SPI

Serial Peripheral Interface

Spot CDS500D
Spot CDS530D

Contents

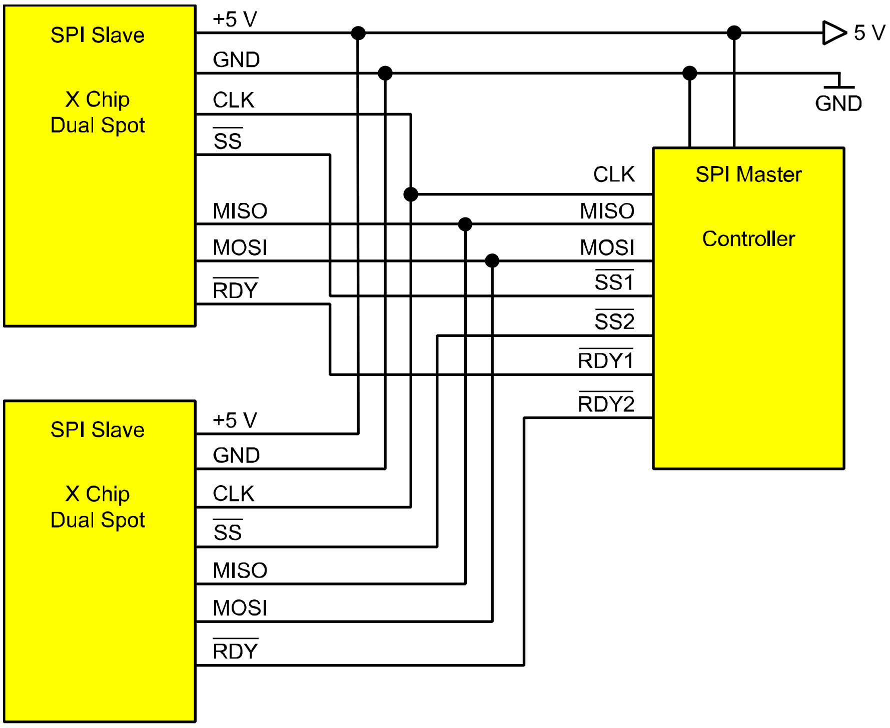
For cross-references within this document, the symbol (→ 🗎 XY) is used.

1 Hardware Concept

This section describes how one or more Spot sensors is physically connected with a master. When doing so, the master will be able to receive pressure and temperature data from each Spot slave separately.

The data exchange link consists of a simple SPI (Serial Peripheral Interface), therefore only three lines and a chip select signal are necessary. The additional RDY signal the end of a measurement cycle. It should be used in noise critical applications. You should not read data from the chip during measurement cycles. (This would cause crosstalk from the SPI to the measurement data).

1.1 Hardware Block Diagram



1.2 Interface Connector and Cable

Connector type: JST 1 mm, 10 pin

Cable length: ≤15 cm

Pin assignment

Pin	Signal	Description	Direction (sensor side)
1	+5 V	Power Supply	input
2	GND	Supply Common	input
3	CLK	SPI Clock	input
4	SS/	SPI Slave Select (low true)	input (low true)
5	MISO	SPI Master Input Slave Output	output (tristate)
6	MOSI	SPI Master Output Slave Input	input
7	RDY/	Ready Signal (new measurement value available)	output (low true)
8	C1/C0	Internal use only, must be left open	output
9	R0/Rref	Internal use only, must be left open	output
10	Vpp_OTP	Internal use only, must be left open	input

1.3 Grounding Concept

The metallic sensor housing (flange) acts as a shielding for the very sensitive electronic measurement frontend. In order to achieve the specified noise specifications, the sensor flange is connected to GND (Supply Common). The impedance of such a connection should be as low as possible. Therefore it is realized directly on the PCB at the frontend of the electronics. This solution guarantees lowest noise and simultaneously maximizes EMC robustness.

1.4 Timing Specifications

For detailed descriptions of the SPI timing and the used expressions → Chapter "Appendix", 🗎 12.

Signal	Description	MIN	TYP	MAX	UNIT
T_tot_cycle	Total Measurement Cycle Time = Data Cycle Time	?	?	?	µs
T_sgl_cycle	Single Measurement Cycle Time	?	?	?	µs
T_rd_out	Readout Time	–	–	?	µs

1.5 Interface Hardware Specifications

1.5.1 Power Supply

Signal	Description	MIN	TYP	MAX	UNIT
Vcc	Supply voltage	4.75	5.0	5.25	V (dc)
Ripple	Supply voltage ripple and noise (BW = 20 MHz)			50	mVpk-pk
Icc	Supply current		1	5	mA

1.5.2 Recommended Operating Conditions

Input lines CKL, SS/, MOSI
Output line MISO

The input lines CKL, SS/ and MOSI and the output line MISO are buffered with a SN74ABT125.

		SN54ABT125		SN74ABT125		
	Description	MIN	MAX	MIN	MAX	UNIT
V_{CC}	Supply voltage	4.5	5.5	4.5	5.5	V
V_{iH}	High-level input voltage	2		2		V
V_{IL}	Low-level input voltage		0.8		0.8	V
V_I	Input voltage	0	V_{CC}	0	V_{CC}	V
I_{OH}	High-level output current		–24		–32	mA
I_{OL}	Low-level output current		48		64	mA
$\Delta t/\Delta v$	Input transition rise or fall rate		10		10	ns/V
$\Delta t/\Delta V_{CC}$	Power-up ramp rate	200		200		µs/V
T_A	Operating free-air temperature	–55	125	–40	85	°C

☞ All unused inputs of the device must be held at V_{CC} or GND to ensure proper device operation. Refer to the Texas Instruments application report, "Implications of Slow or Floating CMOS Inputs", literature number SCBA004.

Output line RDY/

The output line "RDY/" is driven by a SN74AHCT1G125.

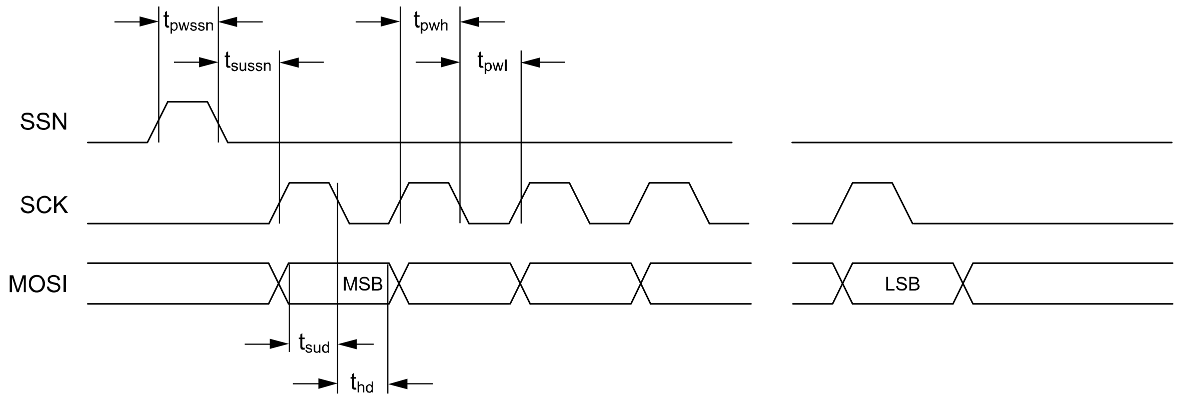
	Description	MIN	MAX	UNIT
V_{CC}	Supply voltage	4.5	5.5	V
V_{iH}	High-level input voltage	2		V
V_{IL}	Low-level input voltage		0.8	V
V_I	Input voltage	0	5.5	V
V_O	Output voltage	0	V_{CC}	V
I_{OH}	High-level output current		–8	mA
I_{OL}	Low-level output current		8	mA
$\Delta t/\Delta v$	Input transition rise or fall rate		20	ns/V
T_A	Operating free-air temperature	–40	85	°C

1.5.3 SP Interface

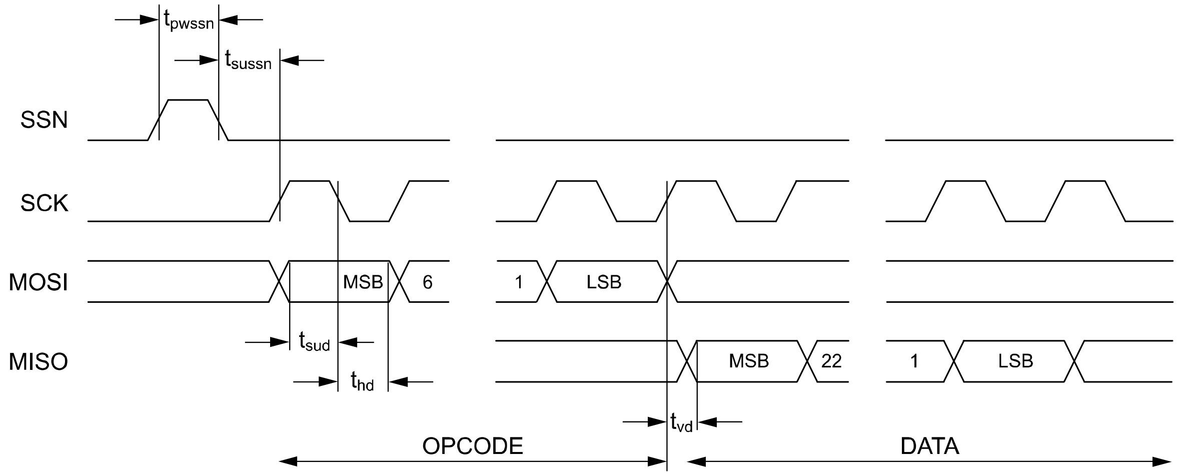
SPI parameters

Parameter	Description	Setting
CPOL	Clock polarity	0, Clock Idle low
CPHA	Clock phase	1, Transmit data on leading edge, read data on falling edge
Mode	SPI mode	1 (CPOL = 0, CPHA = 1)
DORD	Bit sequence order	0, MSB first

SPI write



SPI read



SPI timing

Name	Symbol	Value	Unit
Clock frequency	fSPI-bus	17	MHz
Clock pulse high-state	t_{pwh}	30	ns
Clock pulse low-state	t_{pwl}	30	ns
SS/ (SSN) to valid latch	t_{sussn}	8	ns
SS/ (SSN) minimal pulse length between write cycles	t_{pwssn}	30	ns
Data setup time	t_{sud}	6	ns
Data hold time	t_{hd}	4	ns
Data valid after clock	t_{vd}	26	ns

2 Read Results

2.1 Measurement Data

The sensor provides 5 measurement values:

- Pressure; combined range of sensor 1 and sensor 2
- Press-S-1; sensor 1 only
- Press-S-2; sensor 2 only
- Temperature
- Status

They can be read by a 4 byte SPI-Code as follows.

2.1.1 Pressure

The SPI communication string for reading the pressure value consists of total 4 bytes as follows:

0x41 – 0x00 – 0x00 – 0x00, only the first byte is relevant, the other three must be sent but the content of them doesn't matter.

Read Pressure Op-Code:

Byte_3								Byte_2	Byte_1	Byte_0
0	1	0	0	0	0	0	1	don't care		

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21} as follows:

23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Byte_2								Byte_1								Byte_0							
S	Integer		Fractional (21 bits)																				

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21}, consisting of the sign-bit S, 2 integer and 21 fractional bits. The fourth byte (Byte_3), that's also received, must be ignored.

The resulting pressure is defined as Full_scale × u_press.

p = F.S.R. × u_press (24 bit read result)

u_press is calculated by dividing the 24-bit result by 2^{21} :
2^{21} equals 2'097'152.

Examples

- Fullscale (F.S.R.): 24-bit result = 2'097'152 (0x200000)
- Half F.S.R.: 24-bit result = 1'048'576 (0x100000)
- smallest pos. val: 24-bit result = 1 (0x000001)
  equals to 0.00000047683 × F.S.R.
- Zero Pressure: 24-bit result = 0 (0x000000)
- smallest neg. val: 24-bit result = –1 (0xFFFFFF)
  equals to -0.00000047683 × F.S.R.
- neg. Half F.S.R.: 24-bit result = –1'048'576 (0xF00000)
- neg. F.S.R. 24-bit result = –2'097'152 (0xE00000)

2.1.2 Press-S-2

The SPI communication string for reading the pressure value consists of total 4 bytes as follows:

0x46 – 0x00 – 0x00 – 0x00, only the first byte is relevant, the other three must be sent but the content of them doesn't matter.

Read Pressure Op-Code:

Byte_3								Byte_2	Byte_1	Byte_0
0	1	0	0	0	1	1	0	don't care		

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21} as follows:

23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Byte_2								Byte_1								Byte_0							
S	Integer		Fractional (21 bits)																				

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21}, consisting of the sign-bit S, 2 integer and 21 fractional bits. The fourth byte (Byte_3), that's also received, must be ignored.

The resulting pressure is defined as Full_scale × u_press.

p = F.S.R. × u_press (24 bit read result)

u_press is calculated by dividing the 24-bit result by 2^{21} :
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Examples

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- Zero Pressure: 24-bit result = 0 (0x000000)
- smallest neg. val: 24-bit result = –1 (0xFFFFFF)
  equals to -0.00000047683 × F.S.R.
- neg. Half F.S.R.: 24-bit result = –1'048'576 (0xF00000)
- neg. F.S.R. 24-bit result = –2'097'152 (0xE00000)

2.1.3 Press-S-2

The SPI communication string for reading the pressure value consists of total 4 bytes as follows:

0x47 – 0x00 – 0x00 – 0x00, only the first byte is relevant, the other three must be sent but the content of them doesn't matter.

Read Pressure Op-Code:

Byte_3								Byte_2	Byte_1	Byte_0
0	1	0	0	0	1	1	1	don't care		

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21} as follows:

23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Byte_2								Byte_1								Byte_0							
S	Integer		Fractional (21 bits)																				

The result (u_press) is a fixed-point number in two's complement format with a scaling factor of 2^{21}, consisting of the sign-bit S, 2 integer and 21 fractional bits. The fourth byte (Byte_3), that's also received, must be ignored.

The resulting pressure is defined as Full_scale × u_press.

p = F.S.R. × u_press (24 bit read result)

u_press is calculated by dividing the 24-bit result by 2^{21}:
2^{21} equals 2'097'152.

Examples

- Fullscale (F.S.R.): 24-bit result = 2'097'152 (0x200000)
- Half F.S.R.: 24-bit result = 1'048'576 (0x100000)
- smallest pos. val: 24-bit result = 1 (0x000001) equals to 0.00000047683 × F.S.R.
- Zero Pressure: 24-bit result = 0 (0x000000)
- smallest neg. val: 24-bit result = –1 (0xFFFFFF) equals to -0.00000047683 × F.S.R.
- neg. Half F.S.R.: 24-bit result = –1'048'576 (0xF00000)
- neg. F.S.R. 24-bit result = –2'097'152 (0xE00000)

2.1.4 Temperature

The SPI communication string for reading the temperature value consists of total 4 bytes as follows:

0x4D – 0x00 – 0x00 – 0x00, only the first byte is relevant, the other three must be sent but the content of them doesn't matter.

Read Temperature Op-Code:

<table>
<tr><td colspan="8">Byte_3</td><td>Byte_2</td><td>Byte_1</td><td>Byte_0</td></tr>
<tr><td>0</td><td>1</td><td>0</td><td>0</td><td>1</td><td>1</td><td>0</td><td>1</td><td colspan="3">don't care</td></tr>
</table>

The result (u_temp) is a fixed-point number in two's complement format with a scaling factor of 2^{21} as follows:

<table>
<tr><td>23</td><td>22</td><td>21</td><td>20</td><td>19</td><td>18</td><td>17</td><td>16</td><td>15</td><td>14</td><td>13</td><td>12</td><td>11</td><td>10</td><td>9</td><td>8</td><td>7</td><td>6</td><td>5</td><td>4</td><td>3</td><td>2</td><td>1</td><td>0</td></tr>
<tr><td colspan="8">Byte_2</td><td colspan="8">Byte_1</td><td colspan="8">Byte_0</td></tr>
<tr><td>S</td><td colspan="2">Integer</td><td colspan="21">Fractional (21 bits)</td></tr>
</table>

The result (u_temp) is a fixed-point number in two's complement format with a scaling factor of 2^{21}, consisting of the sign-bit S, 2 integer and 21 fractional bits. The fourth byte (Byte_3), that's also received, must be ignored.

The resulting temperatur is defined as k × u_temp, where k is defined as a Calibration Constant (typically 25 °C).

T = k × u_temp (24 bit read result)
k = 25 °C (calibration temperature)

u_temp is calculated by dividing the 24-bit result by 2^{21}:
2^{21} equals 2'097'152.

Examples

- T ≥ 100 °C: 8'388'607 (0x7FFFFF)
- T = 50 °C: 24-bit result = 4'194'304 (0x400000)
- T = 25 °C: 24-bit result = 2'097'152 (0x200000)
- T = 0 °C: 24-bit result = 0 (0x000000)
- T = –25 °C: 24-bit result = –2'097'152 (0xE00000)

2.1.5 Status and Error

The SPI communication string for reading the status value consists of total 4 bytes as follows:

0x48 – 0x00 – 0x00 – 0x00, only the first byte is relevant, the other three must be sent but the content of them doesn't matter.

Read Status Op-Code:

Byte_3								Byte_2	Byte_1	Byte_0
0	1	0	0	1	0	0	0	don't care		

Byte_3	Byte_2	Byte_1	Byte_0
don't care	24-Bit Status value (Bit 23 … 0)		

Bit	Description
23	SPI communication took place during measurement
13	Pressure error
8	Port 3 error
7	Port 2 error
6	Port 1 error
5	Port 0 error
3	Temperature error

All other bits not mentioned must be ignored.

2.2 Label and Supplemental Data

The Label data as well as other supplemental information can be read from the device. Readable:

- Product Number
- Serial Number
- FullScale_1, upper pressure range incl. unit
- FullScale_2, lower pressure range incl. unit
- Speed Setting, Cycle-Time
- Type, Sensor Name

The information is stored in 4 blocks of 32 bytes each.

Block No.	Start Address	Length [Bytes]	Content	
1	3824 (0xEF0)	32	Product No.	
2	3856 (0xF10	32	Serial No.	
3	3888 (0xF30)	2 × 16	FS1	FS2 @ 3904 (0xF40)
4	3920 (0xF50)	2 × 16	Type	Speed @ 3936 (0xF60)

The data are stored as ASCII strings and can be read at any time by means of the 3 bytes Read-Byte command which is defined as follows:

Byte_2					Byte_1	Byte_0
0	0	0	1	Address <11 … 0>		Data <7 … 0>

Address <11 … 0> defines the start address according to the table above.

The individual sensor content is defined according to the table below. All strings are ASCII coded. Binary 0 (0x0) defines the end of a string.
EOS=EndOfString

Block 1: Product Number:	"PN=……..EOS", max. length = 28 characters
Block 2: Serial Number:	"SN=……..EOS", max. length = 28 characters
Block 3: Subblock 1: FS_1:	"FS1=xxxxxxyyyyyEOS", max. 6 characters for range and 5 for unit
Block 3: Subblock 2: FS_2:	"FS2=xxxxxxyyyyyEOS", max. 6 characters for range and 5 for unit
Block 4: Subblock 1: Type:	"Type=xx…xxEOS", max. length = 10 characters
Block 4: Subblock 2: Speed:	"Speed=xxxx.yymsEOS", max. 7 characters for speed

3 Power-Up Reset

After powering up the device, it must be reset by sending the reset command to the device. The reset command consists of the single byte 0x88h. It is highly recommended to send the reset command (0x88h) to the sensor after every power up.

Appendix

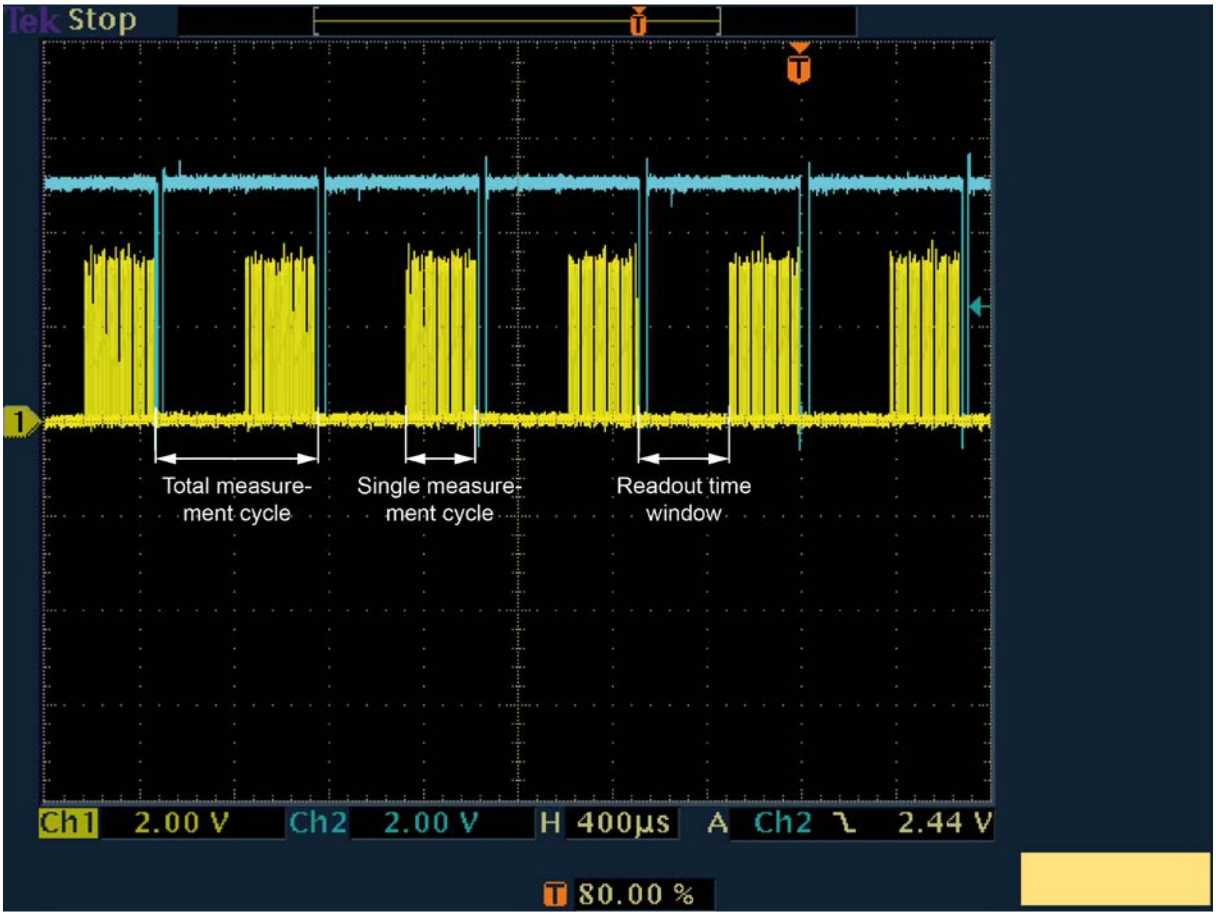
A: SPI Timing

This chapter describes the current timing behavior of the new Dual Spot sensor. The given examples base on a fast application with a 700 µs cycle- and a 400 µs read-out time.

Timing overview

The figure shows the timing overview:

- Ch 1 (yellow) depicts the signal directly at the sensor
- Ch 2 (blue) equals the RDY (Ready) signal



The Dual Spot sensor is configured to run "free" meaning that it

❶ starts a measurement cycle consisting of 16 single measurements,

❷ computes the average of this 16 measurements,

❸ activates the RDY-signal,

❹ waits until the total measurement cycle time has elapsed,

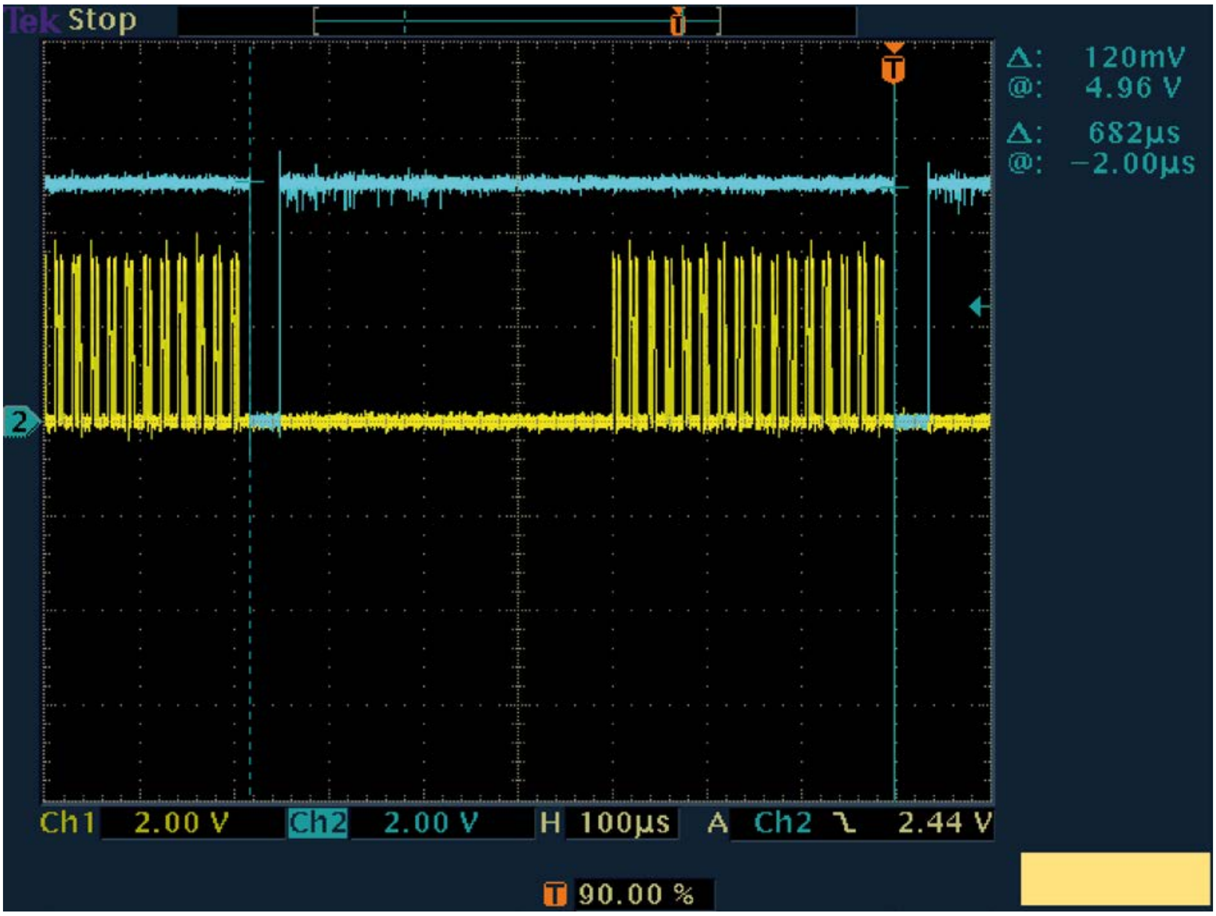
❺ jumps back to step 1.

The corresponding timing is explained in more details in the following chapters.

Total Measurement Cycle

The figure shows one measurement cycle. A measurement cycle is defined as the time between two consecutive negative edges of the Ready-signal. As can be seen in the figure, that time equals 682 µs. The timing source for the measurement cycle is an on chip oscillator. Although it is very stable it shows a relatively large absolute frequency tolerance of about ±15% from chip to chip. Therefore the cycle time can also vary in the range of about ±15% from sensor to sensor.

- Ch 1 (yellow) depicts the signal directly at the sensor
- Ch 2 (blue) equals the RDY (Ready) signal



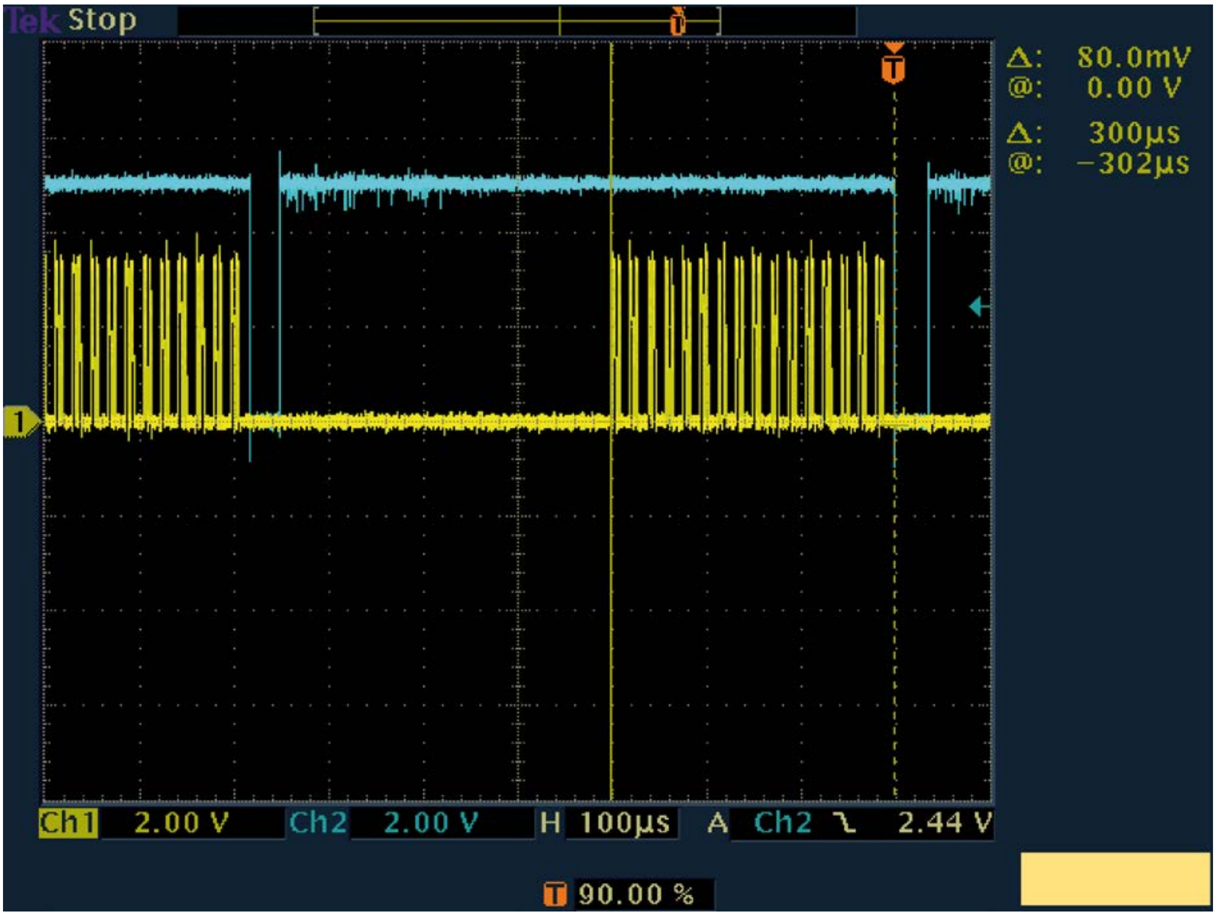
Ready-signal

The Ready-signal is active low and it is set after the first measurement value is available. The Ready-signal is reset by assigning the SS/-signal active. (SPI Slave Select) that means it is automatically reset by a consecutive read of the measure-ment value.

Single Measurement Cycle

As can be seen from the figure, a single measurement cycle needs about 300 µs. Again, this figure can vary from sensor to sensor with up to ±15%. During a single measurement cycle, the electronics takes 16 single measurements and computes the average of them. Then it signals “new measurement available” by asserting the Ready-signal low.

- Ch 1 (yellow) depicts the signal directly at the sensor
- Ch 2 (blue) equals the RDY (Ready) signal



Readout Time Window

The "Readout Time Window" time is the time span between the negative going edge of the Ready-signal and the beginning of a new measurement.

With …

- "Readout Time Window" time = T_rd_out
- "Total Measurement Cycle" time = T_tot_cycle
- "Single Measurement Cycle" time = T_sgl_cycle

we get …

- T_rd_out = T_tot_cycle – T_sgl_cycle

For the example above: T_rd_out = 682 µs – 300 µs = 382µs.

Conclusion

The actual sensor configuration results in the following timing parameters:

- "Total Measurement Cycle" time (T_tot_cycle) 680 µs (±15%)
- "Single Measurement Cycle" time (T_sgl_cycle) 300 µs (±15%)
- "Readout Time Window" time (T_rd_out) 380 µs (±15%)

Notes

Original: English

t i r b49e1

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