Technical Information
TI 283C/07/en
No. 51506685

Sterilisable IsFET sensor for pH measurement
topHit H CPS 401
Ion-selective field effect transistor for long-term stability pH measurement

Features and benefits
- Resistant to breaking
  - No glass, sensor body made completely of PEEK
  - Direct installation into the process in the food and pharmaceuticals industries, reduced effort and costs for sampling and laboratory analyses
- Application possible at low temperatures
  - Short response time
  - Constant high accuracy
- Stable measured values and better hysteresis than with glass electrodes with alternating temperatures
  - Sterilisable
  - Low measuring error after high-temperature loading
- Longer calibration intervals
- Almost no acidic and alkaline errors
- TOP 68 - plug-in connection (IP 68) for ensured measured variable transfer
- Ideal for CIP processes when combined with an automatic retractable assembly

Application
- Process systems and process monitoring with:
  - Quickly changing pH values
  - Alternating temperatures and pressures
- Food industry and pharmaceutical industry (sterilisibility)
- Water purification and wastewater
- Biotechnology
- Monitoring of brines and coolants

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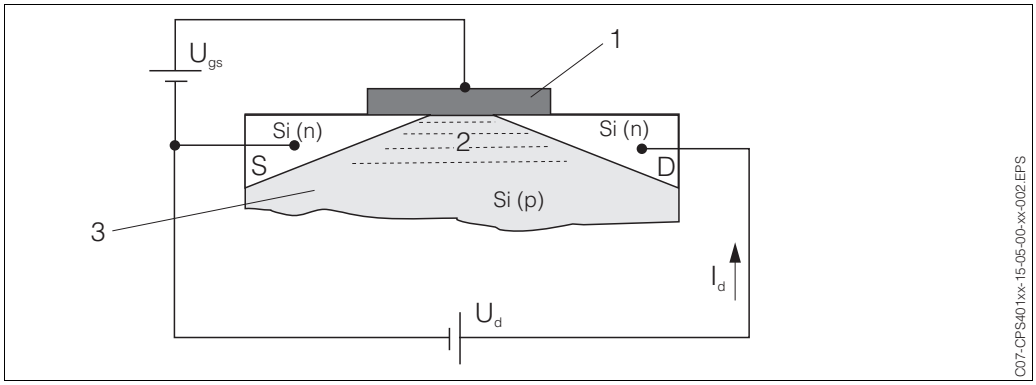
Function and system design

Measuring principle

Ion-**selective** resp. more general ion-**sensitive** field effect transistors (IsFET) were developed in the 1970s as an alternative to the glass electrode for pH measurement.

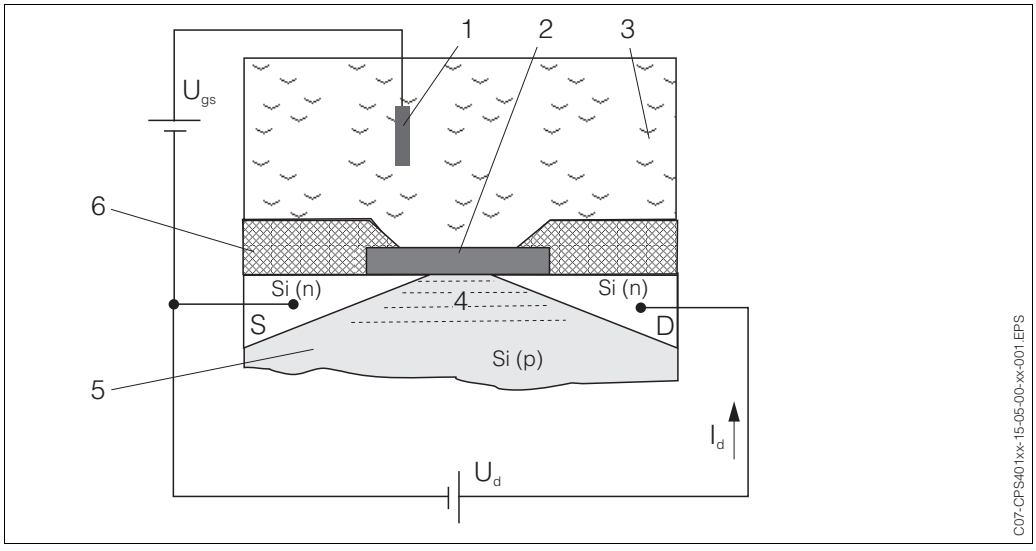
Basics

Ion-selective field effect transistors use an MOS (Metal Oxide Semiconductor) transistor arrangement (first figure) where the metallic *gate* is not a control electrode.
Instead, the medium in the IsFET is in direct contact with the gate isolator layer (second figure). Two strongly N-conducting areas are diffused in P-conducting substrate of the semiconductor material (Si). These N-conducting areas are current supplying (*"Source"*) and current accepting (*"Drain"*) electrodes. The metallic *gate* electrode (in case of the MOSFET) resp. the medium (in case of the IsFET) form together with the below substrate a capacitor. A potential difference between gate and substrate (U_{gs}) causes a higher electron density between "Source" and "Drain". A N-conducting *channel* is formed. Feeding "Source" and "Drain" a current (I_d) is induced.



MOSFET

1	*Metallic gate*	*D*	*Drain*
2	*Channel*	U_d	*Drain voltage*
3	*p-doped silicon substrate*	U_{gs}	*Control voltage between gate and source*
S	*Source*	I_d	*Drain current*



IsFET

1	*Reference electrode*	*S*	*Source*
2	*gate isolator layer*	*D*	*Drain*
3	*Medium*	U_d	*Drain voltage*
4	*Channel*	U_{gs}	*Control voltage between gate isolation and source*
5	*p-doped silicon substrate*	I_d	*Drain current*
6	*Isolating layer (CPS 401: sensor shaft)*		

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In the IsFET, H^+ ions available in the medium, and which are located in the medium / gate isolator boundary layer, create the electric field (*gate potential*). Depending on the effect described above, a N-conducting channel is formed and a current between "Source" and "Drain" is induced. Suitable sensor circuits use the dependence on the ion-selective gate potential to create an output signal proportional to the concentration of the ion type.

pH sensitive IsFET

The gate isolator serves as an ion-selective layer for H^+ ions. The gate isolator is impermeable to the ions as well (isolator effect) but allows *reversible* surface reactions with the H^+ ions.
Depending on the acidic or alkaline character of the measurement solutions, functional groups in the isolator surface accept or reject H^+ ions (amphoteric character of the functional groups). This leads to a *positive* (H^+ acceptance in the acidic medium) or *negative* (H^+ rejection in the alkaline medium) charging of the isolator surface. Depending on the pH value, a *defined* surface charge can be used to control the field effect in the channel between "Source" and "Drain".
The processes which lead to the creation of a charge potential and therefore to a control voltage U_{gs} between "Gate" and "Source" are described with the Nernst equation:

$$U_{gs} = U_0 + \frac{RT}{nF} \cdot \ln a_{ion} \qquad (a)$$

U_{gs}	...	*potential between Gate and Source*	n	...	*mol wt*
U_0	...	*offset potential*	F	...	*Faraday constant*
R	...	*gas constant*	a_{ion}	...	*activity of ions*
T	...	*temperature [K]*			

At 20°C, the Nernst factor is known to have a value of -58 mV/pH.

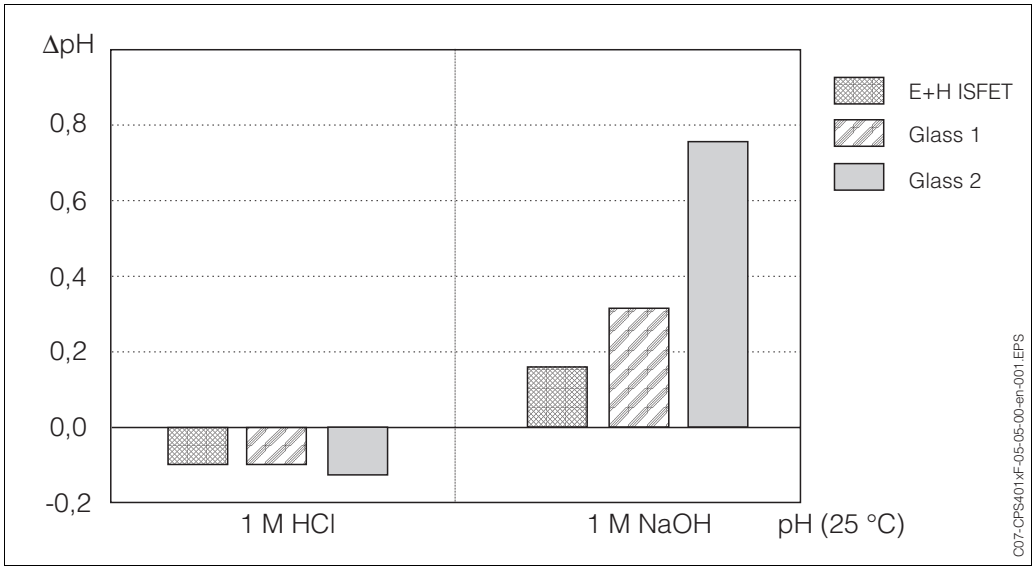
Important characteristics of the TopHit H CPS 401

- Resistance to breaking

Its resistance to breaking is the most obvious feature of the sensor. The complete sensor technology is embedded in a PEEK shaft. Only the highly resistant isolator layer and the reference have direct contact with the medium.

- Acidic or alkaline errors

A further, important benefit compared with the glass electrode is the considerably reduced number of acidic or alkaline errors in extreme pH ranges. In contrast to glass electrodes, practically no foreign ions can build up at the IsFET gate. The error detection limit is < 0.01 pH (between pH 1) and 13 at 25°C. The figure below shows the acidic or alkali error of the IsFET compared to the glass electrode (two different pH glasses) at pH values 0.09 and 13.86.



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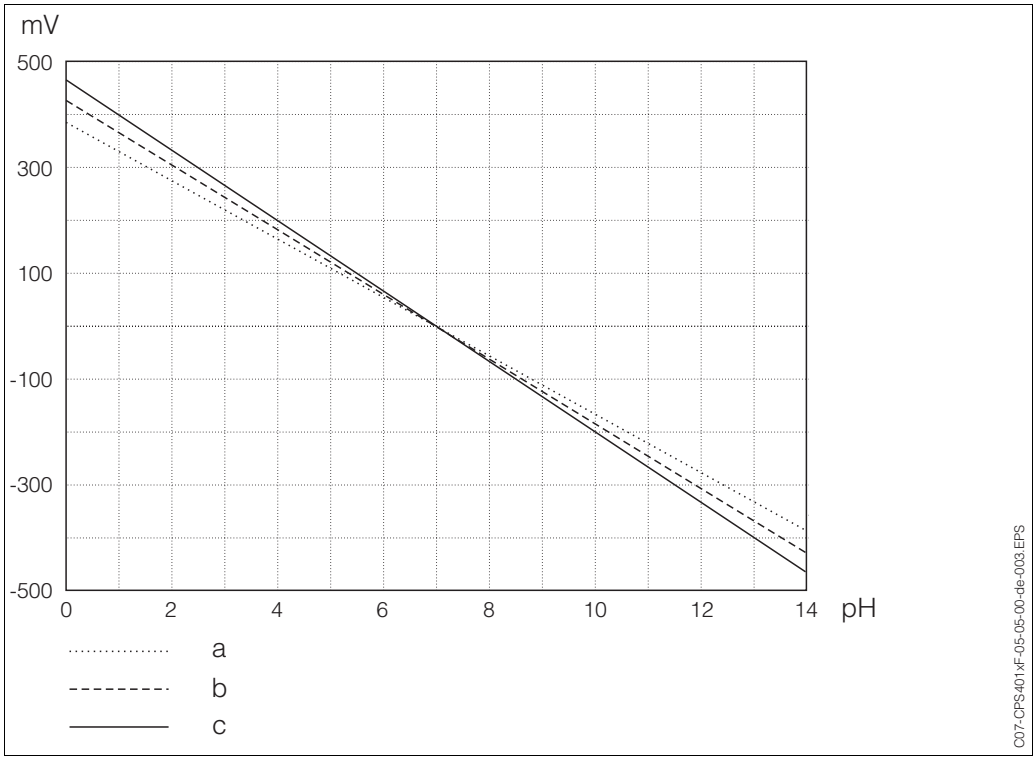
• Isothermic curves
The Nernst equation (a) defines the dependence of the measuring voltage on the hydrogen ion content (pH value) and the temperature. It is the basis of pH measuring technology and for IsFET sensors too. A temperature-dependent value for the potential change per pH value can be worked out from this equation (isothermic curve, potential change per pH value at *a defined* temperature).
The isothermic curves of the IsFET sensor are very close to the theoretical values (figures). This is further proof for the high pH measurement precision of the TopHit H CPS 401.



Isothermic curves TopHit H CPS 401

a ... Isothermic curve at 8°C: slope -55.8 mV/pH)
b ... Isothermic curve at 37°C: slope -61.5 mV/pH)
c ... Isothermic curve at 61°C: slope -66.3 mV/pH)

• Measurement stability and sensor response time
The IsFET response times are very short over the whole temperature range.
With the IsFET sensor, there is no (temperature-dependent) equilibrium setting as in the source layer of a pH glass of a glass electrode. They can also be used to derive an application at low temperatures with a deceleration in response time.
Large and fast temperature and pH value fluctuations have a significantly smaller effect on the measuring error (hysteresis) than with a glass electrode, as there is no stress exerted on the pH glass.
• Reference system
The integrated reference electrode of the CPS 401 is a double-chamber reference system with a bridge electrolyte. The benefits are an efficient and stable contact between the diaphragm and the reference lead, and the extremely long poison path. The bridge electrolyte is highly resistant to temperature and pressure changes.

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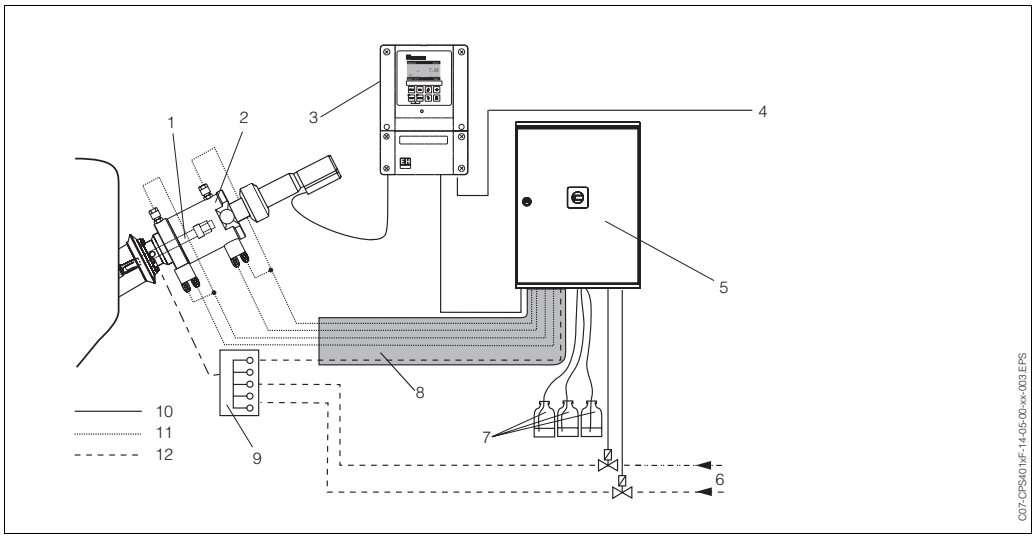
Equipment architecture

The complete measuring system comprises at least:
- IsFET sensor TopHit H CPS 401
- Measuring cable CPK 12 (with TOP 68 connection)
- Measuring transmitter, e.g. Liquisys S CPM 223 (for panel mounting) or Liquisys S CPM 253 (field instrument) or Mycom CPM 153.

There are additional accessories available depending on the application:
- Immersed, flow or retractable assembly, e.g. Cleanfit CPA 475
- TopClean or TopCal automatic cleaning system
- Extension cable, VBA or VBM junction box

The figures below show measuring system examples in different applications.

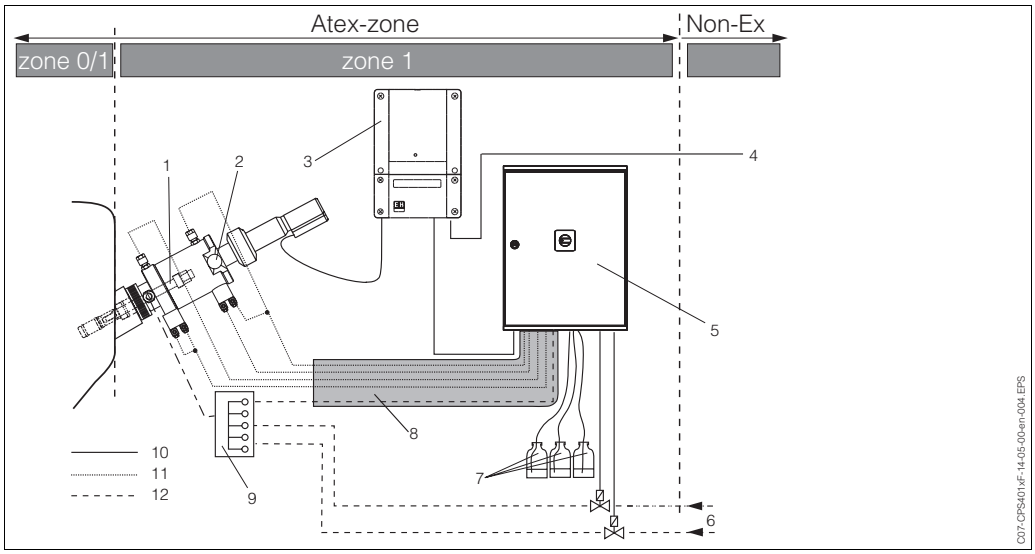
Food industry and chemicals



Food

(with TopCal fully automatic measuring, cleaning and calibration system)

1 ... CPS 401
2 ... Retractable assembly CPA 475
3 ... Mycom CPM 153
4 ... Power supply
5 ... Control unit CPG 300
6 ... Steam, water, cleaner
7 ... Cleaner, buffer solutions
8 ... Multihose
9 ... Rinse block
10 ... Electric cable
11 ... Compressed air
12 ... Liquids/cleaner



Chemicals and process systems

(with TopCal fully-automatic measurement, cleaning and calibration system)

1 ... CPS 401
2 ... Retractable assembly CPA 471
3 ... Mycom CPM 153
4 ... Power supply
5 ... Control unit CPG 300
6 ... Steam, water, cleaner
7 ... Cleaner, buffer solutions
8 ... Multihose
9 ... Rinse block
10 ... Electric cable
11 ... Compressed air
12 ... Liquids/cleaner

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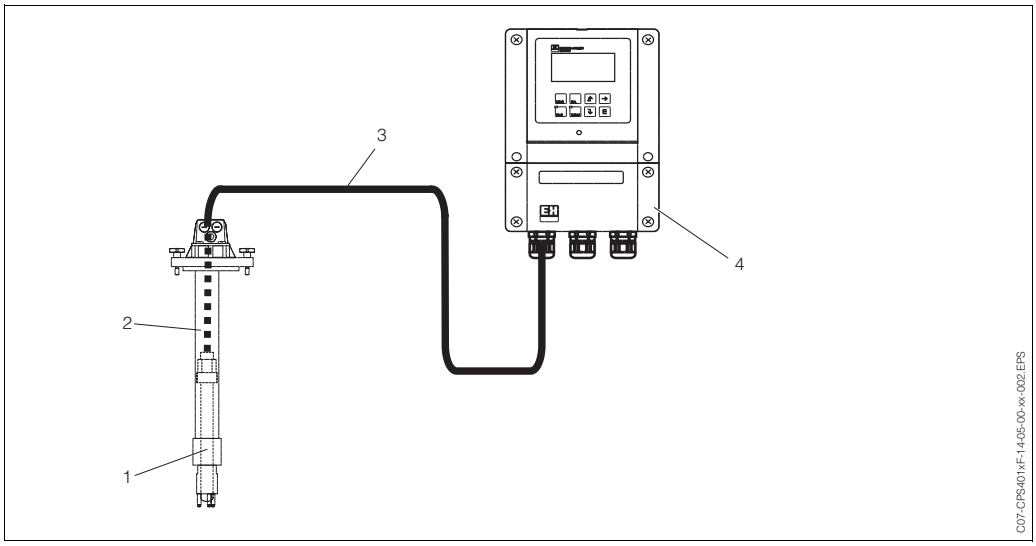
(Food industry and chemicals)

Process sterilisibility is no problem due to the wide range of applications for the IsFET pH sensor, not only relating to temperature but also to pH. There is only a small range of extremely high pH values connected with high temperatures where the sensor is not constantly stable (see "Process conditions" on page 9). Media with these characteristics remove the isolator oxide from the IsFET chip. As this is the pH and temperature range of CIP cleaning media, the IsFET pH sensor should only be used in combination with an automatic retractable assembly.

Benefits of the TopCal fully automatic measurement, cleaning and calibration system:

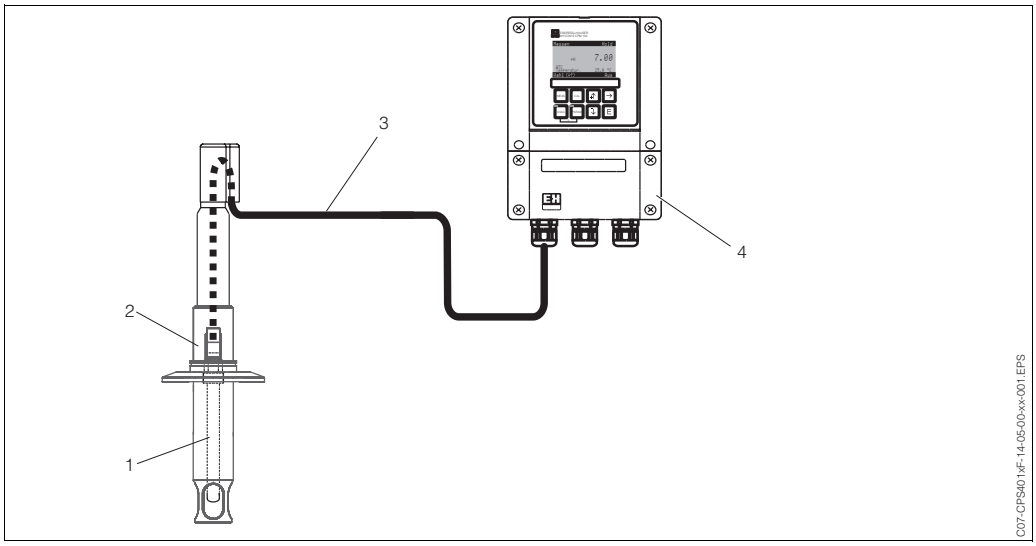
- CIP cleaning is possible - the sensor built into the retractable assembly is automatically "moved" out of the medium before cleaning
- Sensor cleaning in the rinse chamber of the retractable assembly with suitable cleaning solutions
- Calibration cycles settable individually

Water systems and pharmaceuticals



Water and wastewater systems

1 ... CPS 401
2 ... Immersion and built-in assembly CPA 111
3 ... Measuring cable CPK 12
4 ... Measuring transmitter Liquisys CPM 223/253



Pharmaceuticals and biotechnology

1 ... CPS 401
2 ... Built-in assembly CPA 442
3 ... Measuring cable CPK 12
4 ... Measuring transmitter Mycom CPM 153

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Measured parameters

Measured variables	pH value and temperature
Measuring range	0 ... 14 pH –15 ... 135 °C
	Caution! Note the process operating conditions and notes on page 9.

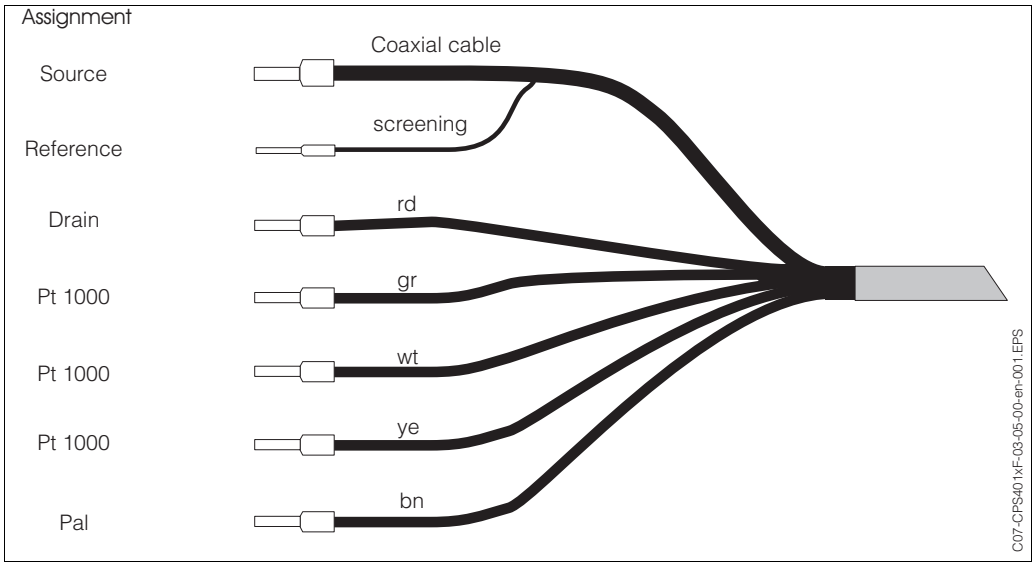
Performance characteristics

Reference operating conditions	Reference temperature: 25°C Reference pressure: 1013 mbar
Sensitivity	pH 0.01
Maximum measured error pH	± 0.2% of measurement range
Non-repeatability	± 0.1% of measurement range
Maximum measured error temperature	Class B to DIN / IEC 751

Electrical connection

Measuring cable

The IsFET TopHit H CPS 401 is connected to the measuring transmitter using the special measuring cable CPK 12 (figure).



Note!
Make sure you comply with the instructions for connecting the sensor (wiring diagram) in the Operating Instructions of the measuring transmitter. The transmitter has to be appropriate for the use of IsFET sensors (e.g. Liquisys CPM 223/253).
A transmitter with only a standard pH input is inappropriate.

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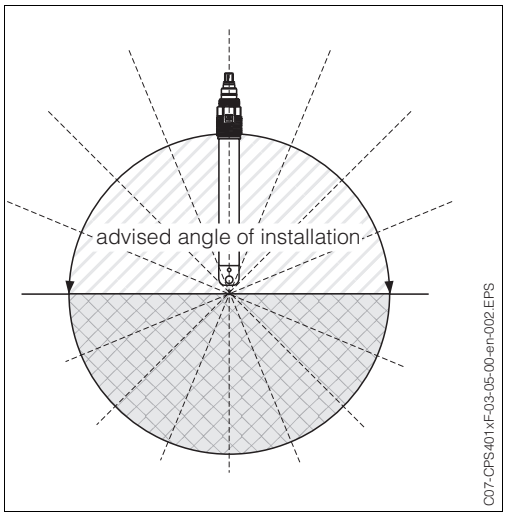
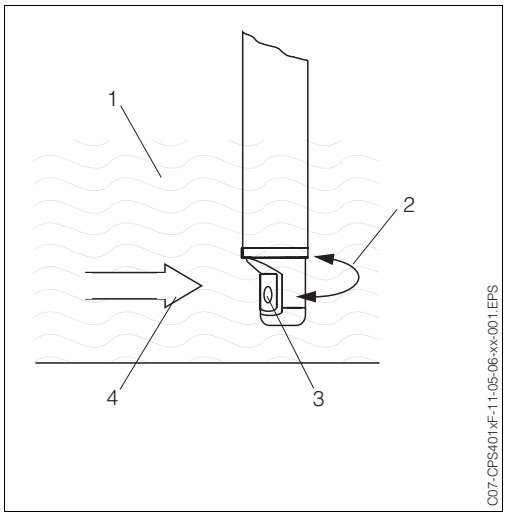
Operating conditions (Installation)

Installation instructions

In principle, IsFET sensors can be installed in any position, as there is no liquid inner lead. However, it must not be ruled out that, with an overhead installation, a possible air cushion* in the reference system may interrupt the electrical contact between the medium and the diaphragm. When installing the TopHit H CPS 401, note the flow-past direction of the medium.
The IsFET chip should be fixed at an angle of approx 45° to the flow-past direction (figure, right). Fixing at the correct angle is very easy with the TopHit H CPS 401because of it's rotable plug-in head.

* The sensor is delivered without air cushions. Air cushion forming is possible in case of working with depression, e.g. cleaning out of tanks.





1 ... Medium
2 ... Rotation angle of the IsFET chip to medium flow-past direction (approx. 45°)
3 ... IsFET Chip
4 ... Medium flow-past direction

Note!
Make sure you comply with the instructions in the operating instructions for the assembly used.

Operating conditions (Environment)

Ambient temperature range

The ambient temperature may not drop below –15°C.

Caution!
Danger of frost damage
Do not operate the sensor at temperatures below –15°C.

Storage temperature

0 ... 50°C

Ingress protection

IP 68 (with TOP 68 plug system)

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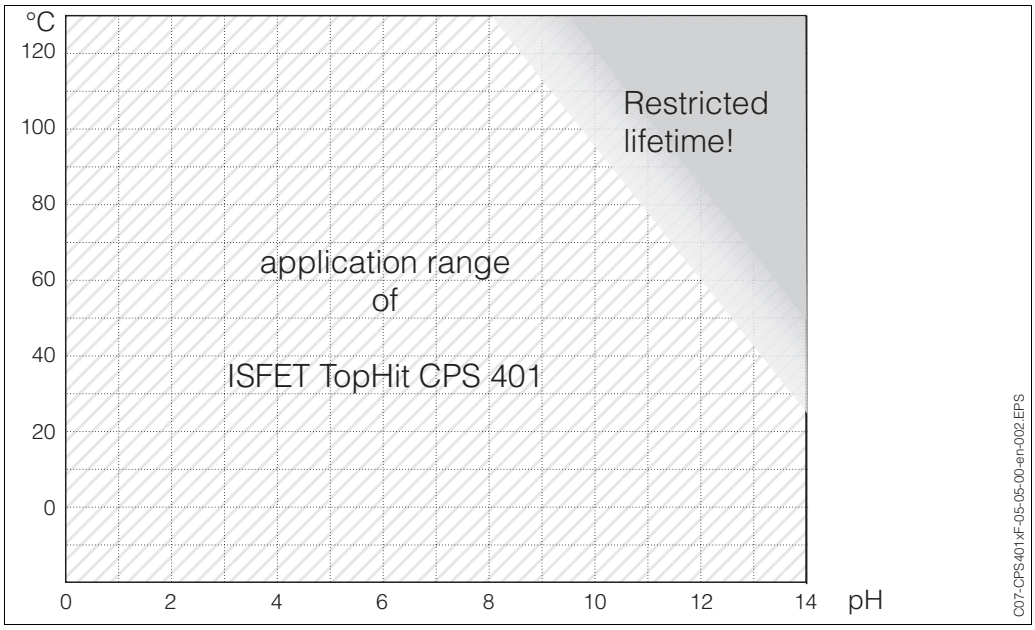
Operating conditions (Process)

Process

At high temperatures over a long period of time, alkalis destroy the gate isolator oxide irreversibly. The sensor can only be used in the indicated range (see diagram below) at a cost to its life span. If it is constantly subjected to the effects of a 2% sodium hydroxide solution at 80°C, the sensor life parameter drops to approx. 10-15 hours.



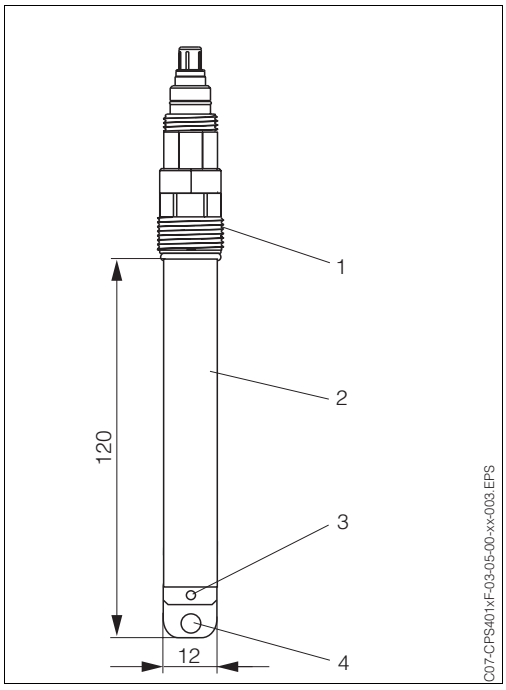
Sterilization

pressure / temperature: max. 100 °C / 10 bar, sterilisable: 135 °C, 1 h

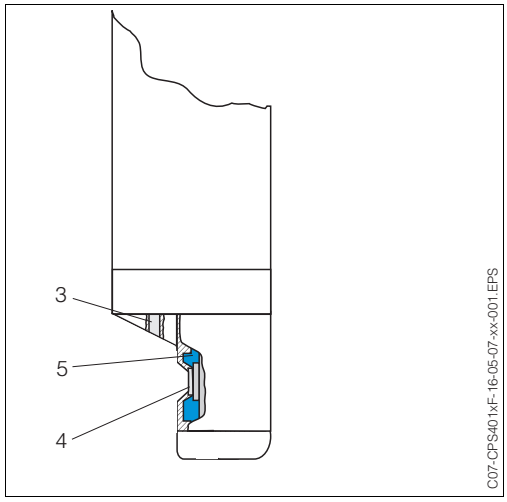
Caution!
Danger of damage to the sensor
Never use the TopHit H CPS 401 for applications outside the given specifications!

Mechanical construction

Design/Dimensions



left: sensor at front, at bottom: sensor head side view
1 ... Top68 plug-in head
2 ... Sensor shaft
3 ... Reference electrode
4 ... IsFET chip
5 ... Seal (EPDM)



Weight	0.1 kg	
Materials	Electrode shaft	PEEK, FDA conform
	Seals	EPDM
Surface roughness	R_a < 0.8 µm	
Temperature sensor	Pt 1000 (Class B to DIN IEC 751)	
Process connection	Pg 13.5	
Plug-in heads	ESB: TOP 68, rotatable	

Certificates and approvals

EHEDG	Sterilization certified to EHEDG test criteria
3-A	is listed with 3-A

Ordering information

Product structure of TopHit H CPS 401

	Application						
	B	pH 0 ... 14, –15 ... 140°C with Pt1000					
		Shaft length					
		2	Shaft length 120 mm				
			Terminal head				
			ESB	Threaded plug-in head Pg 13.5, TOP 68, turnable			
				Sealants			
				1	EPDM (FDA certified)		
					Potential matching		
					A	Standard, external potential matching	
						Version	
						1	Standard
CPS 401-							Complete order code

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Product structure of CPK 12 measuring cable

	Cable length				
	HA	Cable length 5 m, TPE sheath, max. 130°C			
	HB	Cable length 10 m, TPE sheath, max. 130°C			
	HC	Cable length 15 m, TPE sheath, max. 130°C			
	HD	Cable length 20 m, TPE sheath, max. 130°C			
	HF	Cable length 5 - 50 m, TPE sheath, max. 130°C			
	HG	Cable length 16 - 160 ft, TPE sheath, max. 130°C			
		Version			
		A	Standard version		
			Termination		
			1	End sleeve on device side, braided cable screening	
				PAL connection	
				A	PAL lead external with flat plug
CPK 12-					Complete order code

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Accessories

pH buffer solutions	pH 4.0 red, contents: 100 ml; Order No.: CPY 2-0 pH 4.0 red, contents: 1000 ml; Order No.: CPY 2-1 pH 7.0 green, contents: 100 ml; Order No.: CPY 2-2 pH 7.0 green, contents: 1000 ml; Order No.: CPY 2-3
pH measuring cable	CPK 12 pH measuring cable Order No. for measuring cable depending on specification, see Product Structure, page 11

Documentation

Assemblies	Cleanfit CPA 471 Technical Information, TI 217C/07/en; Order No. 51502596 Cleanfit CPA 475 Technical Information, TI 240C/07/en; Order No. 51505599 Dipsys CPA 111 Technical Information, TI 112C/07/en; Order No. 50066449 CPA 442 Technical Information, TI 297C/07/en; Order No. 51506724
Measuring transmitter	Liquisys S CPM 223/253 Technical Information, TI 194C/07/en; Order No. 51500277 Mycom 153 Technical Information, TI 233C/07/en; Order No. 51503788
Cleaning systems	TopClean Technical Information, TI 235C/07/en; Order No. 51504335 TopCal Technical Information, TI 236C/07/en; Order No. 51504330 Measuring cable CPK 1-12 Technical Information, TI 124C/07/en; Order No. 50068526

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