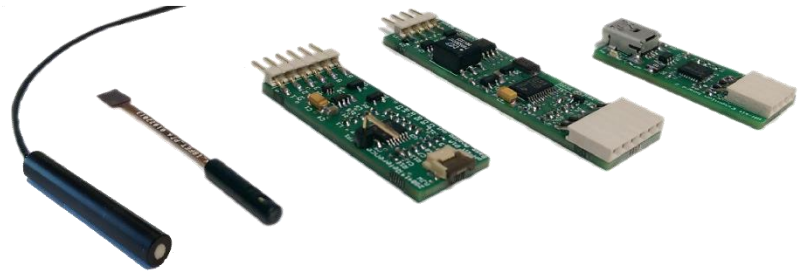
ISFET pH-sensor kit

Technical guide



Contents

1 Description

Sentron offers a glass-free modular pH-kit designed specifically for development and testing purposes. With this pH-kit, development engineers and researchers have a large degree of flexibility in how they integrate our proprietary ISFET pH sensor into their applications or experimental set-ups. Due to the modular design, the functionality can be expanded as required and components can be replaced individually.

The pH-kit consist of a ISFET pH sensor, Reference and Analog front-end module. These modules are always needed as a basis for pH measurement. Thanks to the small size of the ISFET pH sensor and Reference electrode it can be used to measure small volumes or develop applications with small form factors. The Analog Front-end module has an uncalibrated analog pH output signal with a voltage output 0 — 3.3 V of ~ 52 mV / pH and pH 7 between 500 mV and 1800 mV. The PT1000 RDT temperature sensor in the ISFET pH sensor is wired directly to the Analog front-end module output. The reference electrode also connects to the Analog front-end module and either the standard reference electrode with porous PTFE diaphragm can be used or a suitable custom reference electrode can be attached.

The AD Converter module can be attached to the Analog front-end module. This extension module with microprocessor, AD Converter and galvanic isolation makes it well suited for use in embedded applications. The communication with the AD Converter is based on a serial RS232 interface with a TTL level. Using a standard serial interface it is possible to perform calibrations and read pH and temperature values. Application of a temperature correction algorithm to the pH signal is performed directly by the microcontroller of the AD Converter module. The galvanic isolation provides an extra safety barrier and prevents ground loops.

With the USB Interface extension module, which connects to the AD Converter module, it is possible to request measured pH and temperature values from a laptop or PC with a USB port. The USB Interface extension module, with appropriate user developed software, allows the pH-kit to be used for applications that require direct connection to a PC, such as real time monitoring of pH values in an experiment or process.

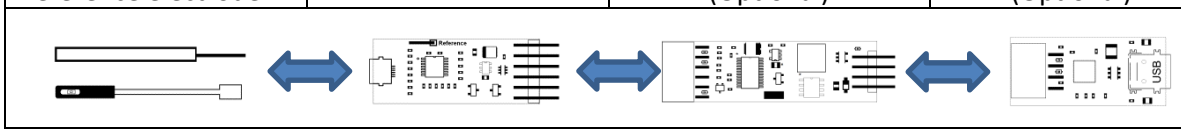
2 Specifications

	ISFET Sensor	Reference	Analog Front-end	AD Converter	USB Interface
Product order code	A120-001	A120-002	A120-003	A120-004	A120-005
pH					
Sensor	Glass-free Ion Sensitive Field Effect Transistor (ISFET)				
Accuracy	+/- 0.01 pH				
Range	pH 0.00...14.00				
Drift *(total after 24 hours in pH7 @ 25°C)*	Max. 0.14 pH				
Reference system					
Elektrode		Ag/AgCl			
Type		Non-flow			
Diafragm		Porous PTFE			
Reference solution		Gelled KCl			
Temperature					
Sensor	PT1000				
Accuracy	+/- 0.5°C (0.9°F)				
Range	0...80°C (32...176°F)				
Physical properties					
					
Dimensions					
Total length	46 mm (1,81")	300 mm (11.80")	45 mm (1.77")	59.5 mm (2.34")	40 mm (1.57")
Length	15 mm (0.59")	40 mm (1.57")	40 mm (1.57")	54.5 mm (2.15")	35 mm (1.38")
Diameter/Width	3 mm (0.12")	6 mm (0.24")	15.5 mm (0.61")	15.5 mm (0.61")	15.5 mm (0.61")
Materials					
Barrel	PEEK	PEEK			
PCB			FR4	FR4	FR4
Weight	0.15 gr.	2.10 gr.	3.18 gr.	4.69 gr.	3.10 gr.
Operation / storage					
Temperature			0...80°C (32...176°F)		
Humidity			30 %...80 % Relative humidity		
Electrical properties					
Power					
Supply input			3.3 VDC +/-100 mV	5 VDC +/-100 mV	5 VDC +/-100 mV
Consumption typical	100 nA		8 mA @ 3.3 V	13 mA @ 5V	2.5 mA @ 5 V
Comunication					
Sampling frequency				3 Hz	3 Hz
Baud rate				115k2 8N1	115k2 8N1
Voltage Level				5V	5V
Connection					
Connector type(s)	6p FFC 0.5 mm pitch	1p Receptacle	6p FPC 0.5 mm pitch 6p header 2.54 mm pitch	6p Receptacle 2.54 mm pitch 4p header 2.54 mm	4p header 2.54 mm pitch Mini USB B Receptacle

3 Electrical connections

The diagram below illustrates how the components of the pH-kit are connected together. The modules will only function when connected in this order.

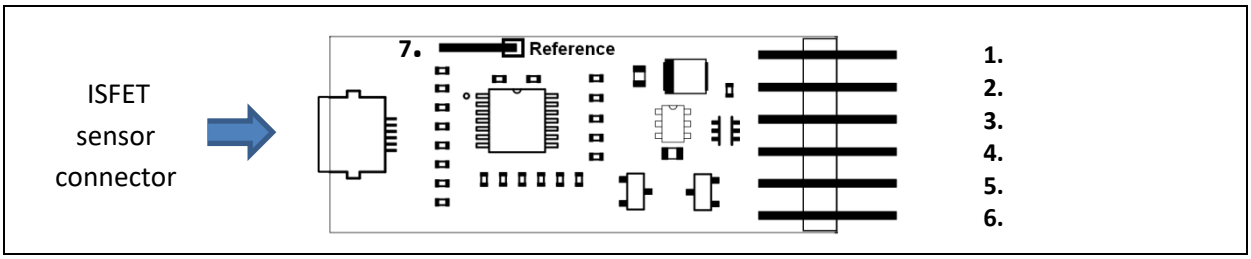
1. ISFET sensor + Reference electrode	**2.** Analog front-end	**3.** AD Converter (Optional)	**4.** USB Interface (Optional)



➔ Modules **1** and **2** are always needed to conduct pH measurements with the test kit. Modules **3** and **4** are optional.

3.1 Analog front-end module

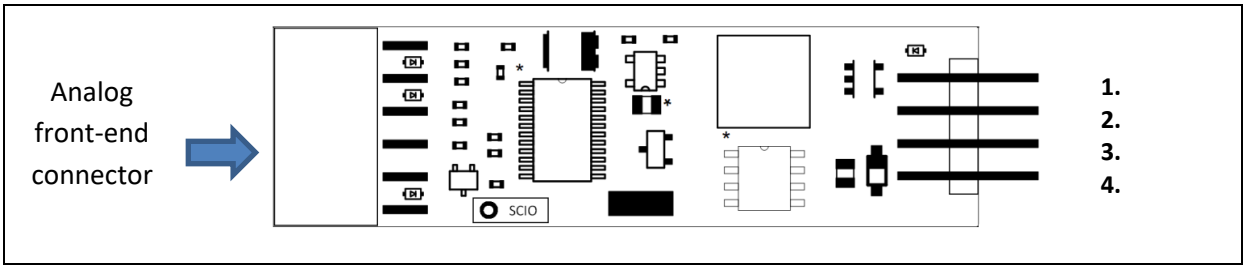
The ISFET sensor is connected to the Analog Front-End module through an FFC connector. There are also 7 pin connections on the module. One pin (Pin 7) is for connection of the reference electrode. The remaining 6 serve as output pins for the Analog front-end module. They are described below:



Pin 1.	pH signal out	~52 mV/pH. pH 7 between 500 and 1800 mV
Pin 2.	+3V3 Power	+3V3 DC power power input +/- 100mV
Pin 3.	AGND	Analog Ground
Pin 4.	PT1000	Directly wired to the PT1000
Pin 5.	PT1000	Directly wired to the PT1000
Pin 6.	N.C.	Not used
Pin 7.	Reference	External reference electrode connection

3.2 AD Converter module

The 6 pin connector of the AD Converter module can be attached directly to the Analog Front-end module. The AD Converter module also had 4 output pins, which are described below:

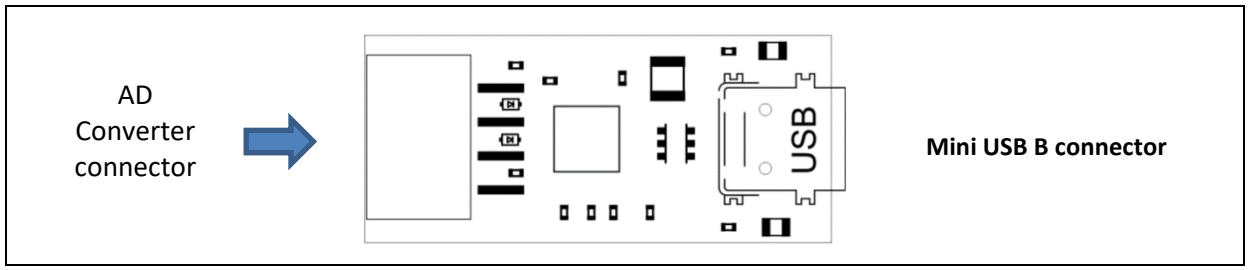


Pin 1.	+5V	+5V DC power input +/- 100mV
Pin 2.	RxD	Data input, TTL 5V level, 115k2, 8N1
Pin 3.	TxD	Data output, TTL 5V level, 115k2, 8N1
Pin 4.	GND	Digital GND.

The AD Converter module contains 1.5kV galvanic insulation between inputs and outputs.

3.3 USB Interface module

The 4 pin connector of the USB Interface module can be attached directly to the AD Converter module. A mini USB cable can be attached to the mini USB B connector.



The USB interface provides a USB 1.1 or 2.0 connection to a computer (note the USB interface is not USB 3.0 compatible). It is possible to connect multiple USB interface modules to one PC, up to the current limit of your USB ports.

USB Driver Installation:

Normally Windows will recognize the USB interface as a USB to COM port converter. Windows will install the driver automatically or download the driver from the internet. In some cases the driver needs to be installed manually. The latest drivers can be downloaded from the FTDI website. (http://www.ftdichip.com/Drivers/VCP.htm)

When Windows has installed the driver properly it will assign a COM port number to the USB Interface. Through this port number the communication can be established. Look up at your device manager to find out the assigned port number. The figure below shows an example that Windows has assigned COM4 to the connected USB interface.

4 Calibration

It is always necessary to calibrate an ISFET pH sensor before use. During prolonged use the senor may need to recalibrated at intervals. The frequency of recalibration is dependent on the conditions the sensor is subjected to and it is recommended to test the calibration at the end of a measurement run to confirm the calibration is still accurate. To perform a calibration place the ISFET sensor in the right buffer solution and communicate according the protocol of chapter 5.1.

5 Data communication

Before connecting and powering up the modules in your embedded environment or to the computer make sure the all the necessary module are connected to each other and correct baud rate of 115k2 8N1 is set. See chapter 3 for power and data pins on the AD converter module when the USB interface is not connected and the communication is directly to the AD converter.

5.1 Protocol

A command is sent to the device in the form of ASCII characters, and the return string is received as a series of bytes representing 6-bit binary decimals. The return bytes will need to be decoded into a measurement value through a calculation. The method of decoding is shown in the table below.

Function	Send ASCII command (bytes)	Receive bytes from AD Converter or USB Interface.	Decimal bytes return														Decode calculation. Multiply or add decimal byte position value.	Units
Retrieve pH value	*999!<CR>*	ABCDEFGHIJK *013 010*	A	B	C	D[1]	E[1]	F[1]	G[1]	H[1]	I[1]	J	K				A*4096+B*64+C	0.001 pH
	(057 057 057 033 013)		byte	byte	byte	*000*	*000*	*000*	*000*	*000*	*000*	*013*	*010*					
Retrieve temperature	*777!<CR>*	ABCDEFG *013 010*	A	B	C[1]	D[1]	E[1]	F	G								A*64+B	0.1 °F
	(055 055 055 033 013)		byte	byte	*000*	*000*	*255*	*013*	*010*									
Start Calibration	*CLR!<CR>*	*082 013 010*																
	(067 076 082 033 013)																	
Calibration pH 2	*111!<CR>*[5]	*001 013 010*[2]																
	(001 001 001 033 013)																	
Calibration pH 4	*112!<CR>*[5]	*002 013 010*[2]																
	(001 001 002 033 013)																	
Calibration pH 7	*113!<CR>*[5]	*003 013 010*[2]																
	(001 001 003 033 013)																	
Calibration pH 10	*114!<CR>*[5]	*004 013 010*[2]																
	(001 001 004 033 013)																	
Calibration pH 12	*115!<CR>*[5]	*005 013 010*[2]																
	(001 001 005 033 013)																	
End calibration[3]	*QIT!<CR>*	*084 013 010*																
	(081 073 084 033 013)																	
Retrieve slope	*000!<CR>*	ABCDEFGHIJKLMN *013 010*	A[4]	B	C	D[4]	E	F	G[4]	H	I	J[4]	K	L	M	N		
	(048 048 048 033 013)		*001*	byte	byte												Slope pH 2-4 = B*64+C	0.1 %
						002	byte	byte									Slope pH 4-7 = E*64+F	0.1 %
									003	byte	byte						Slope pH 7-10 = H*64+I	0.1 %
												004	byte	*byte*	*013*	*010*	Slope pH 10-12 = K*64+L	0.1 %

[1] Dummy bytes
[2] Response time is depending on signal stability, maximum at 120 seconds
[3] Use function after desired number of calibration points is achieved
[4] Separation bytes
[5] Shown numbers are separate bytes, not characters.

5.2 Examples

Below some communication examples on the various protocol functions are presented to illustrate communication with the AD Converter and USB Interface modules.

5.2.1 Performing a single point calibration

pH7 calibration sequence:

- Rinse the probe with deionized water.
- Place ISFET sensor and reference in the calibration pH7 buffer solution. Initiate the calibration process by sending the S*tart Calibration* command: *CLR!<CR>*
- Wait for the AD Converter or USB interface module to acknowledge, receive: *082 013 010*

The AD converter or USB interface module is now ready to receive the calibration pH 7 command…

- Initiate the pH7 calibration by sending the calibration pH 7 command: *113!<CR>*

Allow some time for the module to stabilize (this may take up to 2 minutes maximum)…

- Wait for the module to stabilize, receive bytes: *003 013 010*
- End the calibration process, send: *QIT!<CR>*
- Wait for the module to confirm calibration end, receive: *084 013 010*

Rinse the ISFET sensor and reference electrode with de-mineralized water…

The calibration is completed.

For performing a pH 2, 4, 10 or 12 calibration, repeat the sequence and use the appropriate calibration command bytes. See chapter 5.1 for the command bytes of each pH buffer solution.

5.2.2 Performing a multi-point calibration

To rule out erroneous multi-point calibrations, the calibration can only take place for an increasing or decreasing pH sequence.

Multi-point calibration sequence:

For example a calibration in pH 4 – 7 – 10 buffer.

- Rinse the probe with deionized water.
- Place ISFET sensor and reference in the first calibration buffer solution. In this case pH4 buffer.
- Initiate the calibration process by sending the S*tart Calibration* command: *CLR!<CR>*
- Wait for the AD Converter or USB interface module to acknowledge, receive: *082 013 010*

The AD converter or USB interface module is now ready to receive the first calibration command bytes of the buffer sequence…

- Initiate the pH4 calibration by sending the calibration pH 4 command: *112!<CR>*

Allow some time for the module to stabilize (this may take up to 2 minutes maximum)…

- Wait for the module to stabilize, receive bytes: *002 013 010*

Rinse the probe with deionized water.
Place ISFET sensor and reference in the next calibration buffer solution, pH 7.

- Initiate the pH7 calibration by sending the calibration pH 7 command bytes: *113!<CR>*

Allow some time for the module to stabilize (this may take up to 2 minutes maximum)…

- Wait for the module to stabilize, receive bytes: *003 013 010*

Rinse the probe with deionized water.
Place ISFET sensor and reference in the next calibration buffer solution, pH 10.

- Initiate the pH10 calibration by sending the calibration pH 10 command bytes: *114!<CR>*

Allow some time for the module to stabilize (this may take up to 2 minutes maximum)…

- Wait for the module to stabilize, receive bytes: *004 013 010*

When performing even more calibration points, repeat this part for each extra desired point.

- End the calibration process, send: *QIT!<CR>*
- Wait for the module to confirm calibration end, receive: *084 013 010*

The calibration is completed.
Send the "end calibration command bytes" just once after the last performed calibration point.

5.2.3 Retrieving the pH signal

After a single or multipoint calibration the AD Converter module the pH value can be read out.

Retrieve pH value

- Send the command bytes: *999!<CR>*
- Wait for the module to return the pH value, receive bytes: ABCDEFGHIJK

Data ABCDEFGHIJK marks the byte position. Values in bytes are needed for decoding.

Byte position	A	B	C	D	E	F	G	H	I	J	K
Byte value	byte	byte	byte	*000*	*000*	*000*	*000*	*000*	*000*	*013*	*010*

Decode received sequence if e.g.:

Byte position	A	B	C	D	E	F	G	H	I	J	K
Received bytes	001	023	027	*000*	*00*	*000*	*000*	*000*	*000*	*013*	*010*

Protocol:
A = *001*
B = *023*
C = *027*
DEFGHIJK = n/a

A*4096 + B *64 + C = 1*4096 + 23*64 + 27 = 5595
pH value = 5.595

5.2.4 Retrieving the temperature signal

Retrieve temperature value

- Send the command bytes: *777!<CR>*
- Wait for the module to return the pH value, receive bytes: ABCDEFG

Data ABCDEFG marks the byte position. Values in bytes are needed for decoding.

Byte position	A	B	C	D	E	F	G
Byte value	byte	byte	*000*	*000*	*255*	*013*	*010*

Decode received sequence if e.g.:

Byte position	A	B	C	D	E	F	G
Received bytes	*012*	*023*	*000*	*000*	*255*	*013*	*010*

Protocol:
A = *012*
B = *023*
CDEFG = n/a

A*64 + B = 12*64 + 23 = 791
Temperature value = 79.1 °F

5.2.5 Retrieving the slope values

A slope can only be calculated between two calibration points. When retrieving a slope after only a single point calibration the returned values will represent 0%.

Normal slopes between two consecutive pH buffer solutions should be between 105% – 95%. Slopes outside these values, can indicate a polluted or aging ISFET sensor /reference electrode. Although calibrations and measurements can be performed the measured values may be less accurate. In this case, if cleaning the sensor / reference electrode does not resolve the slope issue be sure to replace the ISFET sensor and/or reference electrode.

Retrieve slope value:

- Send the command bytes: *000!<CR>*
- Wait for the module to return the slope values, receive bytes: ABCDEFGHIJKLMN

Data ABCDEFGHIJKLMN marks the byte position. Values in bytes are needed for decoding.

Byte position	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Byte value	*001*	*byte*	*byte*	*002*	*byte*	*byte*	*003*	*byte*	*byte*	*004*	*byte*	*byte*	*013*	*010*

Decode received sequence if e.g.:

Byte position	A	B	C	D	E	F	G	H	I	J	K	L	M	N
Received bytes	*001*	*000*	*000*	*002*	*015*	*052*	*003*	*000*	*000*	*004*	*000*	*000*	*013*	*010*

Slope positions:

	Protocol	Decode	Result
slope between pH 2 and pH 4	B*64+C	*000**64+*000*	**0%**
slope between pH 4 and pH 7	E*64+F	*015**64+*052*	**101.2%**
slope between pH 7 and pH 10	H*64+I	*000**64+*000*	**0%**
slope between pH 10 and pH 12	K*64+L	*000**64+*000*	**0%**

ADGJ = n/a

5.3 ASCII table

Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char	Decimal	Hex	Char
0	0	[NULL]	32	20	[SPACE]	64	40	@	96	60	`
1	1	[START OF HEADING]	33	21	!	65	41	A	97	61	a
2	2	[START OF TEXT]	34	22	"	66	42	B	98	62	b
3	3	[END OF TEXT]	35	23	#	67	43	C	99	63	c
4	4	[END OF TRANSMISSION]	36	24	$	68	44	D	100	64	d
5	5	[ENQUIRY]	37	25	%	69	45	E	101	65	e
6	6	[ACKNOWLEDGE]	38	26	&	70	46	F	102	66	f
7	7	[BELL]	39	27	'	71	47	G	103	67	g
8	8	[BACKSPACE]	40	28	(	72	48	H	104	68	h
9	9	[HORIZONTAL TAB]	41	29	)	73	49	I	105	69	i
10	A	[LINE FEED]	42	2A	*	74	4A	J	106	6A	j
11	B	[VERTICAL TAB]	43	2B	+	75	4B	K	107	6B	k
12	C	[FORM FEED]	44	2C	,	76	4C	L	108	6C	l
13	D	[CARRIAGE RETURN]	45	2D	-	77	4D	M	109	6D	m
14	E	[SHIFT OUT]	46	2E	.	78	4E	N	110	6E	n
15	F	[SHIFT IN]	47	2F	/	79	4F	O	111	6F	o
16	10	[DATA LINK ESCAPE]	48	30	0	80	50	P	112	70	p
17	11	[DEVICE CONTROL 1]	49	31	1	81	51	Q	113	71	q
18	12	[DEVICE CONTROL 2]	50	32	2	82	52	R	114	72	r
19	13	[DEVICE CONTROL 3]	51	33	3	83	53	S	115	73	s
20	14	[DEVICE CONTROL 4]	52	34	4	84	54	T	116	74	t
21	15	[NEGATIVE ACKNOWLEDGE]	53	35	5	85	55	U	117	75	u
22	16	[SYNCHRONOUS IDLE]	54	36	6	86	56	V	118	76	v
23	17	[ENG OF TRANS. BLOCK]	55	37	7	87	57	W	119	77	w
24	18	[CANCEL]	56	38	8	88	58	X	120	78	x
25	19	[END OF MEDIUM]	57	39	9	89	59	Y	121	79	y
26	1A	[SUBSTITUTE]	58	3A	:	90	5A	Z	122	7A	z
27	1B	[ESCAPE]	59	3B	;	91	5B	[	123	7B	{
28	1C	[FILE SEPARATOR]	60	3C	<	92	5C	\	124	7C	|
29	1D	[GROUP SEPARATOR]	61	3D	=	93	5D	]	125	7D	}
30	1E	[RECORD SEPARATOR]	62	3E	>	94	5E	^	126	7E	~
31	1F	[UNIT SEPARATOR]	63	3F	?	95	5F	_	127	7F	[DEL]

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