ENS220

Premium accuracy barometric pressure and temperature sensor for activity tracking and indoor navigation / localization

ENS220 datasheet

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The ENS220 is an ultra-low-power, high-accuracy barometric pressure and temperature sensor. It comes in the smallest size LGA package with digital I²C and SPI interfaces. This enables new use cases in activity tracking, indoor navigation/localization, fall- and liquid-level detection.

The capacitive pressure sensor of the ENS220 is integrated on a CMOS ASIC. This single die solution not only allows small form factor packages with excellent immunity to changes in environmental conditions, but also achieves ultra-low current consumption due to the capacitive read-out. High intrinsic pressure sensitivity combined with an ultra-low noise 24-bit ADC converter results in unprecedented low pressure noise. The integrated temperature sensor matches the performance of dedicated temperature measurement devices. It ensures a stable, temperature compensated pressure output with a fast response time. The highly accurate pressure reading, and the short conversion time make the ENS220 perfect for height measurements with a high output data rate and high bandwidth.

Key Features & Benefits

Premium **absolute accuracy:** ±0.5 hPa

Relative accuracy: ±0.025 hPa (equiv. to ±20 cm) allows ultra-fine differential pressure measurements for reliable **centimeter resolution positioning**

Lowest power: average supply current of 0.1 µA at idle, 0.8 µA when sampling at 1/60 Hz, ensures **long battery life** even at high sampling rates

Ultra-low noise of 0.1 Pa rms (≈ 1 cm) at 2 Hz sample rate

User-configurable sample rate up to 1 kHz (0.9 Pa rms)

Temperature accuracy of 0.2 K with 8 mK resolution

Fully digital interface with **best-of-breed form factor**, which perfectly integrates into **space-constraint designs**, e.g., mobiles, wearables, hearables

Interrupt on multiple conditions **including pressure thresholds** for ultra-low power applications

Applications

- Mobile/Wearables: activity tracking, indoor localization/navigation, fall detection
- Gaming, AR/VR, Drones: height tracking
- Appliances/HVAC: filter clogging detection
- White goods: liquid level detection
- Medical: blood pressure measurement
- Accurate temperature meter for gasses and surfaces

Properties

- Small 2.0 x 2.0 x 0.75 mm³ LGA package
- P operating range from 300 to 1200 hPa
- T operating range from −40 to +85 °C
- Power supply range from 1.62 V to 1.98 V
- Standard, fast, and high speed I²C and SPI interface
- T&R packaged, reflow solderable.
- MSL1 compliant

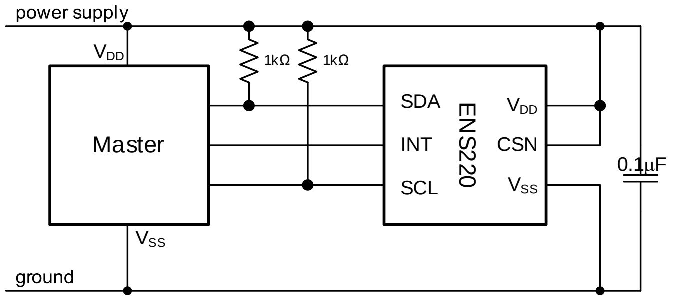
Content Guide

1 Quick Start

A typical application circuit for ENS220 is shown on the left-hand side of Figure 1. After reaching the minimal supply voltage and allowing for the maximal power-up time of 1 ms the sensor is ready for I^2C communication. The quickest way to measure pressure and temperature is pseudo-coded in Figure 1. The conversion formulae given in equations in Table 5 and Table 6 are used to translate the digital signals into absolute pressure and temperature readings.

More application examples can be found in chapter 9.

Typical application circuit



Pseudo code

```
Write(0x06,0x93)    //Set HP, direct path, measure, P enabled, T enabled
Repeat forever
       I=Read(0x14)        //read DATA_STAT
       //make sure to use 32 bit integers
       if (I & 0x1)!=0     //check TR flag
              T=Read(0x1A) + 256*Read(0x1B)
              Print( T/128.0 - 273.15, “C”)
       if (I & 0x2)!=0     //check PR flag
              P=Read(0x17) + 256*Read(0x18) + 256*256*Read(0x19)
              Print( P/64.0, “Pa”)
```

Figure 1: Typical application circuit (top) and pseudo code (bottom) for easy starting. For details on the sensor configuration see section 6.

Find code resources and embedded drivers on: https://github.com/ScioSense

2 Pin assignment

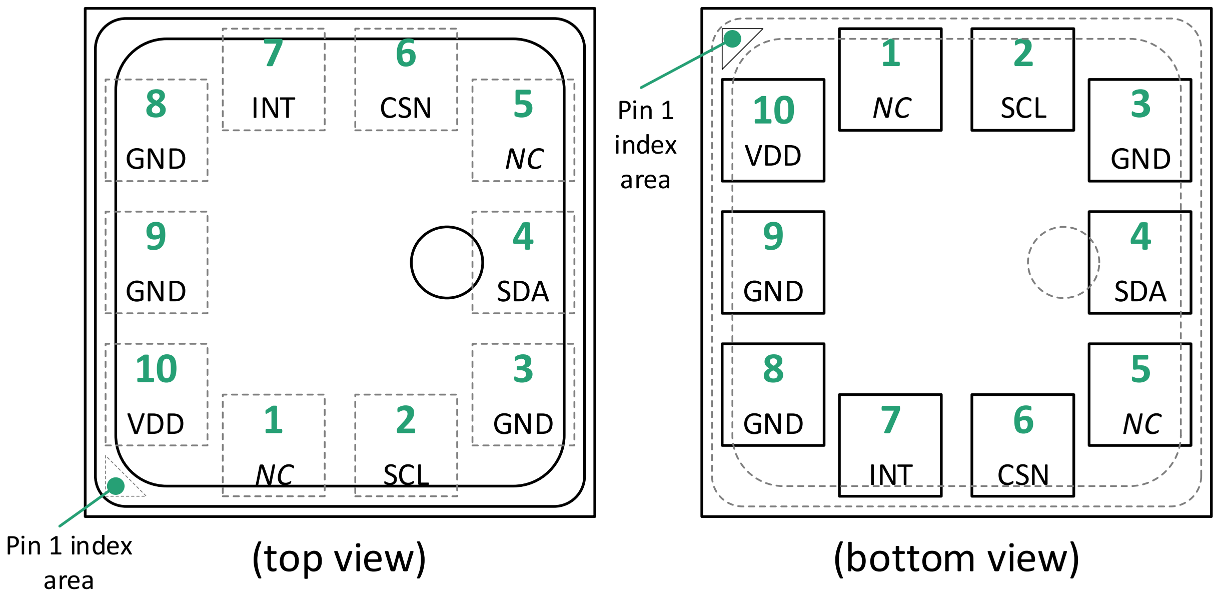


Figure 2: Pin diagram (NC = not connected)

Also see sections 9.1 "I2C operation circuitry" and 9.2 "SPI operation circuitry" for wiring.

Table 1: Pin description

Pin	Pin Name	Pin Type	Description
1, 5	NC	unconnected	Unconnected pins. These are isolated from each other pin.
2	SCLK / SCL	Input	SPI Serial Clock / I²C Bus Serial Clock Input
3, 8, 9	GND (V_{SS})	Supply	Ground Supply Voltage
4	MOSI / SDA	Input / Output	SPI Master Output Slave Input / I²C Bus Bi-Directional Data
6	CSn	Input	SPI Interface Select (CSn low -> SPI / CSn high -> I²C)
7	MISO / INTn	Output	SPI Master Input Slave Output / Interrupt to Host
10	V_{DD}	Supply	Supply Voltage

3 Pressure and temperature specifications

Default conditions of 25 °C, 50 % RH, without MSL1 pre-conditioning, default periodic measurement apply to values in the table below, unless otherwise stated.

Table 2: Pressure and temperature specifications

Symbol	Parameter	Min	Typ	Max	Unit	Comments
	Pressure					
P_{RANGE}	Pressure operating range	300		1200	hPa	
P_{ACC}	Absolute pressure accuracy 500-1100hPa -5 °C ... 55 °C		±0.5		hPa	
	Absolute pressure accuracy 500-1100 hPa, -20 °C … 70 °C		±1		hPa	
	Absolute pressure accuracy 300-1200 hPa, -40 °C … 85 °C		±3		hPa	
P_{REL}	Relative accuracy P step of 10hPa in 600..1100 hPa and/or T change -5..55 °C		2.5		Pa	
P_{RES}	Pressure resolution (1 LSB)		1/64		Pa	
P_{DRIFT}	Long term stability[1]		±10		Pa/year	
P_{SOLDER}	Solder shift (conditions in Figure 31)		±1		hPa	
T_{SENS}	Temperature sensitivity 500-1100 hPa, 25 °C … 45 °C		0.5		Pa/K	
P_{NOISE}	Pressure noise, 4 ms conversion, no oversampling, 1000 hPa, 25 °C		0.85	1.25	Pa rms	(ca. 50 Hz ODR for PT-rate=1)
	Temperature					
T_{RANGE}	Temperature operating range	-40		85	°C	
T_{ACC}	Temperature accuracy between 0 °C and 70 °C			0.2	°C	
	Temperature accuracy between -40 °C and 85 °C			0.5	°C	
T_{RES}	Temperature resolution		1/128		K	

[1] Average over lifetime, based on temperature-accelerated measurements.

4 Electrical characteristics

The following figure details the electrical characteristics of the ENS220. All limits are guaranteed. The parameters with min and max values are guaranteed with production tests or SQC (Statistical Quality Control) methods.

Table 3: Electrical characteristics

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	Positive supply		1.71	1.8	1.98	V
$TEMP_{RNG}$	Operating temperature range		-40		85	°C
I_{I_ULP}	Current consumption in idle state with HP activated	VDD=1.8 V, 35 °C		105		nA
		VDD=1.98 V, 85 °C		1600		nA
I_{I_LP}	Current consumption in idle state with HP deactivated			40		uA
I_C	Current consumption during T, P conversion	OVP=128, OVT=128, continuous mode		75		uA
ODR	Sampling rate				970	1/s = Hz
T_{PUP}	Power up time				1	ms
T_{VddTr}	VDD rise time at power on				10	ms
$T_{stbyAcc}$	Stand-by time accuracy				20	
T_{CONV_T}	Temperature Conversion time	OVT = 1, T = 25 °C		4		
T_{CONV_P}	Pressure Conversion time	OVP = 1, CV_time = 1, Toff = 1 (no Temp. mmnt)		1		
V_{IH}	High-level input voltage		VDD - 0.5			
V_{IL}	Low-level input voltage					

V_{OH}	High-level output voltage					
V_{OL}	Low-level output voltage					

At power on the supply voltage (VDD) must rise within 10 ms (T_{VddTr}) to the minimum supply voltage otherwise the internal reset may malfunction.

5 Absolute maximum ratings

Table 4: Absolute Maximum Ratings

Symbol	Parameter	Min	Max	Units	Comments
Electrical Parameters					
V_{DD}	Supply Voltage	-0.3	2.17	V	
V_{DDIO}	Interface I/O voltage	-0.3	V_{DD}+0.3	V	
I_{SCR}	Input Current (latch-up immunity)	- 50	50	mA	JESD78C
Electrostatic Discharge					
ESD_{HBM}	Electrostatic Discharge HBM	± 2000		V	JS-001-2014
ESD_{CDM}	Electrostatic Discharge CDM	± 500		V	JESD22-C101E
Operating and Storage Conditions					
T_{STRG}	Storage Temperature	-40	85	°C	
RH_{STRG}	Storage Relative Humidity	10	90	%	Non-condensing
T_{AMB}[2]	Operating Ambient Temperature	-40	85	°C	
RH_{AMB}	Operating Ambient Rel. Humidity	5	95	%	Non-condensing
P_{MAX}	Survival pressure		5000	hPa	
$T_{lifetime}$	Sensor lifetime	10		years	Under typical operating conditions

Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated under Electrical Characteristics is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability and lifetime.

Note: The ENS220 is not designed for use in safety-critical or life-protecting applications.

[2] The ENS220 is electrically operable in this range, however its pressure sensing performance might vary.

6 Functional description

The ENS220 integrates an absolute pressure sensor, a temperature sensor and an ASIC which performs A/D conversions and provides the pressure and temperature data through a digital interface.

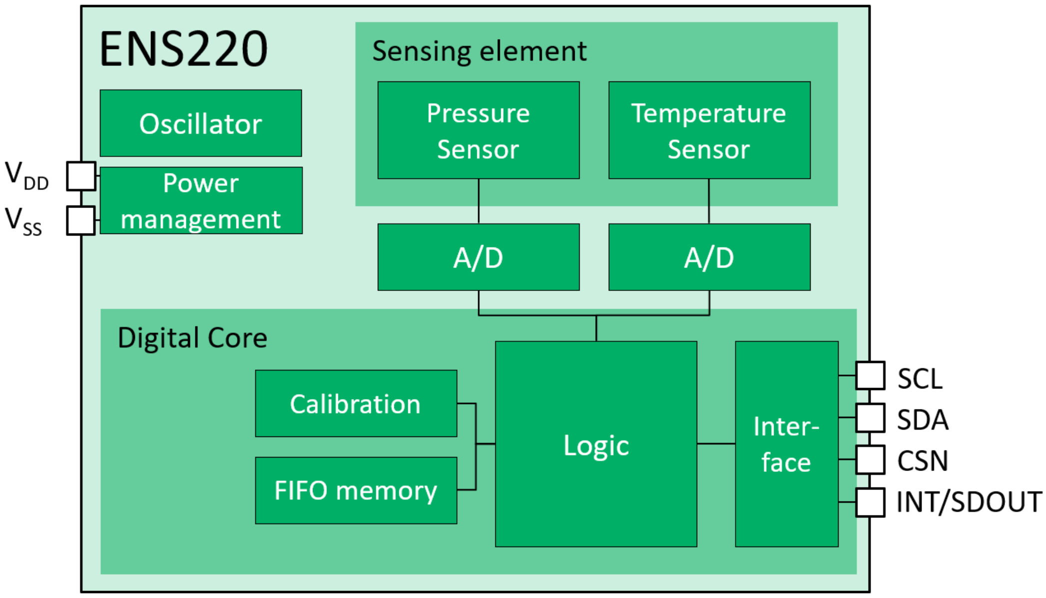


Figure 3: Block diagram of the ENS220

The ENS220 is a sensor capable of providing fast, accurate and temperature measurements at low current consumption. To meet the requirements of different use cases the ENS220 offers very high configuration flexibility.

The configurable features are:

- Operating mode
  - Continuous
  - Pulsed
  - Single Shot
- Pressure measurement precision (conversion time and oversampling) and rate
- Temperature measurement precision (oversampling) and rate
- Ultra-low power mode
- FIFO
- Interrupt behavior
  - New measurement available
  - FIFO at watermark level
  - FIFO full
  - High resolution pressure threshold
  - No interrupt
- Moving average

6.1 Measurement modes

The sensor starts powering-up after reaching the power-up threshold voltage V_{DD}, Min = 1.62 V. The sensor enters default the idle mode, in which no measurements are performed, and the sensor configuration can be chosen.

By switching the START bit to 1, the sensor starts measuring pressure and temperature. The ENS220 can be operated in three measurement modes, which can be selected with the value of STBY_T (see also Figure 4):

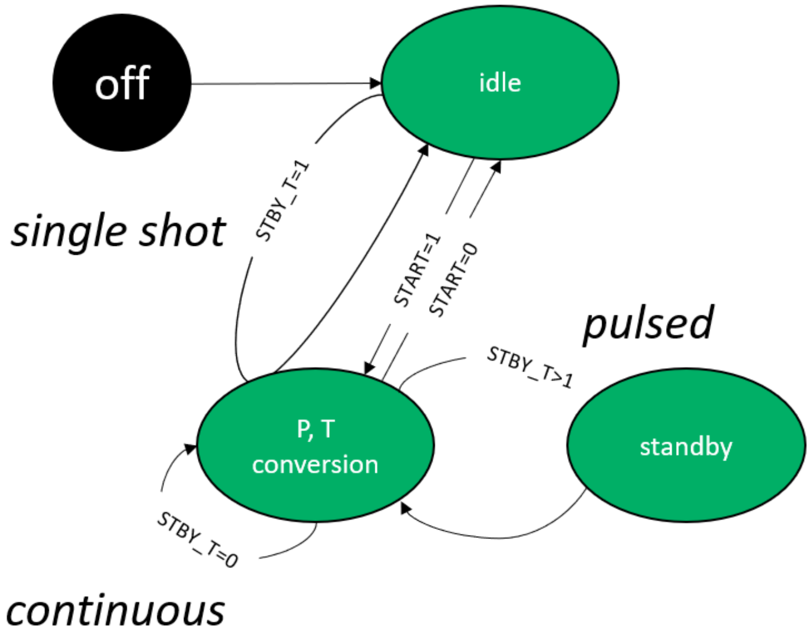


Figure 4: Simplified schematic of measurement modes

- If STBY_T=0 the device performs **continuous** measurements (temperature and pressure).
- If STBY_T>1 the device alternates a measurement phase and a standby phase (**pulsed** operation)
- If STBY_T=1 the device performs a **single** measurement (temperature and pressure) and goes back into idle mode.

The length of the standby phase can be selected from 10 ms to 600 s by writing on STBY_T. A timing diagram of pulsed operation is shown below in Figure 5.

6.2 PT-Rate

In default configuration (see default values in register table), the device performs one pressure measurement followed by a temperature measurement. The ratio between pressure and temperature measurements can be altered by selecting a pressure/temperature rate by writing on PT_RATE. The value varies from 1 to 256. The device will perform a new temperature measurement once every PT_RATE pressure measurements (see Figure 5).

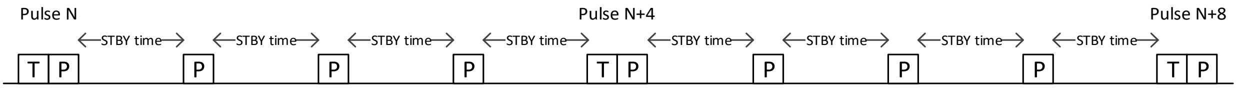


Figure 5: Effect of PT_RATE=1 (meaning P/T rate is 4)

MEAS_P and MEAS_T determine whether pressure or temperature measurements take place. If only temperature or only pressure is enabled, PT_RATE has no effect.

The ENS220 uses the temperature value to compensate the pressure output. It is therefore advisable to take regular temperature measurements (at least once per second) to correct temperature fluctuations. For fast temperature transients the temperature measurement should be performed more often to avoid errors in the temperature compensation. The exact requirements for temperature update rate depend on the use case and the physical properties of the soldering substrate and should be evaluated by the user (see also use case examples in chapter 9).

If only pressure measurements are enabled (MEAS_P=0), the device will begin with a temperature measurement, then it will continue measuring only pressure (see also Figure 8 in section 6.5).

6.3 Readout

6.3.1 Absolute Pressure

The pressure value is a 24 bit unsigned integer and is available in the sensor readout registers PRESS_OUT and PRESS_OUT_F.

The PRESS_OUT value is already calibrated, linearized, and temperature-compensated. It requires a division by 64 to achieve a pressure reading in Pa:

Table 5: Pressure conversion formula

Pascal
$P/[\mathrm{Pa}] = \frac{PRESS\_OUT}{64}$

6.3.2 Temperature

The temperature value is a 16-bit unsigned integer and is available in the sensor readout registers TEMP_OUT. Temperature can be calculated as:

Table 6: Temperature conversion formulas

Celsius	Kelvin
$T_C/[°\mathrm{C}] = \frac{TEMP\_OUT}{128} - 273.15$	$T_K/[\mathrm{K}] = \frac{TEMP\_OUT}{128}$

6.4 Ultra low power mode

Power consumption can be reduced at the expense of some functionality.

If the HP bit is 0 (see MODE_CFG), the power consumption in idle and standby state is low (current draw is I_{I_ULP}) and only the following registers are accessible via SPI/I²C: MODE_CFG, PART_ID, DATA_STAT, FIFO_STAT, PRESS_OUT, TEMP_OUT, INT_STAT.

The use of this feature is recommended for every measurement mode except continuous mode.

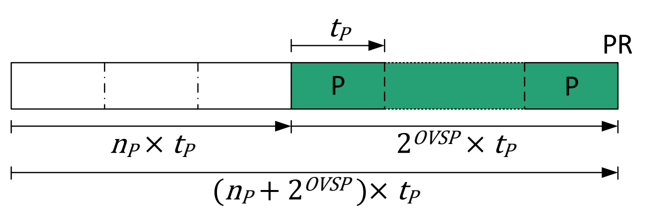
By setting HP to 1, the power consumption increases to I_{I_LP} and all registers become available.

6.5 Precision and oversampling rate

6.5.1 Absolute Pressure

The precision of the pressure output can be optimized by adjusting the conversion time and oversampling rate.

The ENS220 has a default conversion time t_P of 2 ms for pressure conversion. The conversion time can be selected via P_CONV to 1 ms, 2 ms or 4 ms. The first measurement after ADC power-up (i.e., after exiting standby mode or after a temperature measurement) requires 4 times the nominal duration (see Figure 6 and Figure 7).



$t_P = 1\text{ ms}, 2\text{ ms}$ or 4 ms

$n_P = 0$, if in continuous mode and previous measurement was a pressure measurement

$n_P = 3$, in all other cases

Figure 6: Timing diagram of a pressure pulse (values are typical)

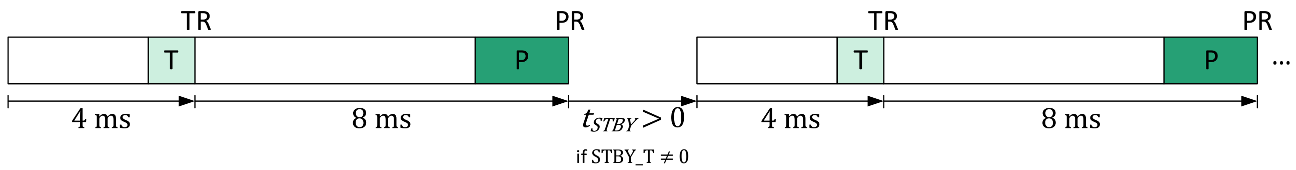


Figure 7: Typical timing for a continuous or pulsed measurement in default configuration. (PT_RATE = 1, P_CONV = 1 (2 ms) and no oversampling)

Oversampling is available to reduce the measurement noise at the expense of conversion time. Between 1 and 128 measurements (see also OVS_CFG) are performed and averaged to calculate the output value. Every additional conversion for oversampling takes 1 ms, 2 ms or 4 ms, depending on the conversion time selected (Figure 8). The effect of oversampling on noise is shown in Figure 9.

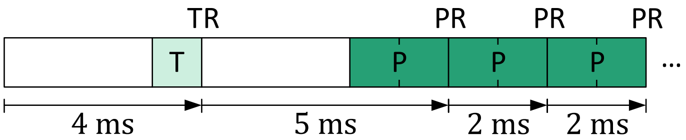


Figure 8: Typical timings for a continuous pressure-only measurement (P_MEAS = 0, P_CONV = 0) with activated 2× oversampling (OVSP = 1)

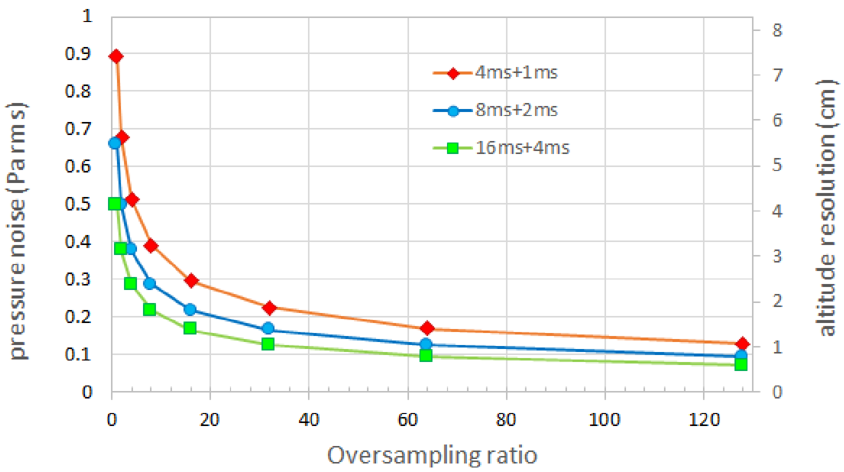


Figure 9: Pressure noise as function of oversampling ratio for three conversion time settings.

The oversampled pressure value can either be transferred directly to the readout registers, can be recorded in a FIFO buffer, or can be further processed by a moving average filter. The desired path is selected by writing on MODE_CFG.FIFO_MODE (see chapter 6.6 and 6.8).

6.5.2 Temperature

The precision of the temperature output can be optimized by oversampling rate. Between 1 and 128 measurements (see also OVS_CFG) are performed and averaged to calculate the output value. The temperature conversion time is 4 ms. In case of oversampling, every additional conversion requires 1 ms (see Figure 10).

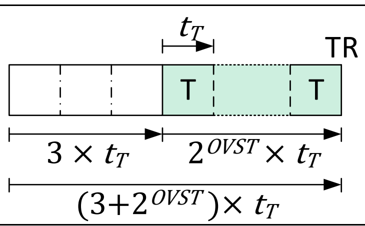
	$t_T = 1$ ms

Figure 10: Timing diagram of a temperature pulse (values are typical)

Note: When measuring only temperature, each oversampled measurement will start with a 4 ms time followed by 1 ms for the measurements required to complete oversampling (Figure 11).

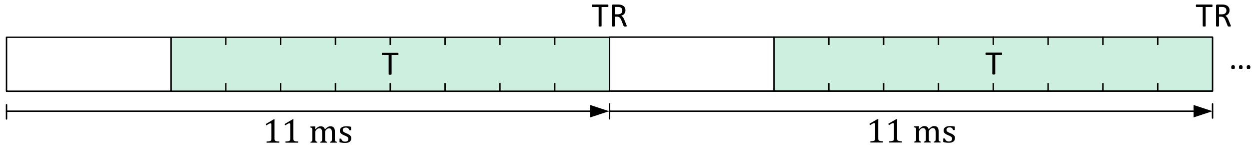


Figure 11: Typical timing of a continuous temperature-only measurement (MEAS_P=0) with 8× oversampling (OVST=3)

6.6 FIFO

A FIFO buffer with 32 positions is available to store pressure values; it is enabled by writing on MODE_CFG.FIFO_MODE.

The FIFO works as a circular buffer, with a write pointer used to store new pressure values and a read pointer used to retrieve them (the structure is shown in Figure 12). The write pointer is increased whenever a new measurement is complete, then the new value is written on the buffer. The pointer will increase even when the buffer is full, overwriting the oldest values recorded. Reads from PRESS_OUT_H increase the read pointer until it reaches the write pointer, subsequent reads will return 0. Both pointers wrap around (31 increments to 0).

Reading the entire FIFO quickly can be done by using PRESS_OUT_F. In this case a continuous read past address 0x29 will cycle the memory read pointer back to 0x27, increasing at the same time the FIFO read pointer. In this way the entire FIFO buffer can be transferred without addressing overhead.

NOTE: in order to read more than one value it is necessary to set the HP bit in MODE_CFG.

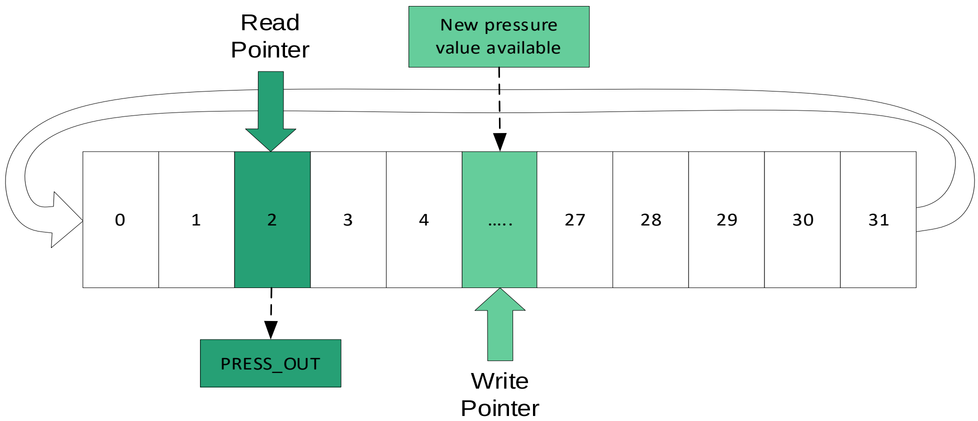


Figure 12: FIFO structure

FIFO operations are controlled by FIFO_CFG. The FIFO can be cleared by setting FP_CLEAR. FIFO status is available in FIFO_STAT and the current FIFO fill level (number of elements available) can be read on FP_FILL. When FIFO is empty, FE is set, when FIFO is full, FF is set. If a new pressure value arrives while FIFO is full, the overrun bit DATA_STAT.PO is set, and the oldest value is overwritten.

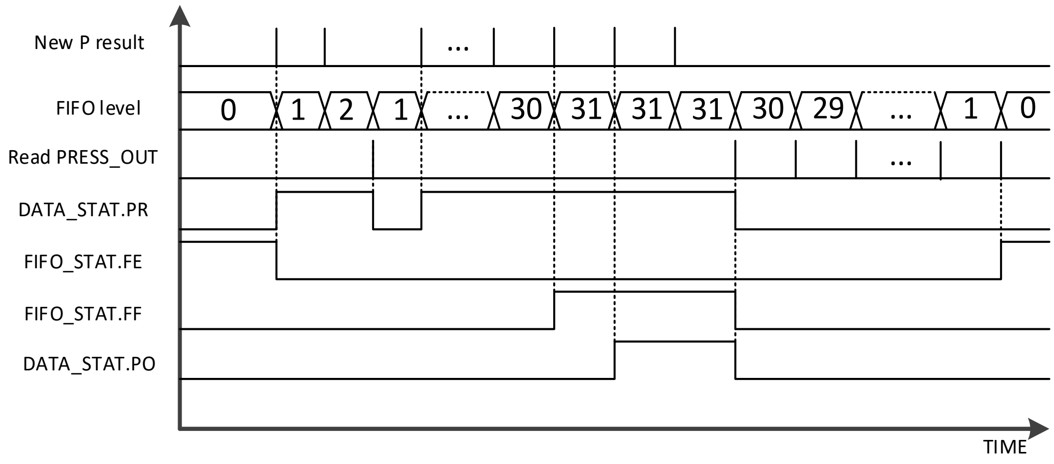


Figure 13: Sample FIFO timing diagram

Interrupts can be configured so that they will assert when FIFO is full, empty or filled to a certain level (see chapter 6.7 and 0)

6.7 Interrupt

Interrupts can be enabled by writing on INT_CFG. Interrupts are available for the following events:

- Pressure measurement ready
- Temperature measurement ready
- FIFO level high
- FIFO full
- FIFO empty
- Pressure below PRESS_LO
- Pressure above PRESS_HI

Once an interrupt is asserted, the interrupt source can be read in INT_STAT.

Reading INT_STAT will automatically clear all interrupt source flags, will clear IA, and will reset the INT/SDOUT pin value to the de-asserted state.

The polarity of the INT pin can be selected by writing on INTF_CFG.

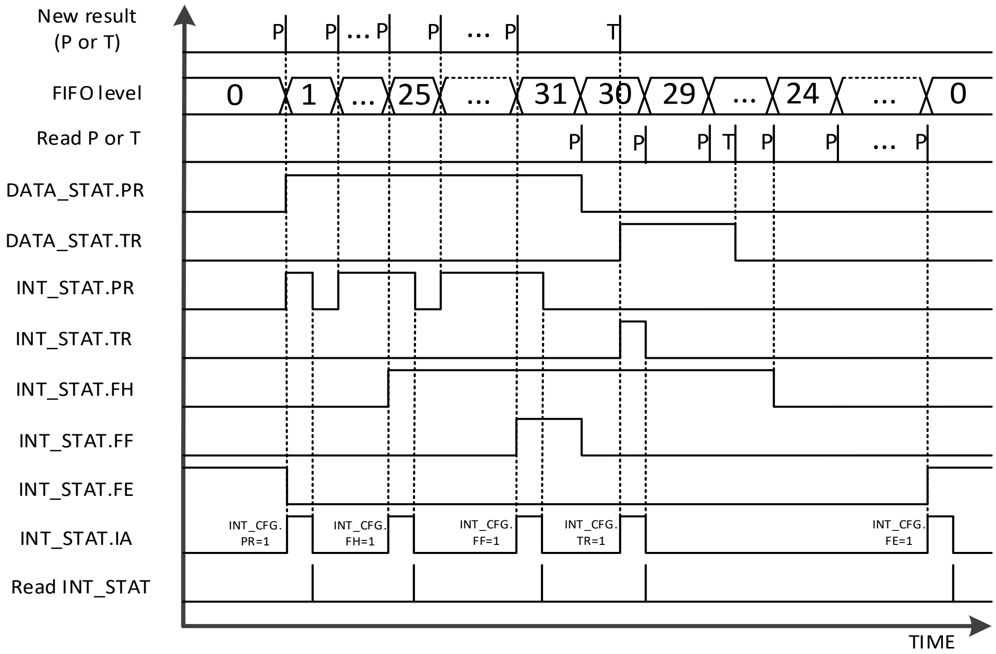


Figure 14: Sample interrupt timing diagram

6.8 Moving average

A moving average filter can be applied to pressure measurements. The filter is enabled by writing on MODE_CFG.FIFO_MODE. The FIFO buffer is used to implement this function, so FIFO is not functional when moving average is enabled.

The window size, i.e. the number of samples used by the moving average filter, is controlled by MAVG (1 to 32); it should only be changed while the moving average filter is disabled. After moving average is enabled (by setting MODE_CFG.FIFO_MODE=2), the first pressure value available is used to initialize the window with that first pressure value.

NOTE: moving average settings are independent from pressure oversampling enabled via OVSP. The result of pressure oversampling is processed by the moving average filter (see Figure 15: Moving average example (16 values)).

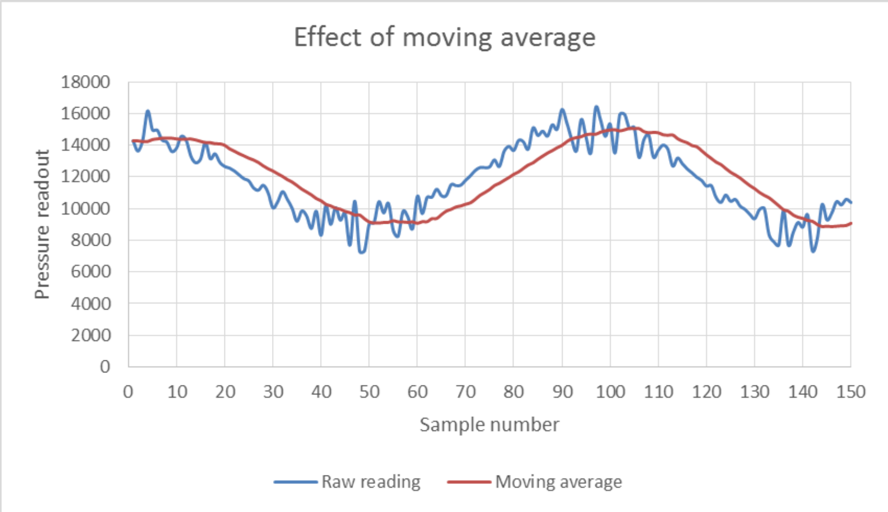


Figure 15: Moving average example (16 values)

7 Digital interface description

The ENS220 can be accessed as a slave device through either SPI 3-wire, SPI 4-wire, or I²C serial interface.

7.1 Interface selection

Selection between I²C and SPI is done through CSN.

If CSN is high, the I²C interface will be active and the SPI interface inactive. For systems where the host communicates via I²C to this device, connect CSN to VDD permanently.

A falling edge of CSN will disable the I²C interface until the next power-on cycle or software reset. The SPI host should make sure to generate a low pulse on CSN before communicating to other devices on the bus, in order to avoid that the device interprets SPI bus traffic as I²C.

7.2 I²C interface

The EN220 is an I²C slave device with a fixed 7-bit address 0x20.

The I²C interface supports fast (400 kbit/s) and high-speed (3400 kbit/s) mode. Details on I²C protocol is according to I²C-bus specifications [UM10204, I²C-bus specification and user manual, Rev. 6, 4 April 2014].

The device applies all mandatory I²C protocol features for slaves: START, STOP, Acknowledge, 7-bit slave address and also the optional clock stretching. The latter means that the master must support clock stretching in order to successfully communicate with the ENS220. None of the other optional features (10-bit slave address, general call, software reset or Device ID) are supported, nor are the master features (Synchronization, Arbitration, START byte).

The ENS220 uses a register model to interact with the host. This means that the I²C master can directly read or write values to one of the registers by first sending the single byte register address. The ENS220 implements “auto increment” which means that it is possible to read or write multiple bytes (e.g. read multiple DATA_X bytes) in a single transaction.

7.2.1 I²C write operation

After the START (S) condition (which blocks the bus), in a single continuous transaction:

- The I²C Master sends the 7-bit slave address and 0 into the R bit (indicates a write transaction, the byte sent would be 0x40). The transaction will be acknowledged by the slave (ACK).
- The I²C Master then sends the address of the first register to write. The transaction will be acknowledged by the slave (ACK). (or not acknowledged (NACK) when the address is not writable)
- The I²C Master then sends 1-n data bytes which are written into sequential registers (if valid) until the transaction is concluded with a STOP (P) condition.

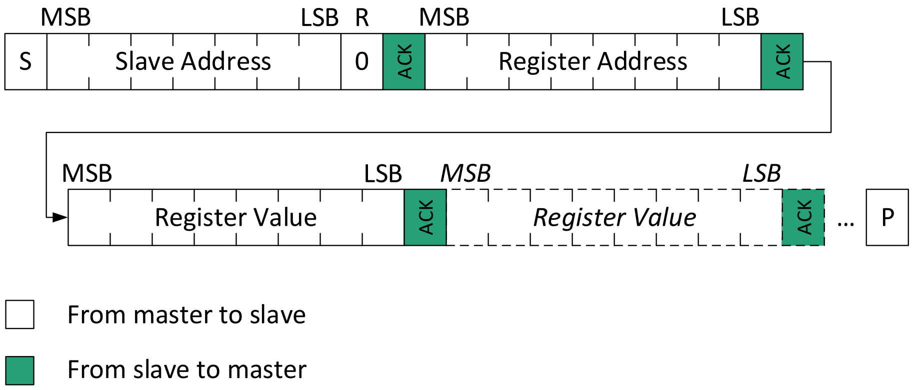


Figure 16: I²C Write operation

7.2.2 I²C read operation

A *read* transaction (see Figure 17) starts with a write (of the register address), followed by a read. Consequently, it has the following format:

After the START condition, in the first transaction:

- The I²C Master sends the 7-bit slave address and 0 into the R bit (indicates a write transaction, the byte sent would be 0x40). The transaction will be acknowledged by the slave (ACK).
- The I²C Master then sends the address of the first register to read.

Then after a repeated START condition by the master:

- The I²C Master sends the 7-bit slave address and 1 into the R bit (indicates a read transaction, the byte sent would be 0x41).
- The I²C slave then sends 1-n data bytes from sequential registers (if valid), each acknowledged by the master until the transaction is concluded with a STOP condition.

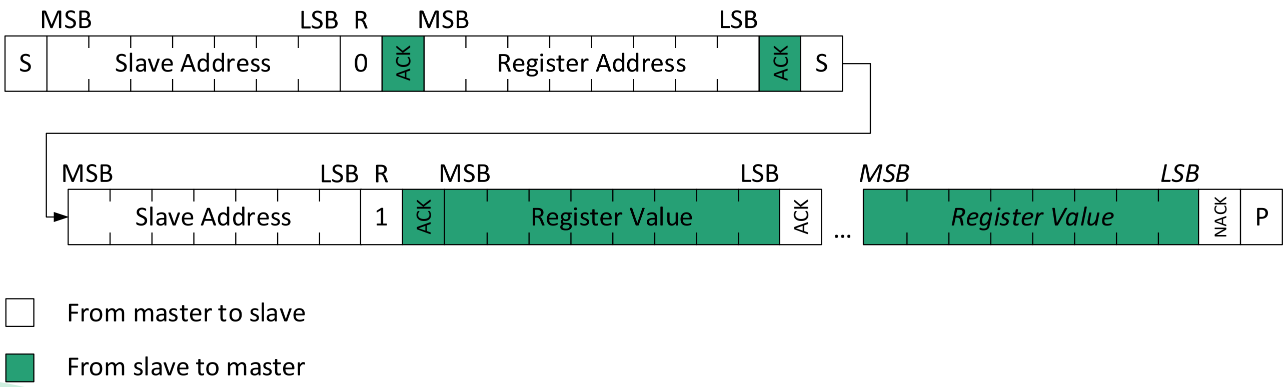


Figure 17: I²C read operation

7.2.3 High speed mode

The bus operation speed is limited to 400 kHz unless a high speed enable command (00001xxx) is issued by the master device as the first byte after START condition. This switches the bus to a high-speed operation which allows data transfer frequencies up to 3.4 MHz. Such command is not acknowledged (NACK) by the slave but the input filter time constant on the serial interface (SDA and

SCL) is adapted to allow higher transfer rate. After a high-speed command, the slave address is transmitted by the master in order to invoke a data transfer. The bus keeps operating at the highest operating frequency until the master issues a STOP condition. Upon reception of the STOP condition by the slave, the input filters are switched to their initial time constants, which allow only up to 400 kHz transfer rates.

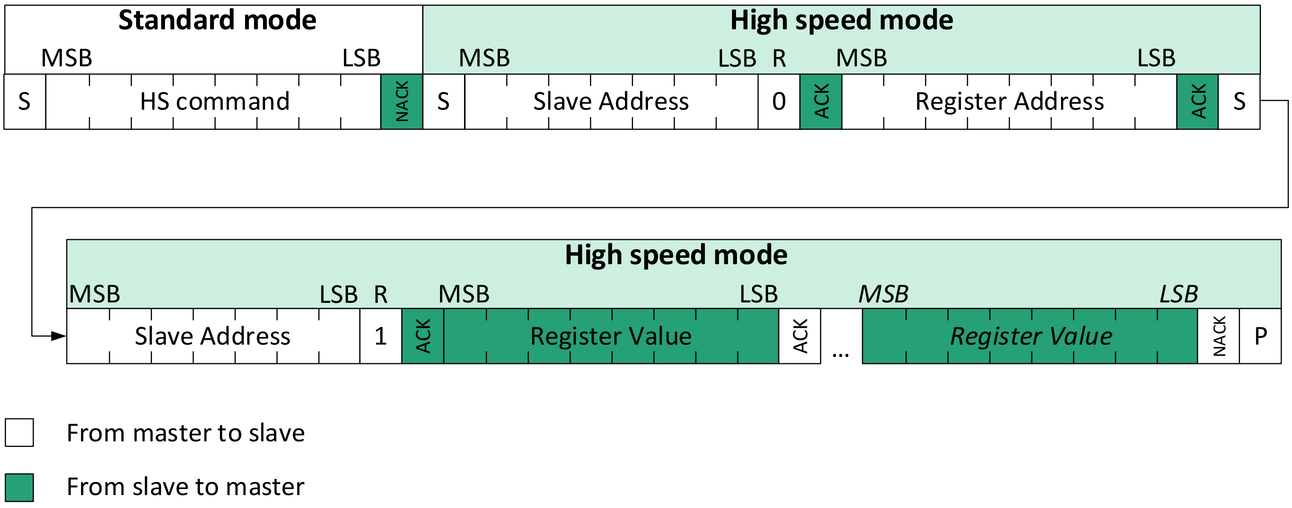


Figure 18: I²C high-speed read operation

7.2.4 Timing specifications

ENS220 is compliant to the I²C bus specifications [UM10204, I²C-bus specification and user manual, Rev. 6, 4 April 2014].

Table 7: ENS220 I²C timing parameters[3]

Parameter	Symbol	Units	Fast Mode		High-Speed Mode	
			Min	Max	Min	Max
SCL frequency	Fscl	kHz		400		3400
SCL low time	Twscll	µs	1.3		0.16	
SCL high time	Twsclh		0.6		0.06	
SDA setup time	Tsup	ns	100		10	
SDA hold time (host transmits)	Th	ns	0	-	0	-
SDA hold time (device transmits)	Tv	ns	40	900	20	160
SCL rise time	TrCL	ns		300	10	40
SCL fall time	TfCL			300	10	40
SDA rise time	TrDA			300	10	80

[3] All values referred to V_{IHmin} and V_{ILmax} levels.

SDA fall time	TfDA			300	10	80
Start condition hold time	Thst	µs	0.6		0.16	
Repeated start condition setup time	Tsupst		0.6		0.16	
Stop condition setup time	Tsupsp		0.6		0.16	
Bus free time between start-stop	Twspst		1.3		0.16	
Load capacitance	CL	pF		400		100

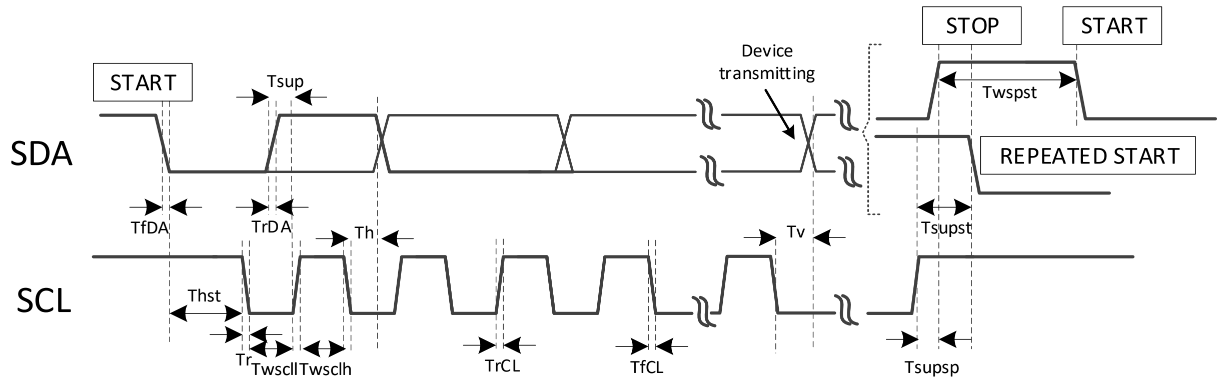


Figure 19: I²C timing diagram

7.3 SPI interface

The ENS220 is an SPI bus slave. The SPI allows to write and read the registers of the device. The serial interface interacts with the outside world with 4 wires: CSN, SCLK, SDIN and SDOUT; an optional 3 wire mode uses a single bi-directional data line instead of two.

CSN is the serial port enable and it is controlled by the SPI master. It is driven low at the start of the SPI frame and returns high at the end.

SCLK is the serial port clock and is controlled by the SPI master. It should stay high in the absence of transmissions. SDIN and SDOUT are respectively the serial port data input and output. Those lines are driven at the falling edge of SCLK and should be captured at the rising edge of SCLK.

The SDOUT pin is shared between SPI output data and interrupt function. When CSN=1 and interrupt functionality is enabled, SDOUT will provide interrupt service.

If interrupts are disabled then SDOUT stays in high impedance mode until data is requested from the device, i.e., during an SPI transaction.

Both the read register and write register commands are completed in 16 clock pulses or in multiples of 8 in the case of multiple bytes read/write. Bit duration is the time between two falling edges of SCLK. The first bit (bit 0) starts at the first falling edge of SCLK after the falling edge of CSN while the last bit (bit 15, bit 23, ...) starts at the last falling edge of SCLK just before the rising edge of CSN.

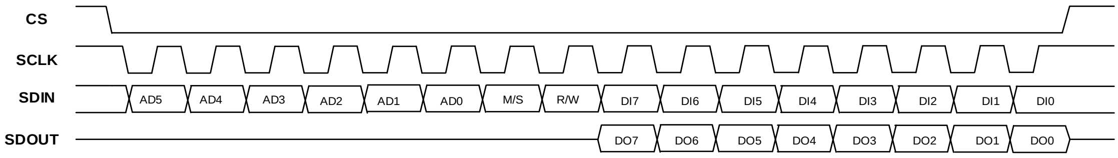


Figure 20: Minimum SPI frame

The device can also work with a low idle value of SCLK (also known as SPI mode 0), as shown below.

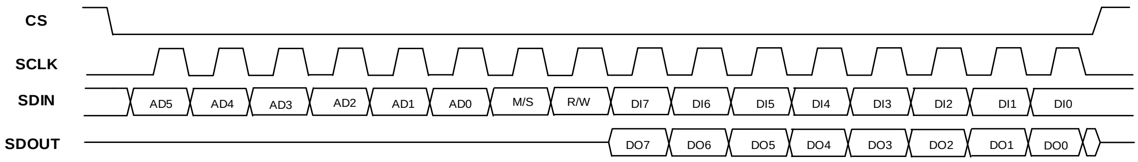


Figure 21: SPI frame using mode 0

A standard SPI frame is organized as follows:

Table 8: SPI frames for reading and writing registers

Byte	Bit	Name	Description	
			read	write
0	7:2	AD[5:0]	Address of the indexed register	
0	1	MS	0: address will be auto incremented in multiple read/write commands. 1: no auto-incrementing of the address	
0	0	RW	1: data D*i* is read from the device. SDOUT becomes active at bit 8.	0: data D*i* is written to the device.
1	15:8	D1[7:0]	Data output from the device (MSB first) to pin SDOUT.	Data written to the device from pin MOSI (MSB first)
…				
n	(8×n+7): 8×n	D*n*	*n*-th byte output to pin SDOUT (MSB first)	*n*-th byte input from pin MOSI (MSB first)

In multiple read/write commands, further blocks of 8 clock periods are added. When the MS bit is 0 the address used to read/write data remains the same for every block. When MS bit is 1 the address used to read/write data is increased at every block. The function and the behavior of SDIN and SDOUT remain unchanged.

7.3.1 SPI write operation

The SPI single byte write command consists of 16 clock pulses. A multiple byte write is performed by adding blocks of 8 clock pulses to the single byte write.

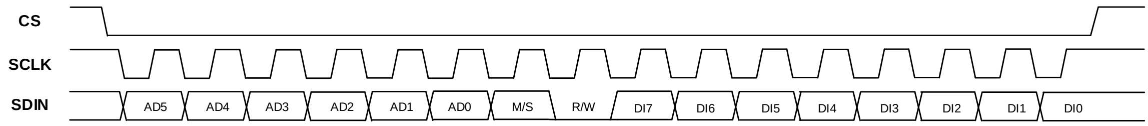


Figure 22: Single byte write

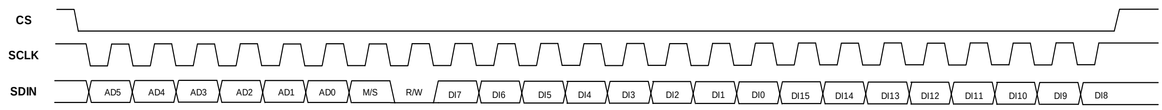


Figure 23: Multiple bytes write (2 bytes)

7.3.2 SPI read operation

The SPI single byte read command consists of 16 clock pulses. A multiple byte read is performed by adding blocks of 8 clock pulses to the single byte read. All register data is copied into an intermediate buffer at the beginning of a read transaction; multiple reads in the same read transaction will refer to the intermediate buffer.

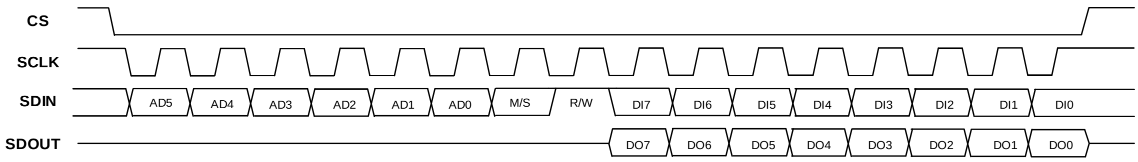


Figure 24: SPI read timing diagram

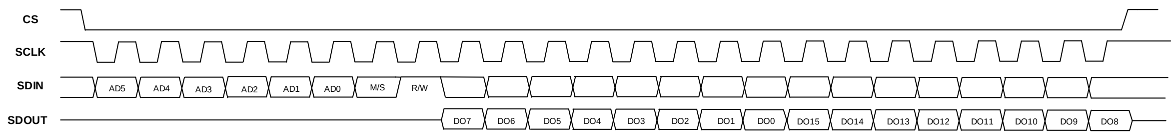


Figure 25: Multiple byte SPI read (2 bytes)

A 3-wire SPI mode can be selected by setting bit SPI3 in the INTF_CFG register. In this case, SDA acts as a bi-directional data line, and should be connected to an external pull-up resistor. Multiple byte read is also available in 3-wire mode.

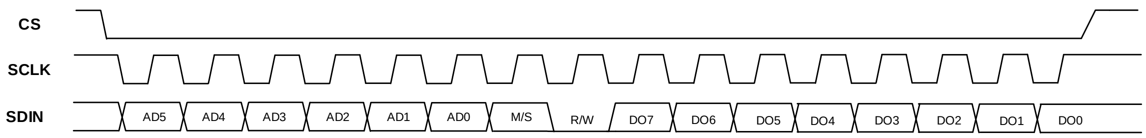


Figure 26: SPI read in 3-wire mode

7.3.3 Timing specifications

Description	Parameter	Min	Max	Units
SPI clock frequency	Fsclk		10	MHz
1/(SPI clock frequency)	Tsclk	100		ns
CSN falling edge to SCLK falling edge	Tdel	25		ns
SCLK rising edge to CSN rising edge	Tquiet	25		ns
CSN rising edge to SDO disabled	Tdis		50	ns
CSN deassertion between SPI communications	Tcs_dis	100		ns
SCLK low pulse width	Ts	0.4* t_{SCLK}		ns
SCLK high pulse width	Tm	0.4* t_{SCLK}		ns
SDI valid before SCLK rising edge	Tsetup	25		ns
SDI valid after SCLK rising edge	Thold	25		ns
SCLK falling edge to SDO output transition	Tsdo		40	ns
SDO output low to output high transition	Tr		11.5	ns
SDO output high to output low transition	Tf		11.5	ns
Capacitance load at SDO pin	CL		25	pF

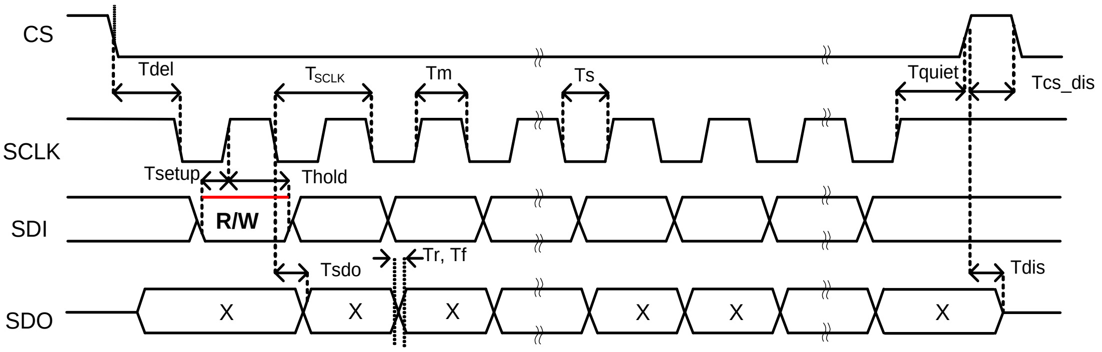


Figure 27: SPI timing diagram

8 Registers

This section describes the registers of the ENS220.

8.1 Register map

Table 9: Register map

Adr.	Name	Default	R/W	7	6	5	4	3	2	1	0	Description
0x00	PART_ID0	0x2X	Rr	PART_ID0								Part ID [7:0]
0x01	PART_ID1	0x03	Rr	PART_ID1								Part ID [15:8]
0x02	UID0		R	UID0								Unit ID [7:0]
0x03	UID1		R	UID1								Unit ID [15:8]
0x04	UID2		R	UID2								Unit ID [23:16]
0x05	UID3		R	UID3								Unit ID [31:24]
0x06	MODE_CFG	0x00	RWrw	HP	FIFO_MODE		START	RESET	0	MEAS_T	MEAS_P	Device configuration
0x07	MEAS_CFG	0x08	RW	0	0		P_CONV		PT_RATE			Conversion time, P/T rate
0x08	STBY_CFG	0x00	RWw	0				STBY_T				Standby time configuration
0x09	OVS_CFG	0x00	RW	0		OVSP			OVST			Oversampling settings
0x0A	MAVG_CFG	0x00	RW	0					MAVG			Moving average config.
0x0B	INTF_CFG	0x00	RWw	0					INT_EN	INT_HL	SPI3	Interface configuration
0x0C	INT_CFG	0x7F	RWw	0	TR	FH	FF	FE	PR	PH	PL	Interrupt mask configuration
0x0D	PRESS_LO_XL	0x00	RW	PRESS_LO_XL								Low press. threshold [7:0]
0x0E	PRESS_LO_L	0x00	RW	PRESS_LO_L								Low press. threshold [15:8]
0x0F	PRESS_LO_H	0x00	RW	PRESS_LO_H								Low press. threshold [23:16]
0x10	PRESS_HI_XL	0xFF	RW	PRESS_HI_XL								High press. threshold [7:0]
0x11	PRESS_HI_L	0xFF	RW	PRESS_HI_L								High press. threshold [15:8]
0x12	PRESS_HI_H	0xFF	RW	PRESS_HI_H								High P threshold [23:16]
0x13	FIFO_CFG	0x00	RW	0		FP_CLEAR	FP_FILL_TH					FIFO configuration
0x14	DATA_STAT	0x00	Rr	0				PO	TO	PR	TR	Measurement data status
0x15	FIFO_STAT	0x02	R	FP_FILL					FF	FE	FH	FIFO status
0x16	INT_STAT	0x08	Rr	IA	TR	FH	FF	FE	PR	PH	PL	Interrupt status
0x17	PRESS_OUT_XL	0x00	Rry	PRESS_OUT_XL								Pressure value [7:0]
0x18	PRESS_OUT_L	0x00	Rry	PRESS_OUT_L								Pressure value [15:8]
0x19	PRESS_OUT_H	0x00	Rry	PRESS_OUT_H								Pressure value [23:16]
0x1A	TEMP_OUT_L	0x00	Rr	TEMP_OUT_L								Temperature value [7:0]
0x1B	TEMP_OUT_H	0x00	Rr	TEMP_OUT_H								Temperature value [15:8]
0x27	PRESS_OUT_F_XL	0x00	RFry	PRESS_OUT_F_XL								Pressure value [7:0]
0x28	PRESS_OUT_F_L	0x00	RFry	PRESS_OUT_F_L								Pressure value [15:8]
0x29	PRESS_OUT_F_H	0x00	RFry	PRESS_OUT_F_H								FIFO Pressure value [23:16]

Legend: *(the letters in the R/W column define the colours of the register fields)*

W	Write access in low power mode	w	Write access in ultra-low power mode	0	Must write 0
R	Read access in low power mode	r	Read access in ultra-low power mode	0	Reads 0
F	Address counter wraps. See text.	y	Read only the last value in ultra-low power mode		

Note that some registers are spread over multiple addresses. For example, PART_ID at address 0 is spread over 2 addresses (its “Size” is 2). Registers are stored in little endian so the LSB of PART_ID is at address 0 and the MSB of PART_ID is at address 1.

8.2 Detailed register description

8.2.1 PART_ID (Address 0x00-0x01)

The value is available when the ENS220 is initialized after power-up.

Table 10: Register PART_ID

PART_ID					
Address	Bits	Field Name	Default	Access	Field Description
0x00	7:0	PART_ID0	0x2X	Rr	Least significant byte (LSB) of Part ID
0x01	15:8	PART_ID1	0x03	Rr	Most significant byte (MSB) of Part ID

8.2.2 UID (Address 0x02-0x05)

32 bit unique device identifier

Table 11: Register UID

UID					
Address	Bits	Field Name	Default	Access	Field Description
0x02	7:0	UID0		R	Least significant byte (LSB) of UID
0x03	15:8	UID1		R	Second byte of UID
0x04	23:16	UID2		R	Third byte of UID
0x05	31:24	UID3		R	Most significant byte (MSB) of UID

8.2.3 MODE_CFG (Address 0x06)

Table 12: Register MODE_CFG

Address 0x06		MODE_CFG		Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**
7	HP	0b0	RWrw	High Power Bit 0b1: All registers are accessible via SPI/I²C; power consumption is high. A delay of 0.5 ms is required from high power enable to the next SPI/I²C access. 0b0: The following registers are accessible via SPI/I²C: MODE_CFG, PART_ID[1:0], DATA_STAT, FIFO_STAT, PRESS_OUT, TEMP_OUT, INT_STAT. Power consumption is low.
6:5	FIFO_MODE	0b00	RWrw	Pressure data path 0b00: Direct path 0b01: FIFO 0b10: Moving average
4	START	0b0	RWrw	Operating mode configuration 0b0: Stop measurements (idle mode) 0b1: Start measurements (measurement mode) Idle Mode is intended for configuration before running an active sensing mode. This bit is automatically reset in case of one-shot operation, after the required measurements have been performed
3	RESET	0b0	RWrw	Device reset 0b1: The device is reset to the power-on configuration. RESET is automatically cleared Device reset should be performed with HP bit at 0; the suggested reset sequence is: 0x08 ⟶ wait 0.5 ms ⟶ 0x80 ⟶ wait 0.5 ms ⟶ configure device
2	X	0b0	RWrw	Reserved – must be set to default value
1	MEAS_T	0b0	RWrw	See Table 13
0	MEAS_P	0b0	RWrw	

Table 13: MEAS_T, MEAS_P: measurement selection

MEAS_T	MEAS_P	
0	1	Only pressure measurements are enabled; the device will begin with a temperature measurement, then it will continue measuring only pressure
1	0	Only temperature measurement is enabled.
1	1	Pressure and temperature measurements are enabled. PT_RATE controls the temperature interleaving timer

8.2.4 MEAS_CFG (Address 0x07)

Table 14: Register MEAS_CFG

Address 0x07		MEAS_CFG			Default: 0x08
Bits	Field Name	Default	Access	Field Description	
7:5	X	0b0	RW	Reserved – needs to be set to default value	
4:3	P_CONV	0b01	RW	Pressure ADC conversion time (see Table 15)	
2:0	PT_RATE	0b000	RW	Determines the ratio between P and T measurements as produced by the measurement engine (see Table 16)	

Table 15: Typical pressure ADC conversion time

P_CONV[1:0]	Conversion time [ms] First conversion	Conversion time [ms] Next conversions
0	4	1
1	8	2
2	16	4

Table 16: PT_RATE

PT_RATE[2:0]	P/T rate
0	1
1	4
2	8
3	16
4	32
5	64
6	128
7	256

8.2.5 STBY_CFG (Address 0x08)

Table 17: Register STBY_CFG

Address 0x08		STBY_CFG			Default: 0x00
Bits	Field Name	Default	Access	Command	
7:4	X	0x0	RWw	Reserved, needs to be set to default value	
3:0	STBY_T	0x0	RWw	Measurements will be alternated with a standby phase. (see Table 18)	

Table 18: Measurements will be alternated with a standby phase with the following duration:

STBY_T[3:0]	Standby time (ms)
0	Continuous operation
1	One-shot operation (device returns to idle after one measurement is produced by the measurement engine)
2	10
3	20
4	30
5	50
6	100
7	250
8	500
9	750
10	1000
11	2000
12	5000
13	10000
14	60000
15	600000

8.2.6 OVS_CFG (Address 0x09)

Oversampling works by averaging the value of a certain number of samples. Oversampling applies to all measurement modes.

Table 19: Register OVS_CFG

Address 0x09		OVS_CFG			Default: 0x00
Bits	Field Name	Default	Access	Field Description	
7:6	X	0b00	RW	Reserved, must be set to default value	
5:3	OVSP	0b000	RW	Oversampling of pressure measurements (see Table 20)	
2:0	OVST	0b000	RW	Oversampling of temperature measurements (see Table 21)	

Table 20: Oversampling of pressure measurements

OVSP[5:3]	Number of averages
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128

Table 21: Oversampling of temperature measurements

OVST[2:0]	Number of averages
0	1
1	2
2	4
3	8
4	16
5	32
6	64
7	128

8.2.7 MAVG_CFG (Address 0x0A)

Moving average configuration

Table 22: Register MAVG_CFG

Address 0x0A		MAVG_CFG			Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**	
7:3	X	0x00	RW	Reserved, must be set to default value	
2:0	MAVG	0b00	RW	Controls the number of samples used by the moving average filter. (see Table 23)	

Table 23: Moving average configuration

MAVG[2:0]	Samples
0	1
1	2
2	4
3	8
4	16
5	32
6	32
7	32

8.2.8 INTF_CFG (Address 0x0B)

Host interface configuration register

Table 24: Register INTF_CFG

Address 0x0B		INTF_CFG		Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**
7:3	X	0x0	RWw	Reserved, must be set to default value
2	INT_EN	0b0	RWw	Interrupt enable 0b1: INT/SDOUT is controlled by INT_STAT.IA 0b0: INT/SDOUT is always low
1	INT_HT	0b0	RWw	Interrupt polarity 0b1: INT/SDOUT low signals that interrupt is asserted 0b0: high signals that interrupt is asserted
0	SPI3	0b0	RWw	SPI mode control 0b1: SPI works in 3-wire mode 0b0: SPI works in 4-wire mode

8.2.9 INT_CFG (Address 0x0C)

Interrupt configuration register.

Table 25: Register INT_CFG

Address 0x0C		INT_CFG		Default: 0x7F
Bits	**Field Name**	**Default**	**Access**	**Field Description**
7	X	0b0	RWw	Reserved, must be set to default value
6	TR	0b1	RWw	Temperature data ready 0b1: interrupt is triggered when new temperature data becomes available 0b0: interrupt disabled
5	FH	0b1	RWw	Pressure FIFO level high 0b1: interrupt is triggered when the filling level of the pressure FIFO becomes greater than the programmed level in FP_FILL_TH 0b0: interrupt disabled
4	FF	0b1	RWw	Pressure FIFO is full 0b1: interrupt is triggered when the pressure FIFO becomes full (32 values) 0b0: interrupt disabled
3	FE	0b1	RWw	Pressure FIFO is empty 0b1: interrupt is triggered when the pressure FIFO becomes empty 0b0: interrupt disabled
2	PR	0b1	RWw	Pressure data is available 0b1: interrupt is triggered when new pressure data becomes available 0b0: interrupt disabled
1	PH	0b1	RWw	Pressure is high 0b1: interrupt is triggered when the pressure is greater than the programmed pressure high threshold (PRESS_HI). 0b0: interrupt disabled
0	PL	0b1	RWw	Pressure is low 0b1: interrupt is triggered when the pressure is lower than the programmed pressure low threshold (PRESS_LO).

				0b0: interrupt disabled

8.2.10 PRESS_LO (Address 0x0D-0x0F)

This 3-byte register sets the pressure threshold for the low-pressure interrupt.

Table 26: Register PRESS_LO

PRESS_LO					
Address	Bits	Field Name	Default	Access	Field Description
0x0D	7:0	PRESS_LO_XL	0x00	RW	Least significant byte (LSB) of PRESS_LO
0x0E	15:8	PRESS_LO_L	0x00	RW	Middle Byte of PRESS_LO
0x0F	23:16	PRESS_LO_H	0x00	RW	Most significant byte (MSB) of PRESS_LO

8.2.11 PRESS_HI (Address 0x10-0x12)

This 3-byte register sets the pressure threshold for the high pressure interrupt.

Table 27: Register PRESS_HI

PRESS_HI					
Address	Bits	Field Name	Default	Access	Field Description
0x10	7:0	PRESS_HI_XL	0x00	RW	Least significant byte (LSB) of PRESS_HI
0x11	15:8	PRESS_HI_L	0x00	RW	Middle Byte of PRESS_HI
0x12	23:16	PRESS_HI_H	0x00	RW	Most significant byte (MSB) of PRESS_HI

8.2.12 FIFO_CFG (Address 0x13)

FIFO configuration register

Table 28: Register FIFO_CFG

Address 0x13		FIFO_CFG			Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**	
7:6	X	0b00	RW	Reserved, must be set to default value	
5	FP_CLEAR	0x00	RW	FIFO clear. 0b1: the content of the FIFO is cleared; FP_CLEAR is automatically cleared. 0b0: no operation	
4:0	FP_FILL_TH	0x00	RW	FIFO level threshold. The value is used as target for interrupt and status generation.	

8.2.13 DATA_STAT (Address 0x14)

Data status register

Table 29: Register DATA_STAT

Address 0x14		DATA_STAT			Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**	
7:4	X	0x0	Rr	Reserved	
3	PO	0b0	Rr	Pressure overwrite With FIFO enabled (MODE_CFG.FIFO_MODE=1), this bit is set whenever a new pressure measurement is produced by the measurement engine while the pressure FIFO was already full. PO is cleared after reading PRESS_OUT_H or PRESS_OUT_F_H. With FIFO disabled PO is undefined.	
2	TO	0b0	Rr	Temperature overwrite This bit is set when a new temperature measurement is produced by the measurement engine and the previous data was not read. TO is cleared after reading TEMP_OUT_H.	
1	PR	0b0	Rr	Pressure ready.	

				This bit is set when new pressure data becomes available. PR is cleared after reading PRESS_OUT_H.
0	TR	0b0	Rr	Temperature ready This bit is set when new temperature data becomes available. TR is cleared after reading TEMP_OUT_H.

8.2.14 FIFO_STAT (Address 0x15)

FIFO status register

Table 30: Register FIFO_STAT

Address 0x15		FIFO_STAT			Default: 0x02
Bits	**Field Name**	**Default**	**Access**	**Field Description**	
7:3	FP_FILL	0x0	R	FIFO level Fill level of the pressure FIFO. FP_FILL is equal to 0x1F when FIFO has 31 but also 32 elements.	
2	FF	0b0	R	FF is set when the FIFO is enabled and is full (32 elements).	
1	FE	0b1	R	FE is set when the FIFO is enabled and is empty (0 elements).	
0	FH	0b0	R	FH is set when is enabled and the number of elements is greater than FP_FILL_TH.	

8.2.15 INT_STAT (Address 0x16)

Interrupt status register. Each bit except IA is set if the corresponding interrupt source has generated an event (even if the hardware interrupt is disabled by the INT_CFG register). Reading this register will clear all flags.

Table 31: Register FIFO_STAT

Address 0x16		FIFO_STAT			Default: 0x00
Bits	**Field Name**	**Default**	**Access**	**Field Description**	
7	IA	0b0	Rr	General interrupt flag It is set if any of the interrupt flags (bits 6:0) relative to sources enabled in INT_CFG are set; see also INTF_CFG.INT_EN.	
6	TR	0b0	Rr	TR is set when a new temperature measurement is produced by the measurement engine	
5	FH	0b0	Rr	FH is set when FP_FILL > FP_FILL_TH.	
4	FF	0b0	Rr	FF is set when the FIFO becomes full.	
3	FE	0b0	Rr	FE is set when FIFO becomes empty as effect of a data read.	
2	PR	0b0	Rr	PR is set when new pressure measurement is produced (i.e. without considering oversampling; refer to Figure 22).	
1	PH	0b0	Rr	PH is set when the measurement engine produces a pressure measurement that is greater than PRESS_HI.	
0	PL	0b0	Rr	PL is set when the measurement engine produces a pressure measurement that is lower than PRESS _LO.	

8.2.16 PRESS_OUT (Address 0x17-0x19)

This 3-byte register contains a 24-bit unsigned integer representing the pressure in 1/64 Pa.

When the FIFO is enabled, a read on this register extracts one element from the FIFO. When the FIFO is empty, the read returns 0x000000.

When the FIFO is not enabled (bypass or moving average), reads from this register return the latest measurement result. If reads occur faster than measurements, values are repeated.

To ensure a consistent value during readout, PRESS_OUT registers are double buffered. When PRESS_OUT_XL is read, the device copies all bytes from the internal measurement registers to the I^2C registers, then reads are always directly from the I^2C/SPI registers. The double buffering is thus only available if all PRESS_OUT registers are read within the same I^2C or SPI transaction (see sections

7.2.2, 7.3.2). If the application does not support reading multiple bytes at once, then the user must ensure that the PRESS_OUT register is not updated during the reading. This can be achieved by reading quickly after an interrupt occurred, or by using the single-shot mode (STBY_CFG = 1)

Please note that the hardware implementation of this double buffering does not guarantee the alignment between data ready flags and data if they are accessed in the same I^2C/SPI transaction. It is advised to access the flags in a separate transaction.

NOTE: HP must be 1 when reading this register with FIFO_MODE=1 to access the whole FIFO.

Table 32: Register PRESS_OUT

PRESS_OUT					
Address	**Bits**	**Field Name**	**Default**	**Access**	**Field Description**
0x17	7:0	PRESS_OUT_XL	0x00	Rry	Least significant byte (LSB) of PRESS_OUT
0x18	15:8	PRESS_OUT_L	0x00	Rry	Middle byte of PRESS_OUT
0x19	23:16	PRESS_OUT_H	0x00	Rry	Most significant byte (MSB) of PRESS_OUT

Example: For a stored PRESS_OUT value of 0x62F340 the absolute pressure in Pa is calculated as follows:

$$P = \frac{0\text{x}062\text{F}340}{64}\ \text{Pa} = 101325\ \text{Pa}$$

See section 6.3.1 for further information.

8.2.17 TEMP_OUT (Address 0x1A-0x1B)

This 2-byte register contains a 16-bit unsigned integer representing the temperature in 1/128 K.

Reads from this register return the latest measurement result. If reads occur faster than measurements, values are repeated.

To ensure a consistent value during readout, TEMP_OUT registers are double buffered. When TEMP_OUT_L is read, the device copies all bytes from the internal measurement registers to the I^2C/SPI registers, then reads are always directly from the I^2C/SPI registers. The hardware implementation does to guarantee the alignment between data ready flags and data if they are accessed in the same I^2C or SPI transition; it is advised to access the flags separately from the data. But please note that double buffering only works for TEMP_OUT if TEMP_OUT_L and TEMP_OUT_H are read in the same I^2C or SPI transaction with auto-increment of the register address (see 7.2.2).

Table 33: Register TEMP_OUT

TEMP_OUT					
Address	**Bits**	**Field Name**	**Default**	**Access**	**Field Description**
0x1A	7:0	TEMP_OUT_L	0x00	Rr	Least significant byte (LSB) of TEMP_OUT
0x1B	15:8	TEMP_OUT_H	0x00	Rr	Most significant byte (MSB) of TEMP_OUT

Example: For a stored TEMP_OUT value of 0x9513, the temperature in degrees Celsius is calculated as follows:

$$T_C = \frac{0\text{x}9513}{128}\text{K} - 273.15\ \text{K} \approx 25\ °\text{C}$$

See section 6.3.2 for further information.

8.2.18 PRESS_OUT_F (Address 0x27-0x29)

This register is the same as PRESS_OUT, except that reading in a single I^2C/SPI transaction wraps around from address 0x29 to 0x27. A single I^2C/SPI transaction can thus read multiple P measurements from the FIFO.

NOTE: HP must be 1 when reading this register to access the whole FIFO.

Table 34: Register PRESS_OUT_F

PRESS_OUT_F					
Address	**Bits**	**Field Name**	**Default**	**Access**	**Field Description**
0x27	7:0	PRESS_OUT_F_XL	0x00	RFry	Least significant byte (LSB) of PRESS_OUT_F
0x28	15:8	PRESS_OUT_F_L	0x00	RFry	Middle byte of PRESS_OUT_F
0x29	23:16	PRESS_OUT_F_H	0x00	RFry	Most significant byte (MSB) of PRESS_OUT_F

9 Application information and use case examples

9.1 I²C operation circuitry

The recommended application circuit for the ENS220 I²C interface operation is shown in Figure 28.

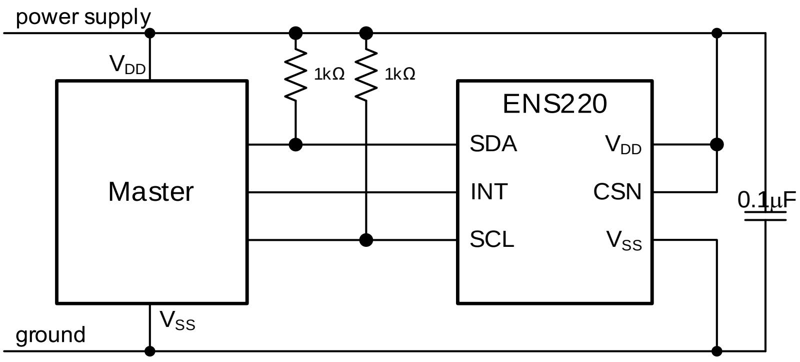


Figure 28: Recommended application circuit (I²C operation)

Note(s):

1. CSn must be pulled high (directly to V_{DD}) to ensure I²C interface is selected.
2. Pull-up resistors.
   The above recommendation for pull-up resistance values applies to I²C standard mode only. Pull-up resistors for SCL and SDA are assumed to be part of the host system and should be selected dependent on the intended I²C data rate and individual bus architecture.
3. Decoupling capacitor must be placed close to the V_{DD} supply pin (pin 10) of the ENS220.

9.2 SPI operation circuitry

9.2.1 Three wire SPI

The recommended application circuit for the ENS220 for three wire SPI interface is shown in

Figure 29.

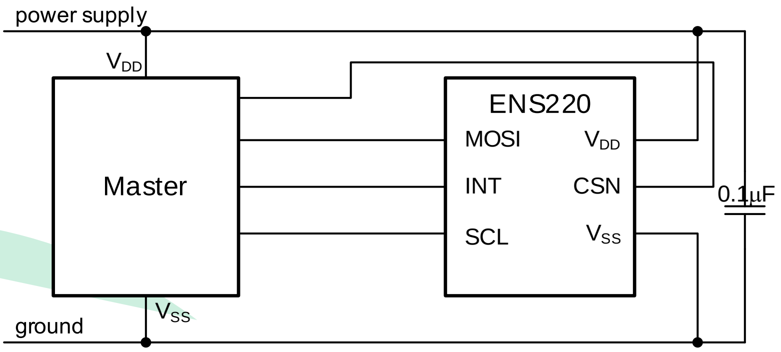


Figure 29: Recommended application circuit (three wire SPI operation)

9.2.2 Four wire SPI

The recommended application circuit for the ENS220 for four wire SPI interface is shown in Figure 30.

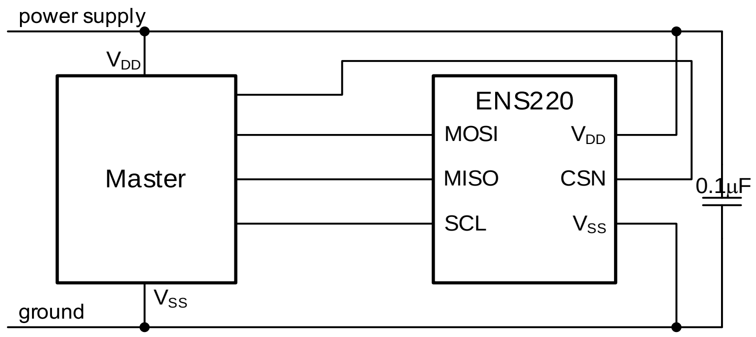


Figure 30: Recommended application circuit (four wire SPI operation)

9.3 Recommended settings for different use cases

Table 35 lists relevant use cases with the associated configuration parameters and the expected performance with these settings.

NOTE: current consumption due to the communication interface used (I^2C or SPI) is not included.

Table 35: Relevant use-cases with the associated configuration parameters and typical performance

Application examples	HP	P_CONV	PT_RATE	STBY_T	OVSP	OVST	Performance
Highest data rate - door/window opening detection	1	1 ms	128	0 ms (continuous)	1x	1x	1.8 Pa noise 1000 Hz 75 µA
Height tracking (drones, gaming, AR/VR)	1	4 ms	16	0 ms (continuous)	32x	8x	0.2 Pa noise 10 Hz 75 µA
Sports, activity tracking	1	4 ms	1	50 ms (pulsed)	4x	4x	0.5 Pa noise 10 Hz 30 µA
Home- and Building Automation, HVAC (filter clogging)	1	2 ms	1	1 s (pulsed)	4x	4x	0.7 Pa noise 1 Hz 1.7 µA

Lowest power - barometer, weather station	0	1 ms	1	60 s (pulsed)	1x	1x	1.5 Pa noise 1/60 Hz 0.8 µA
Lowest noise	1	4 ms	1	0 ms (continuous)	128x	128x	0.1 Pa noise 2 Hz

9.4 Sample communication sequence for common tasks

The following code is a functional example and does not include error checking, so it is not suited for production.

For `Write()` instructions, the first attribute is the register address and the second is the value to be written to that address.

9.4.1 Basic example using single shot measurement mode

```
Write(0x06, 0x08)       // soft reset, equivalent to power-up
Wait(500 us)
// *** configuration: shortest measurement time and one-shot ***
// (default is 2 ms + continuous measurements)
Write(0x06, 0x80)       // enable all registers with bit HP=1
Wait(500us)
Write(0x07, 0x00)       // 1 ms conversion time
Write(0x08, 0x01)       // one-shot operation
Write(0x06, 0x00)       // switch back to ultra-low power mode HP=0
                        // (this saves power if the measurement is triggered later)
Wait(500 us)            // wait a user-defined time until a measurement starts
// *** perform a measurement in ultra-low power mode ***
Write(0x06, 0x13)       // start T+P measurement, ultra-low power, no FIFO
Wait(10 ms)             // wait T+P measurement time (8 ms + margin)
// *** read the data ***
S = Read(0x14)          // check PR & TR in DATA_STAT to confirm that data is ready
If ((S & 3) != 3) {
      Print("Warning: measurement was not complete" ) }
buffer = ReadN(0x17, 5) // read all five data bytes (register 0x17 to 0x1B)
// *** convert, and print the data ***
T = buffer[3] | (buffer[4] << 8)    // = buffer[0] + 256*buffer[1]
P = buffer[0] | (buffer[1] << 8) | (buffer[2] << 16)
Print(P/64.0, "Pa")
Print(T/128.0 - 273.15, "C")
```

9.4.2 Example using continuous mode with FIFO

```
Write(0x06, 0x08)       // soft reset, equivalent to power-up
Wait(500us)
```

```
Write(0x06, 0x80)       // enable all registers with HP bit
Wait(500 us)
Write(0x07, 0x04)       // 1ms measurement time, PT-rate 32
Write(0x09, 0x00)       // OVSP 1X, OVST 1X
Write(0x0B, 0x04)       // interrupt enabled
Write(0x0C, 0x50)       // interrupt on TR and FIFO full
Write(0x06, 0xB3)       // start measurement, P+T, FIFO enabled
// *** Repeat as long as measurements are required ***
      Wait(INT==1)      // Wait until INT hardware pin is high
      S=Read(0x16)      // INT_STAT
      If (S & 0x40) {   // TR flag: temperature ready
            buffer = ReadN(0x1A, 2)             // read TEMP_OUT bytes
            T = buffer[0] | (buffer[1] << 8)    // = buffer[0] + 256*buffer[1]
            Print(T/128.0 - 273.15, “C”)
      }
      If (S & 0x10) {                     // FF flag: FIFO is full
            buffer = ReadN(0x27, 32*3)    // read all data in FIFO
            for(i=0; i<32*3; i=i+3) {
               P = buffer[i] | (buffer[i+1] << 8) | (buffer[i+2] << 16)
            Print(P/64.0, “Pa”)
            }
      }
// *** Turn off when measurements are not needed ***
Write(0x06, 0)          //HP=0: put device in ultra-low power mode
```

10 Soldering information

The ENS220 uses an open LGA package. This package can be soldered using a standard reflow process in accordance with IPC/JEDEC J-STD-020E (Figure 31). Devices have been verified against MSL1 storage conditions.

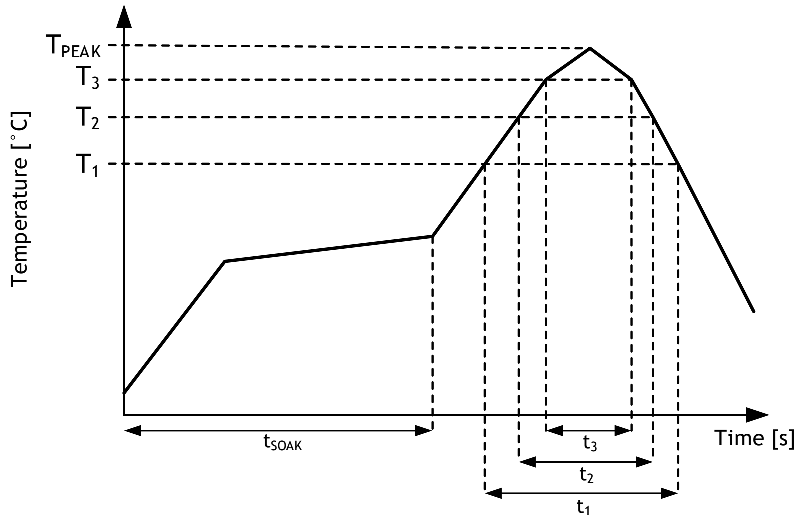


Figure 31: Solder reflow profile graph

The detailed settings for the reflow profile are shown in Table 36.

Table 36: Solder Reflow Profile

Parameter	Reference	Rate / Unit
Average temperature gradient in preheating		2.5 K/s
Soak time	t_{SOAK}	2..3 min
Soak temp range	Ts max	200 °C
	Ts min	150 °C
Time above 217 °C (T1)	t_1	Max. 60 s
Time above 230 °C (T2)	t_2	Max. 50 s
Time above TPEAK -10 °C (T3)	t_3	Max. 10 s
Peak temperature in reflow	T_{PEAK}	260 °C
Temperature gradient in cooling		Max. -5 K/s

It is recommended to use a no-clean solder paste. There should not be any board wash processes, to prevent cleaning agents or other liquid materials contacting the sensor area.

11 Package drawings & markings

11.1 Package outline dimensions

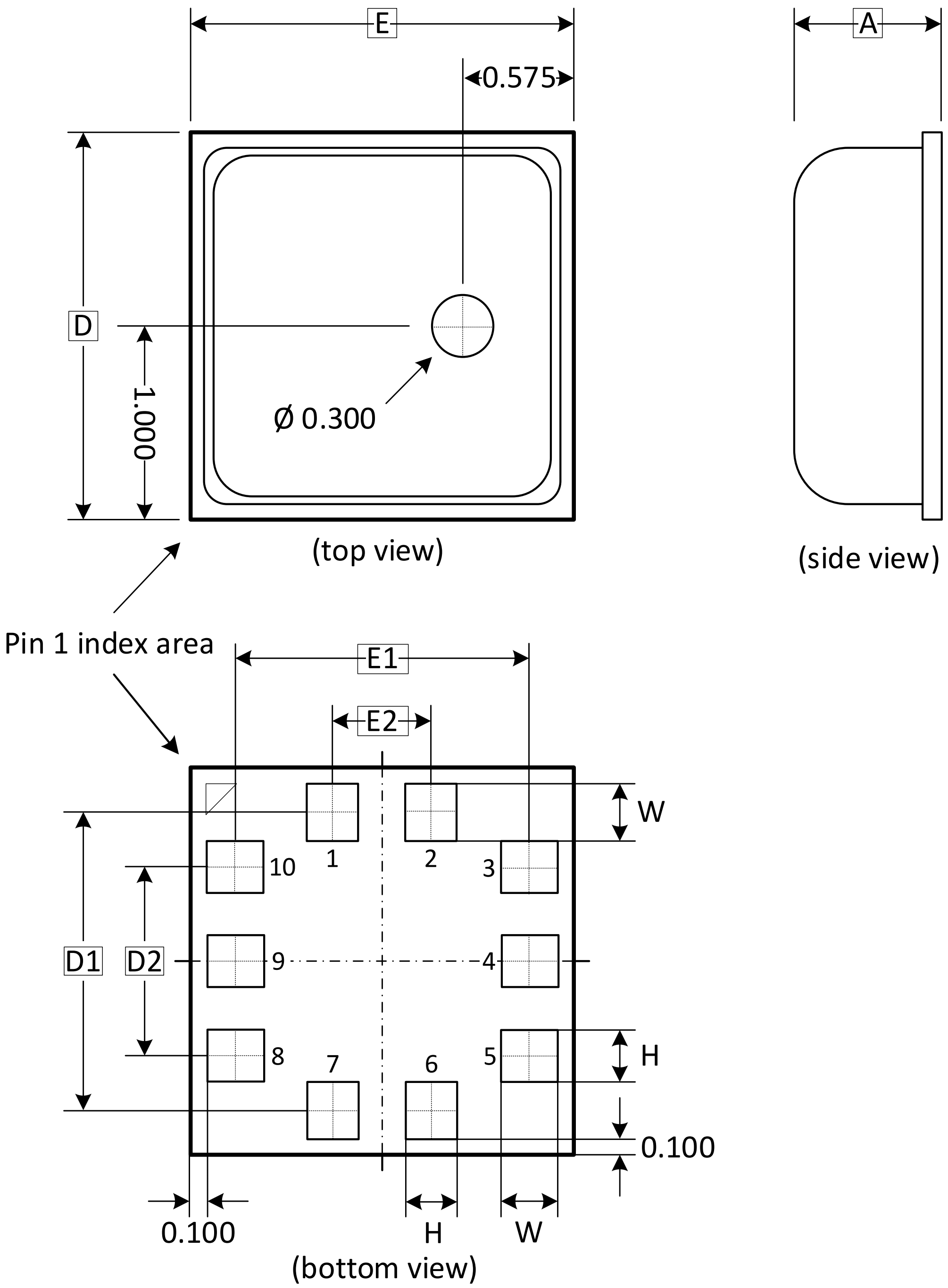


Figure 32: LGA package drawing

Table 37: LGA package dimensions in mm

Parameter	Symbol	Dimensions		
		Min	Nominal	Max
Total thickness	A	0.70	0.75	0.80
Body Size	D	1.95	2.00	2.05
	E	1.95	2.00	2.05
Lead Width	W		0.275	
Lead Length	H		0.250	
Lead Count	n		10	
Lead Centre to Centre	D1		1.525	
	D2		1.00	
	E1		1.525	
	E2		0.5	

11.2 Landing pattern

ScioSense suggests a footprint (land pattern) on the PCB as depicted in Figure 33 (which is identical to the pad pattern in the outline drawing Figure 32). Please find the dimensions in Table 37.

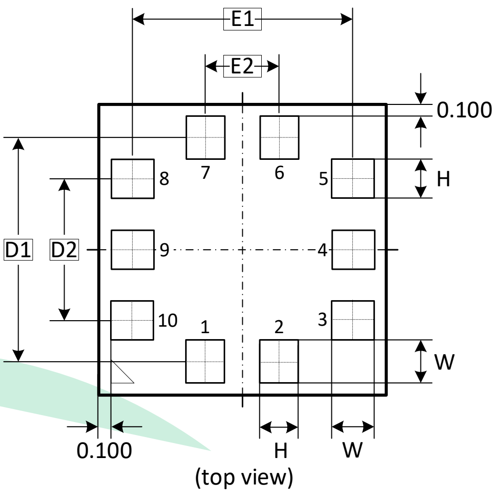


Figure 33: LGA land pattern (top view)

11.3 Device marking

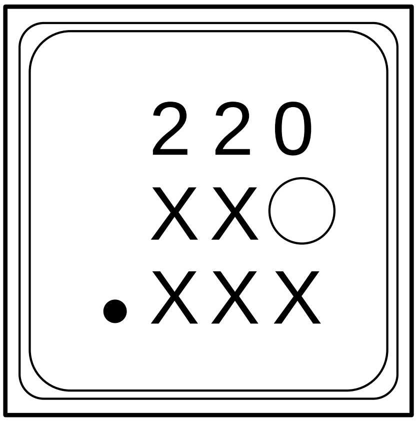


Figure 34: LGA package marking

12 Ordering information

Table 38: Ordering information

Ordering Code	Material ID	Package	Delivery Form	Delivery Quantity
ENS220S-BLGT	503700104	10-pin LGA	7” Tape & reel	3’500 pcs

13 RoHS Compliance & ScioSense Green Statement

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15 Document status

Table 39: Document status

Document Status	Product Status	Definition
Product Preview	Pre-Development	Information in this datasheet is based on product ideas in the planning phase of development. All specifications are design goals without any warranty and are subject to change without notice.
Preliminary Datasheet	Pre-Production	Information in this datasheet is based on products in the design, validation, or qualification phase of development. The performance and parameters shown in this document are preliminary without any warranty and are subject to change without notice.
Datasheet	Production	Information in this datasheet is based on products in ramp-up to full production or full production which conform to specifications in accordance with the terms of Sciosense B.V. standard warranty as given in the General Terms of Trade.
Datasheet (Discontinued)	Discontinued	Information in this datasheet is based on products which conform to specifications in accordance with the terms of Sciosense B.V. standard warranty as given in the General Terms of Trade, but these products have been superseded and should not be used for new designs.

16 Revision information

Table 40: Revision history

Revision	Date	Comment	Page
0.10	2023-02-10	Preliminary Version – Improved functional description, PRESS_OUT description, TEMP_OUT description and examples	13, 41-43, 46-47
0.9	2023-01-20	Preliminary Version – Update ordering information & device markings	51
0.8	2022-12-05	Preliminary Version – Correct package outline information	49
0.7	2022-12-01	Preliminary Version – Update specifications	7
0.6	2022-11-15	Preliminary Version – Product launch	All

Note(s) and/or Footnote(s):

1. Page and figure numbers for the previous version may differ from page and figure numbers in the current revision.
2. Correction of typographical errors is not explicitly mentioned.

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