-wire mode (WIRE=0). The 3-wire mode can be selected by setting WIRE=1.

In the SPI bus the device selection is done by CSB chip select pin. By setting the CSB pin low also activates the SPI bus communication. Note that the CSB pin has internal pull up and to minimize current consumption it should be set low only during SPI communication periods.

Bits are transferred always MSB bit first including address and data bits. See figure 8 for an example of a 4- wire and 3-wire write access communication. The data is latched at rising edges of the serial clock (SCK) during which the data input line (SDI) should be kept stable. The selection between write or read access is done by register address MSB bit A7 (see Table 1 "*Register and EEPROM data addresses*"). In write access the bit A7 is cleared (0) and in read access it is set (1). The following seven address bits A6…A0 define register address. The address bits are followed by eight data bits.

The MAS6505 has an auto increment function which means that if there are more than one data byte transferred in write/read by continuing the SCK clocking the additional data bytes are delivered to/from following incremented register addresses by incrementing the register address automatically to the next address. The SPI bus data transfer is ended by setting the CSB pin high. In write access communication the MAS6505 keeps the SDO line in high impedance state (HI-Z) during the whole communication.

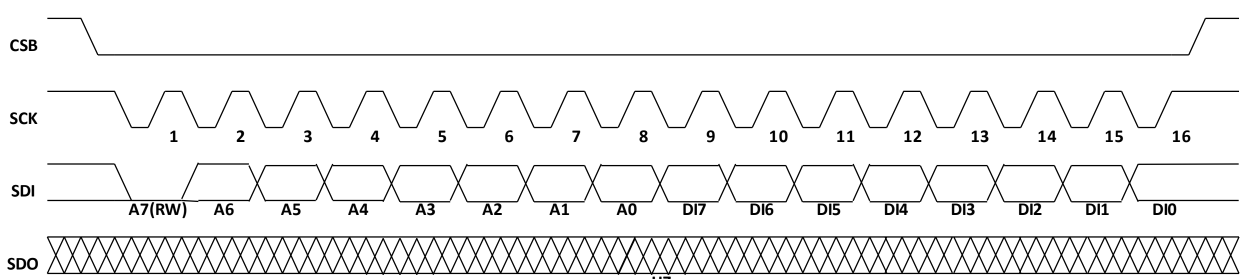


Figure 8. SPI 4-Wire (WIRE=0) and 3-Wire (WIRE=1) Protocol– Write Access (register address MSB bit A7=0)

4-WIRE OR 3-WIRESERIAL DATA INTERFACE (SPI BUS)

Figure 9 illustrates 4-wire (WIRE=0) SPI bus read access communication. The SDO line is at high impedance state (HI-Z) until it outputs the MSB data bit (DO7) at falling edge of the eight SCK clock pulse.

The auto increment function can be utilized also in read access. If there are more than one data byte read the additional data bytes are delivered from following incremented register addresses.

Returning CSB high ends the SPI communication and sets the SDO pin to high impedance state (HI-Z).

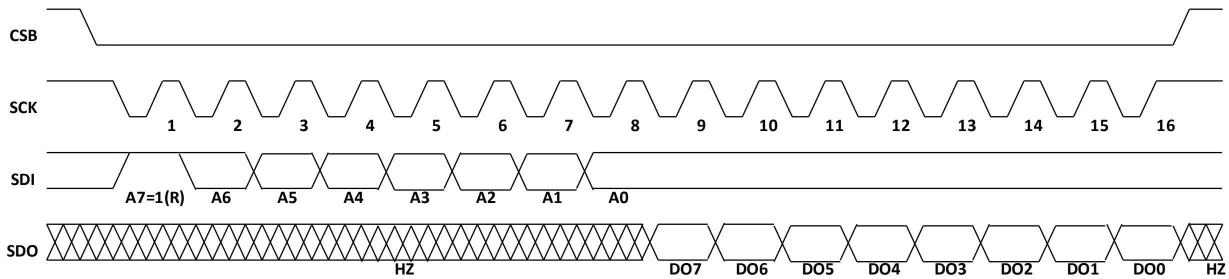


Figure 9. SPI 4-Wire (WIRE=0) Protocol – Read Access (register address MSB bit A7=1)

Figure 10 illustrates 3-wire (WIRE=1) SPI bus read access communication. The SDI input line turns into output after falling edge of the eight SCK clock pulse. The first read data bit is the MSB bit and the last LSB bit is send to SDI line at the falling edge of the 15th SCK clock pulse. Master reads the data bits at the rising edges of the SCK clock pulses.

The auto increment function can be utilized also in read access and if there are more than one data byte read the additional data bytes are delivered from following register addresses.

In 3-wire SPI bus write access communication the MAS6505 keeps the SDO line in high impedance state (HI-Z) during the whole communication.

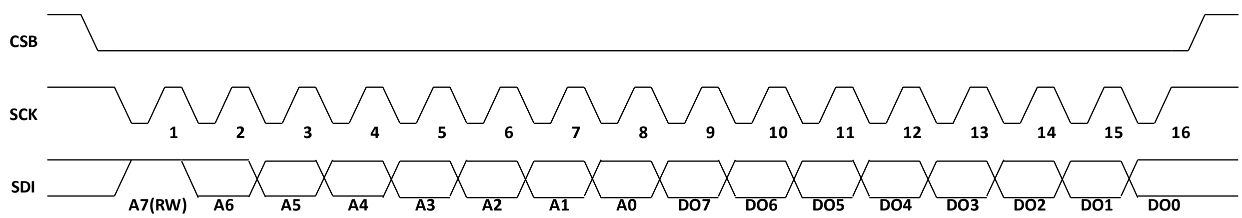


Figure 10. SPI 3-Wire (WIRE=1) Protocol – Read Access (register address MSB bit A7=1)

AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS

The MAS6505 has PI and NI input pins which allow measuring differential sensor bridge signal with both positive and negative polarities. The differential input signal VIN is defined as voltage difference between positive (PI) and negative (NI) input pin voltages VPI and VNI respectively.

$$VIN = VPI - VNI$$ **Equation 2**

Overall minimum and maximum differential input signals are defined by AFE GAIN and ADC OFS% settings as follows.

$$VIN_{MIN} = ISRADC\left(-\frac{1}{2}+\frac{OFS\%}{100\%}\right)/GAIN$$ **Equation 3**

$$VIN_{MAX} = ISRADC\left(+\frac{1}{2}+\frac{OFS\%}{100\%}\right)/GAIN$$ **Equation 4**

where

ISRADC = 1400mV Overall input signal range of ADC
OFS% = -49% .. +49% ADC offset setting in percentage
GAIN = ±(1x .. 55.8x) AFE gain setting

Overall input signal range (ISR) of the MAS6505 is difference between maximum and minimum allowed differential input signals.

$$ISR = VIN_{MAX} - VIN_{MIN} = \frac{ISRADC}{GAIN}$$ **Equation 5**

Signal clipping occurs for signals beyond VIN_{MIN} and VIN_{MAX} limits and exceeding the ISR value.

The ISRADC corresponds to overall input signal range of the ADC but from which 80% is considered linear (ISRLINADC) and suitable for accurate measurements.

$$ISRLINADC = 80\% \cdot ISRADC$$ **Equation 6**

The AFE gain and ADC offset settings should be chosen so that minimum and maximum sensor signal voltages are within the linear input signal range of the MAS6505. The minimum ($VNLIN_{MIN}$) and maximum ($VINLIN_{MAX}$) differential input signals in the linear input signal range are as follows.

$$VINLIN_{MIN} == ISRADC\left(-\frac{80\%}{2}+\frac{OFS\%}{100\%}\right)/GAIN$$ **Equation 7**

$$VINLIN_{MAX} == ISRADC\left(+\frac{80\%}{2}+\frac{OFS\%}{100\%}\right)/GAIN$$ **Equation 8**

Linear input signal range (ISRLIN) is difference between maximum and minimum allowed differential input signals which are in the linear signal range of the MAS6505. Signal distortion occurs beyond this signal range due to increased non-linearity.

$$ISRLIN = VINLIN_{MAX} - VINLIN_{MIN} = \frac{ISRLINADC}{GAIN} = \frac{80\% \cdot ISRADC}{GAIN}$$ **Equation 9**

Signal distortion occurs for signals beyond $VINLIN_{MIN}$ and $VINLIN_{MAX}$ limits and exceeding the ISRLIN value due to increased non-linearity.

Example

Temperature signal settings: OFST%=-7%, GAINT=+17.6
VIN_{MIN} =1400mV*(-0.5+(-7%)/100%)/17.6 ≈ -45.3mV
VIN_{MAX}=1400mV*(0.5+(-7%)/100%)/17.6 ≈ +34.2mV
$VINLIN_{MIN}$ =1400mV*(-0.5*80%+(-7%)/100%)/17.6 ≈ -37.4mV
$VINLIN_{MAX}$=1400mV*(0.5*80%+(-7%)/100%)/17.6 ≈ +26.3mV

AFE AND ADC INPUT SIGNAL RANGE DEFINITIONS (continued)

Pressure signal settings: OFSP%=+35%, GAINP=+26.6
VIN_{MIN}=1400mV*(-0.5+35%/100%)/26.6 ≈ -7.9mV
VIN_{MAX}=1400mV*(0.5+35%/100%)/26.6 ≈ +44.7mV
$VINLIN_{MIN}$=1400mV*(-0.5*80%+35%/100%)/26.6 ≈ -2.6mV
$VINLIN_{MAX}$=1400mV*(0.5*80%+35%/100%)/26.6≈ +39.5mV

The digital A/D conversion result (CODE) is an unsigned 24-bit number between 0 and 11184810. The maximum A/D conversion code value 11184810 is referred here as CODEFS. The linear input signal range codes range from 10% to 90% of CODEFS i.e. from 1118481 to 10066329. Thus it is possible to see from the A/D conversion result whether or not the input signal is within the linear input signal range of the ADC (ISRLINADC). The A/D conversion result (CODE) depends on the input signal (VIN) as follows.

$$CODE = CODEFS\left[\frac{1}{2}+\frac{VIN\cdot GAIN}{ISRADC}-\frac{OFS\%}{100\%}\right]$$ **Equation 10**

where

CODEFS = 11184810 A/D-converter maximum code (minimum code is zero)
ISRADC = 1400mV Overall input signal range of ADC
GAIN = ±(1x .. 55.8x) AFE gain setting
OFS% = -49% .. +49% ADC offset setting in percentage

The corresponding input signal voltage (VIN) can be calculated from the A/D conversion result (CODE) as follows.

$$VIN = \frac{ISRADC}{GAIN}\cdot\left(\frac{CODE}{CODEFS}-\frac{1}{2}+\frac{OFS\%}{100\%}\right)$$ **Equation 11**

Examples

VIN=+20mV, GAIN=+17.6, %OFS=+21%:
CODE=11184810*(0.5+20mV*17.6/1400mV-21%/100%)+)≈3246407

CODE=5160991, GAIN=+17.6, %OFS=+21%:
VIN=(1400mV/17.6)* (5160991/11184810-0.5+21%/100%)≈+13.6mV

AFE GAIN AND ADC OFFSET SELECTIONS

The AFE gain (GAIN) and ADC offset (OFS%) settings should be chosen such a way that the sensor signal (VS) stays in the linear input signal range of the ADC (ISRLINADC) in all conditions to avoid inaccuracies due to non-linearity or even signal clipping. The optimal offset ($OFS\%_{OPT}$) and gain ($GAIN_{OPT}$) settings are such which maximize resolution while keeping the amplified signal within the ISRLINADC. To be able to determine these settings the sensor signal minimum (VS_{MIN}) and maximum (VS_{MAX}) values need to be known.

The optimal GAIN and OFS% values can be calculated using equations 12 and 13.

$$OFS\%_{OPT} = \frac{K}{2}\cdot\frac{VS_{MAX}+VS_{MIN}}{VS_{MAX}-VS_{MIN}}\cdot 100\%$$ **Equation 12**

$$GAIN_{OPT} = \frac{K\cdot ISRADC}{VS_{MAX}-VS_{MIN}}$$ **Equation 13**

In above the factor K is ADC input range coverage factor which is K=80%=0.8 when fitting signal to the linear input range of the ADC (ISRLINADC). Note that these equations can result OFS% and GAIN values which are not supported by the MAS6505. Values which are within supported range can be rounded to closest available setting. However, in case out of range values there is needed separate search routine for finding best settings which maximize gain but also keep the signal within the ISRLINADC. See datasheet extension document DAE6505 for further details.

EXTERNAL TEMPERATURE DIODE TEMPERATURE SENSING

The MAS6505 supports temperature sensing using an external temperature sensing diode. This is selected by setting TSENSOR=1 in the Temperature sensor configuration register (FB/7B$_{HEX}$). In this configuration the external temperature sensing diode is connected between VDDS (anode) and TD (cathode). During temperature measurement the MAS6505 sinks a constant 10 µA bias current from the external temperature sensing diode and the temperature dependent diode forward voltage (VF~390mV @ 10µA) is measured.

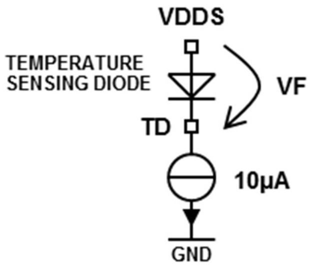


Figure 11. External temperature diode temperature sensing circuit illustration

The external temperature diode forward voltage has roughly -2.2mV/C temperature dependency as follows.

VF(T)=390mV-2.2mV/°C*(T-25°C) **Equation 14**

Following AFE and ADC settings must be used to avoid external diode signal VF(T) clipping.

GAIN=-1 (GAINT= 1, SGNGAINT=1)
OFS%=100%*(-390mV)/1400mV ≈ -28% => OFST%= -28%

Unity AFE gain needs to be used to keep the large diode voltage within input signal range of the ADC. Negative gain value is for achieving positive temperature dependency in the AD conversion result. The ADC offset setting needs to be negative since the negative gain value reverses signal polarity at the ADC input. The above GAIN and OFS% settings correspond to following input signal range limits.

VIN_{MIN} =1400mV*(-0.5-28%/100%)/(-1) ≈ +1092mV
VIN_{MAX}=1400mV*(0.5-28%/100%)/(-1) ≈ -308 mV
$VINLIN_{MIN}$ =1400mV*(-0.5*80%-28%/100%)/(-1) ≈ +952mV
$VINLIN_{MAX}$=1400mV*(0.5*80%-28%/100%)/(-1) ≈ -168mV

From equation 14 we can calculate that the temperature diode signal is between 247mV and 533mV in temperature range from -40°C to +90°C. Figure 12a shows falling temperature diode voltage signal VF (blue line) and overall (red continuous lines) and linear (red dashed lines) input signal range limits.

Using equation 10 the corresponding ADC output code can be also calculated. Figure 12b illustrates ADC output code showing desired positive temperature dependency. Figure includes also both overall (red continuous lines) and linear (red dashed lines) input signal range limits as ADC code values.

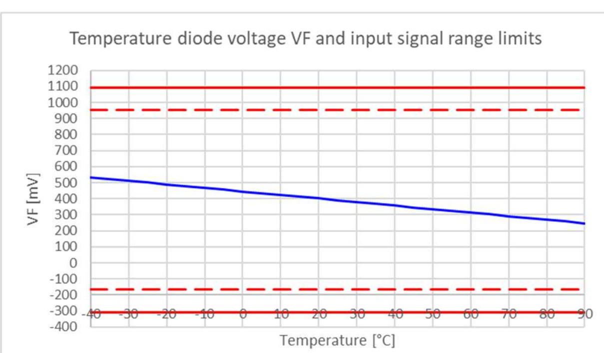


Figure 12a. Temp diode VF signal [mV]

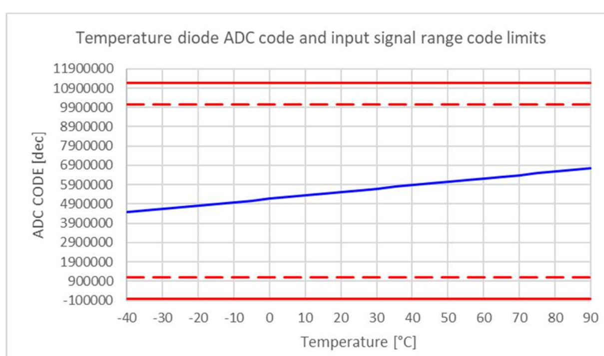


Figure 12b. ADC output code [dec]

SENSOR BRIDGE RESISTANCE TEMPERATURE SENSING

The MAS6505 supports temperature sensing using temperature dependency of sensor bridge resistance. This is selected by setting TSENSOR=0 in the Temperature sensor configuration register (FB/7B$_{HEX}$). In this configuration the piezoresistive sensor bridge R_S is connected into a Wheatstone resistor bridge configuration together with four internal resistors R1, R2, R3 and R4. See Figure 13.

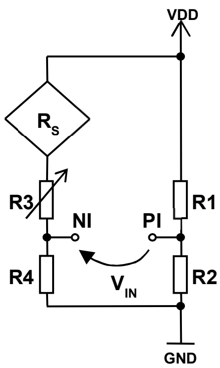


Figure 13. Temperature measurement circuit configuration in sensor bridge resistance temperature sensing

The formed Wheatstone bridge is usually balanced (output signal close to zero) at room reference temperature using RSENSOR sensor bridge resistance trim bits in the Temperature sensor configuration register (FB/7B$_{HEX}$). See table 7 for register details. The temperature signal has following characteristics and it is the input signal for the MAS6505 AFE in the temperature measurement.

$$V_{IN}(T) = VDDS \cdot \left[\frac{1}{\frac{R_1}{R_2}+1} - \frac{1}{\frac{R_S \cdot [1+TC_S \cdot (T-T_{REF})]}{R_4 \cdot [1+TC_R \cdot (T-T_{REF})]} + \frac{R_3}{R_4}+1} \right] \qquad \textbf{Equation 15}$$

VDDS = sensor supply voltage; 1.68V typ
R_S = sensor bridge resistance [Ω]
$R_{1,2,3,4}$ = internal resistors (see value in Electrical characteristics table on page 7) [Ω]
TC_S = sensor resistance temperature coefficient [ppm/°C]
TC_R = internal resistor temperature coefficient [ppm/°C]
T_{REF} = reference temperature for resistor values (typically +25°C) [°C]
T = actual sensor temperature to be measured [°C]

From equation 9 we see that the temperature signal has a rising temperature dependency vs. temperature when the sensor resistance has a positive temperature coefficient $TC_S>0$. With negative sensor resistance temperature coefficient $TC_S<0$ the signal has a falling temperature dependency vs. temperature. See signal illustrations in Figure 14.

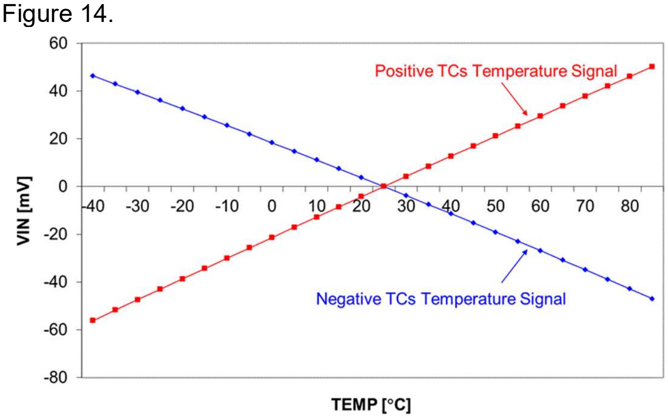


Figure 14. Temperature signals of positive and negative TC bridge resistance sensors

APPLICATION INFORMATION

Table 17 shows an example of calculated minimum and maximum differential signal values at the sensor input based on both full and linear input signal ranges of the ADC using the equations 3, 4, 7 and 8. The table shows input signal values at all eight offset options at both offset polarity signs. The table values are for unity gain amplification setting (GAIN=1). The input signal values for other gain settings can be easily calculated simply by dividing these values by the other gain setting value.

Table 17. Min and max input signal values in overall and linear input signal ranges for GAIN=1 setting

OFS% [% of ISRADC]	VIN_{MIN} [mV]	VIN_{MAX} [mV]	$VINLIN_{MIN}$ [mV]	$VINLIN_{MAX}$ [mV]
-49 %	-1386	14	-1246	-126
-42 %	-1288	112	-1148	-28
-35 %	-1190	210	-1050	70
-28 %	-1092	308	-952	168
-21 %	-994	406	-854	266
-14 %	-896	504	-756	364
-7 %	-798	602	-658	462
0 %	-700	700	-560	560
7 %	-602	798	-462	658
14 %	-504	896	-364	756
21 %	-406	994	-266	854
28 %	-308	1092	-168	952
35 %	-210	1190	-70	1050
42 %	-112	1288	28	1148
49 %	-14.0	1386.0	126.0	1246.0

Pressure Measurement Configuration

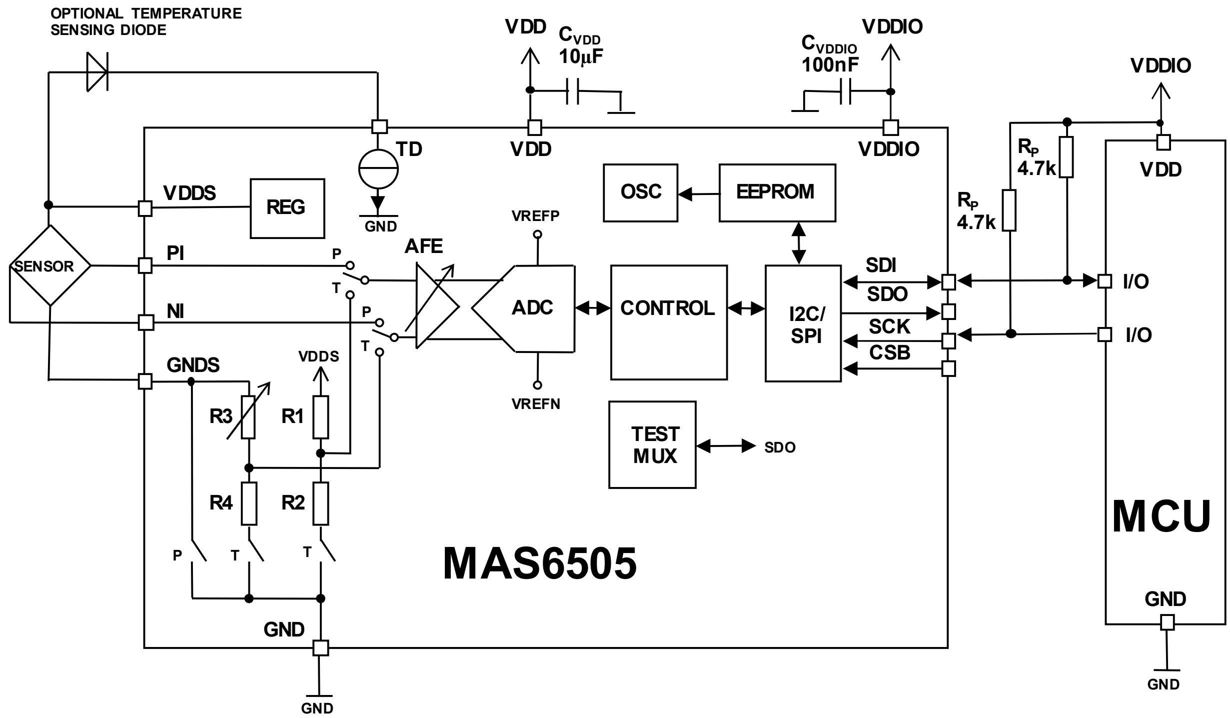
A piezoresistive absolute pressure sensor can be modeled roughly with the following signal voltage characteristic when including only first order pressure and temperature characteristics.

$$V_{IN}(p,T) = \frac{VDDS}{VDD_{REF}} \cdot \left[\frac{FS \cdot (1 + TC_{FS} \cdot (T - T_{REF}))}{p_{FS}} \cdot p + OS \cdot (1 + TC_{OS} \cdot (T - T_{REF})) \right]$$ **Equation 16**

VDDS = sensor supply voltage; 1.68V typ
VDD_{REF} = reference supply voltage at which the sensor parameters (FS, OS) have been specified (often 5V)
p = pressure [bar]
p_{FS} = full-scale pressure range [bar]
FS = full-scale span [V]
OS = zero pressure offset [V]
TC_{FS} = full-scale span temperature coefficient [ppm/°C]
TC_{OS} = offset temperature coefficient [ppm/°C]
T_{REF} = reference temperature for resistor values [°C]
T = actual temperature to be measured [°C]

The above linear approximation includes sensor full-scale span and offset signal temperature dependencies.

APPLICATION INFORMATION (continued)



NOTE: In I2C bus communication the CSB pin is unused and left unconnected (floating). It has an internal pull up to VDDIO.

Figure 15. Typical EEPROM read only application circuit in I2C bus communication

Together with a resistive pressure sensor, MAS6505 can be used in pressure measurement applications. An external micro-controller can control the MAS6505 via an I2C or a SPI serial interface. Note that the I2C serial interface requires suitable pull-up resistors connected to the SDI and SCK pins (see Figure 15). If there is only a single master device connected to the serial bus the master's SCK output can be of push-pull type making the SCK pull-up resistor unnecessary.

The sensor is connected between regulated Sensor bridge supply voltage (VDDS) and Sensor bridge supply ground (GNDS) of MAS6505. The sensor output is read as a differential signal through PI (positive input) and NI (negative input) to the ΔΣ converter in MAS6505.

In the pressure measurement mode, the switches marked "P" are closed and the sensor output is fed through to the ADC. In the temperature measurement mode, the switches marked "T" are closed and the voltage at the ADC input is determined by the internal resistor array and the temperature-dependent resistance of the sensor. In this configuration the sensor bridge is connected as part of a Wheatstone resistor bridge circuit where the other four resistors (R1, R2, R3, R4) are inside the IC.

A decoupling capacitor of at least 10µF should be used at the supply voltage VDD for low noise performance (see Figure 15).

In EEPROM read only application (EEPROM calibration memory readily programmed) the supply voltage operating range is VDD=1.71V…5.5V. However if both EEPROM write and read are needed in application level the 5V supply voltage is necessary (VDD=4.5V…5.5V) as shown in Figure 4.

APPLICATION INFORMATION (continued)

Noise Resolution Improvement

Measurement noise resolution can be improved by using high oversampling ratio (OSR) settings. Additionally IIR filter options (see Table 3) can be used to further improve the noise resolution. The IIR filter has also impact on step response. Table 18 below shows noise scaling factors and step responses at the different IIR filter options. However note that the step response to the first measurement result is immediate since the first result ($CODE_{ADC}$) is considered also as previous filtered output ($CODE_{OLD}$) in the filter equation 1 (see page 18).

Table 18. IIR filter noise reduction factor

Filter Coefficient	Noise Scale Factor	Samples to reach ≥75% of step response	Samples to reach ≥90% of step response
[-]	[-]	[-]	[-]
No filtering	1	1	1
2	0.58	2	4
4	0.38	5	8
8	0.26	11	17
16	0.18	22	35

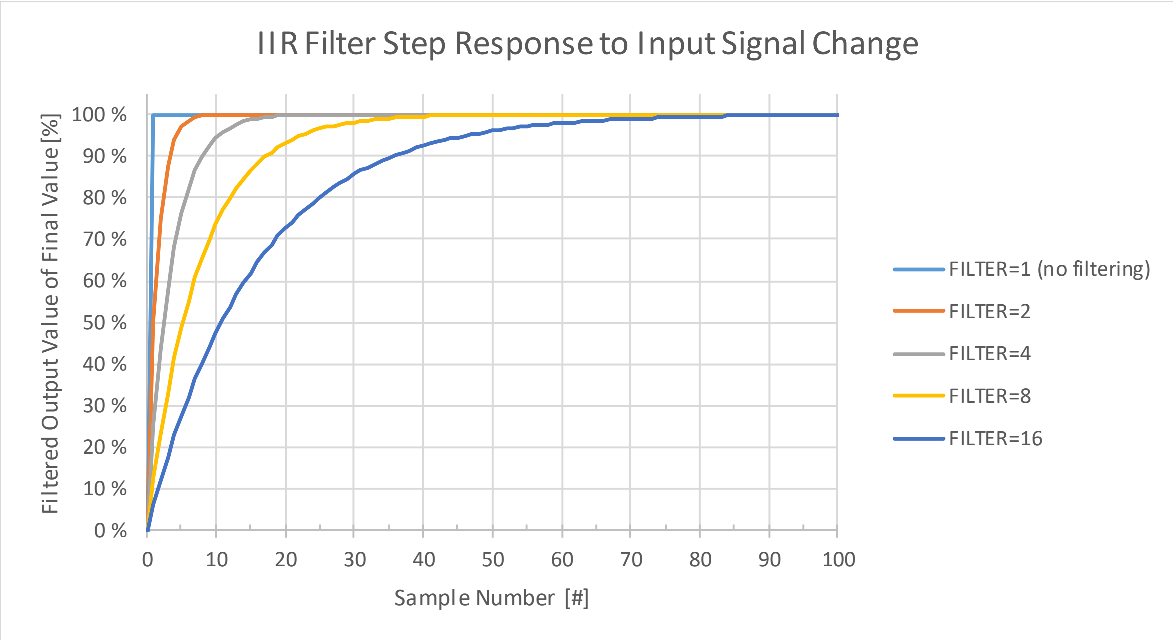
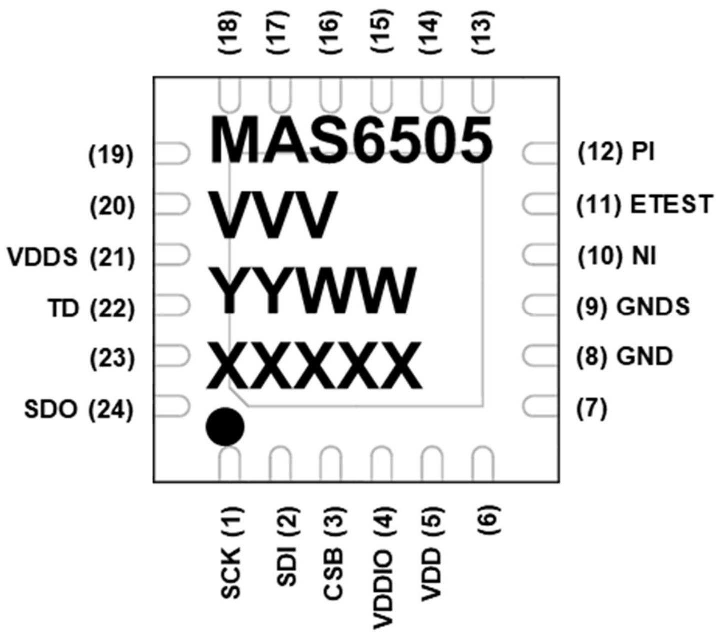


Figure 16. IIR filter step response to input signal change

Example

GAIN=14.9, OSRP=16:
The input noise resolution in pressure mode using different filter options is as follows.
FILTER=1 (no filtering): typ 0.44µV_{RMS}.
FILTER=2: typ 0.58*0.44µV_{RMS} ≈ 260nV_{RMS}.
FILTER=4: typ 0.38*0.44µV_{RMS} ≈ 167nV_{RMS}.
FILTER=8: typ 0.26*0.44µV_{RMS} ≈ 114nV_{RMS}.
FILTER=16: typ 0.18*0.44µV_{RMS} ≈ 79nV_{RMS}.

MAS6505 IN QFN-24 4x4x0.85 PACKAGE



Top Marking Information:
MAS6505 = Product Number
VVV = Product Version
YYWW = Year Week
XXXXX = Lot Number

QFN-24 4x4x0.85 PIN DESCRIPTION

Pin Name	Pin	Type	Function	Notes
SCK	1	DI	Serial bus clock input in I2C and SPI	
SDI	2	DI/O	Data input/output in I2C Data input in 4-wire SPI / Data input/output in 3-wire SPI	
CSB	3	DI	Bus mode select / chip select with pull-up CSB=VDDIO: I2C mode / chip not selected CSB=GND: SPI mode / chip selected	1
VDDIO	4	P	Positive supply voltage for serial bus interface	2
VDD	5	P	Positive supply voltage	
	6-7	NC		3
GND	8	G	Supply ground	
GNDS	9	AO	Sensor bridge supply ground	
NI	10	AI	Negative sensor signal input	
ETEST	11	AI/O	EEPROM test	4
PI	12	AI	Positive sensor signal input	
	13-20	NC		3
VDDS	21	P	Supply voltage for sensor bridge and external sensing diode	
TD	22	AI/O	External temperature sensing diode cathode connection	5
	23	NC		3
SDO	24	DO	Data output in 4-wire SPI mode Test input/output in test mode	6

NC = Not Connected, P = Power, G = Ground, DO = Digital Output, DI = Digital Input, AO = Analog Output, AI = Analog Input

Note 1: In I2C mode the unused CSB pin must be left unconnected (floating). The CSB pin has internal 250 kΩ pull-up resistor to VDDIO. To minimize current consumption the pin should be kept high (at VDDIO) except during chip select events of SPI bus communication mode.

Note 2: If there is no separate supply voltage available for the serial bus interface the VDDIO must be tied to VDD.

Note 3: The not connected (NC) pins should be connected to supply ground (GND) for minimum noise.

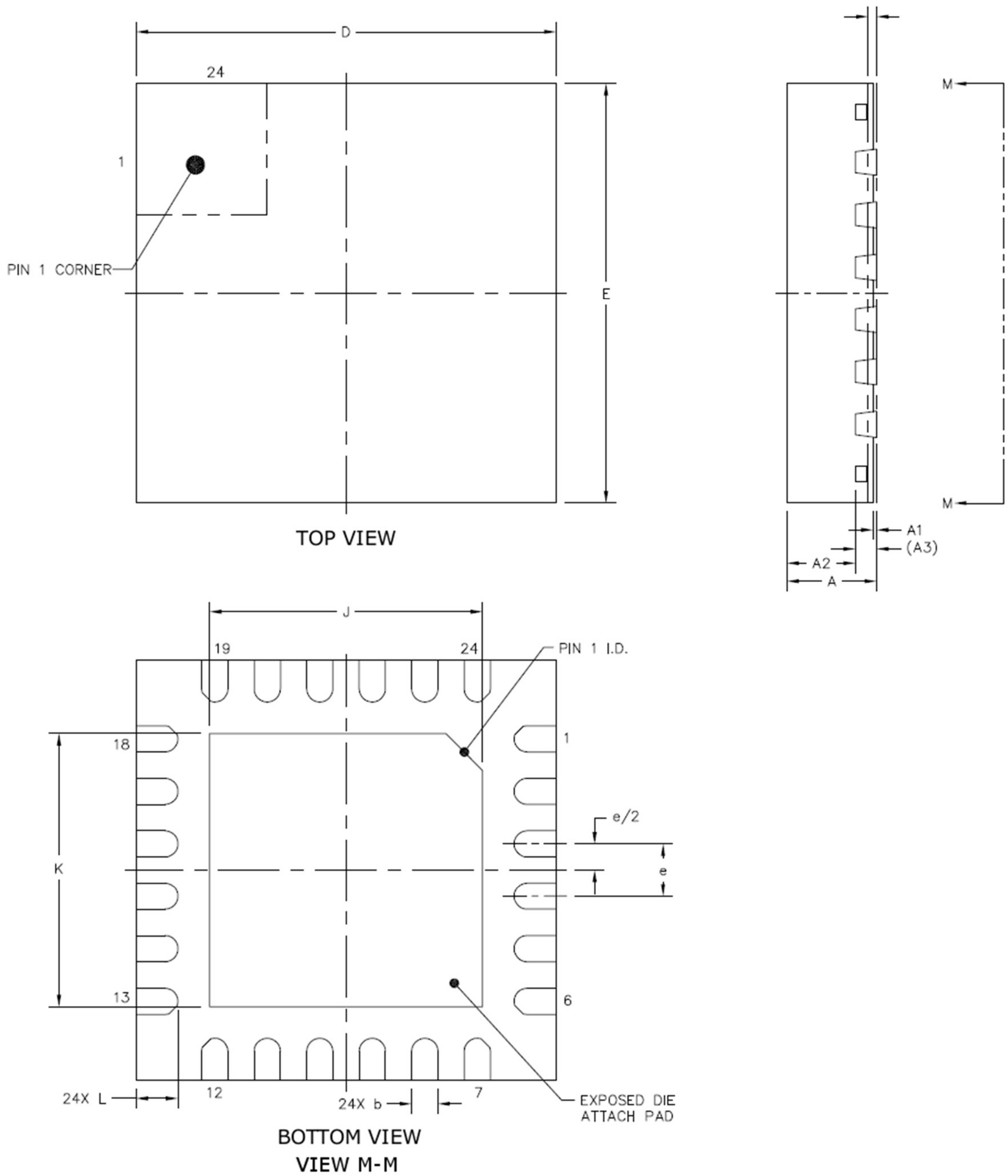
Note 4: The ETEST pin must be left unconnected (floating). It is only for EEPROM testing purpose.

Note 5: Optional external temperature sensing diode is connected between VDDS (anode) and TD (cathode). The unused TD pin is left unconnected.

Note 6: In I2C and 3-wire SPI modes the unused SDO pin must be left unconnected (floating).

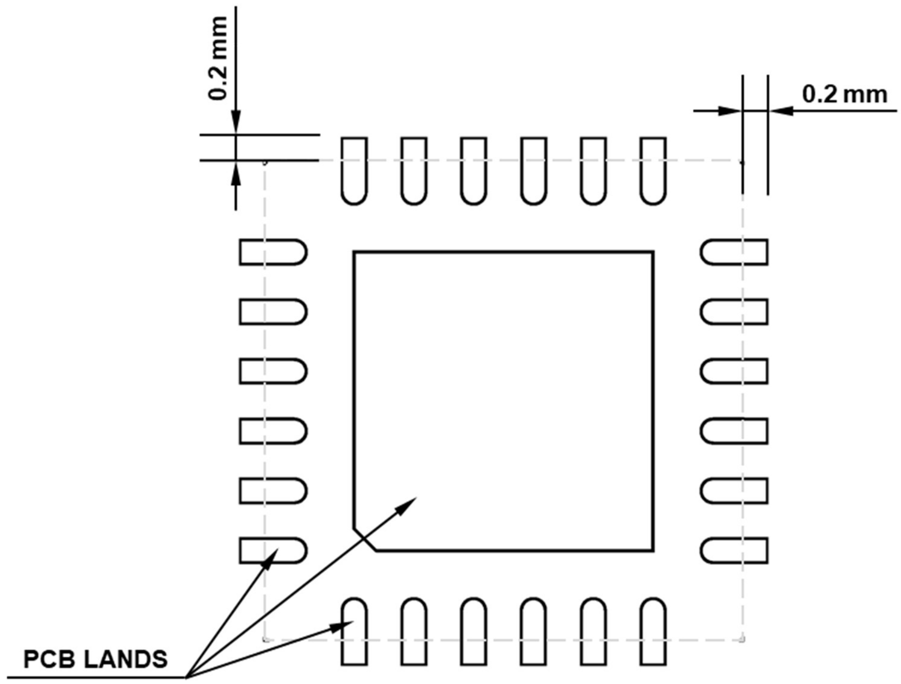
Note: On PCB the exposed pad is recommended to be connected to GND for minimum noise. It can be also left floating but it cannot be connected to any other potential than GND.

PACKAGE (QFN-24 4x4x0.85) OUTLINE



Symbol	Min	Nom	Max	Unit
PACKAGE DIMENSIONS				
A	0.8	0.85	0.9	mm
A1	0	0.035	0.05	mm
A2	---	0.65	---	mm
A3		0.203 REF		mm
b	0.2	0.25	0.3	mm
c		0.203 REF		mm
D		4 BSC		mm
E		4 BSC		mm
e		0.5 BSC		mm
J (Exposed.pad)	2.5	2.6	2.7	mm
K (Exposed.pad)	2.5	2.6	2.7	mm
L	0.35	0.4	0.45	mm

QFN-24 4x4x0.85 PCB LAND PATTERN



Notes

- I/O lands should be 0.2mm longer than QFN pads and extend the same 0.2mm outside package outline
- exposed pad land size should be the same as QFN exposed pad size

solder resist opening should be 120µm…150µm larger than the land size resulting in 60µm…75µm clearance between copper land and solder resist

ORDERING INFORMATION

Product Code	Product	Description
MAS6505BA1WAD00	Piezoresistive Sensor Signal Interface IC	Tested inked wafer, thickness 370 µm.
MAS6505BA1WAD05	Piezoresistive Sensor Signal Interface IC	Bare die in tray, thickness 370 µm
MAS6505BA1WAB05	Piezoresistive Sensor Signal Interface IC	Bare die in tray, thickness 180 µm
MAS6505BA1Q1706	Piezoresistive Sensor Signal Interface IC	QFN-24 4x4x0.85, REACH & RoHS compliant, MSL 3, Tape &Reel, 1000/3000 pcs components on reel

Contact Micro Analog Systems Oy for other wafer and die thickness options.

LOCAL DISTRIBUTOR

MICRO ANALOG SYSTEMS OY CONTACTS

Micro Analog Systems Oy Kutomotie 16 FI-00380 Helsinki, FINLAND	Tel. +358 10 835 1100 http://www.mas-oy.com