

# PCF8883

Capacitive proximity switch with auto-calibration, large voltage operating range and very low power consumption

Rev. 01 — 16 October 2009

Product data sheet

## 1. General description

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The integrated circuit PCF8883 is a capacitive proximity switch that uses a patented (EDISEN) digital method to detect a change in capacitance on a remote sensing plate. Changes in the static capacitance (as opposed to dynamic capacitance changes) are automatically compensated using continuous auto-calibration. Remote sensing plates (e.g. conductive foil) can be connected directly to the IC<sup>1</sup> or remotely using a coaxial cable.

## 2. Features

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- Dynamic proximity switch
- Digital processing method
- Adjustable sensitivity, can be made very high
- Adjustable response time
- Wide input capacitance range (10 pF to 60 pF)
- Automatic calibration
- A large distance (several meters) between the sensing plate and the IC is possible
- Open-drain output (P-type MOSFET, external load between pin and ground)
- Designed for battery powered applications ( $I_{DD} = 3 \mu\text{A}$ , typical)
- Output configurable as push-button, toggle, or pulse
- Wide voltage operating range ( $V_{DD} = 3 \text{ V to } 9 \text{ V}$ )
- Large temperature operating range ( $T_{amb} = -40 \text{ }^\circ\text{C to } +85 \text{ }^\circ\text{C}$ )
- Internal voltage regulator
- Available in SOIC8 (other packages available on request for larger quantities)

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1. The definition of the abbreviations and acronyms used in this data sheet can be found in [Section 16](#).

### 3. Applications

- Proximity detection
- Proximity sensing in
  - ◆ Mobile phones
  - ◆ Portable entertainment units
- Switch for medical applications
- Switch for use in explosive environments
- Vandal proof switches
- Transportation: Switches in or under upholstery, leather, handles, mats, and glass
- Buildings: switch in or under carpets, glass, or tiles
- Sanitary applications: use of standard metal sanitary parts (e.g. tap) as switch
- Hermetically sealed keys on a keyboard

### 4. Ordering information

Table 1. Ordering information

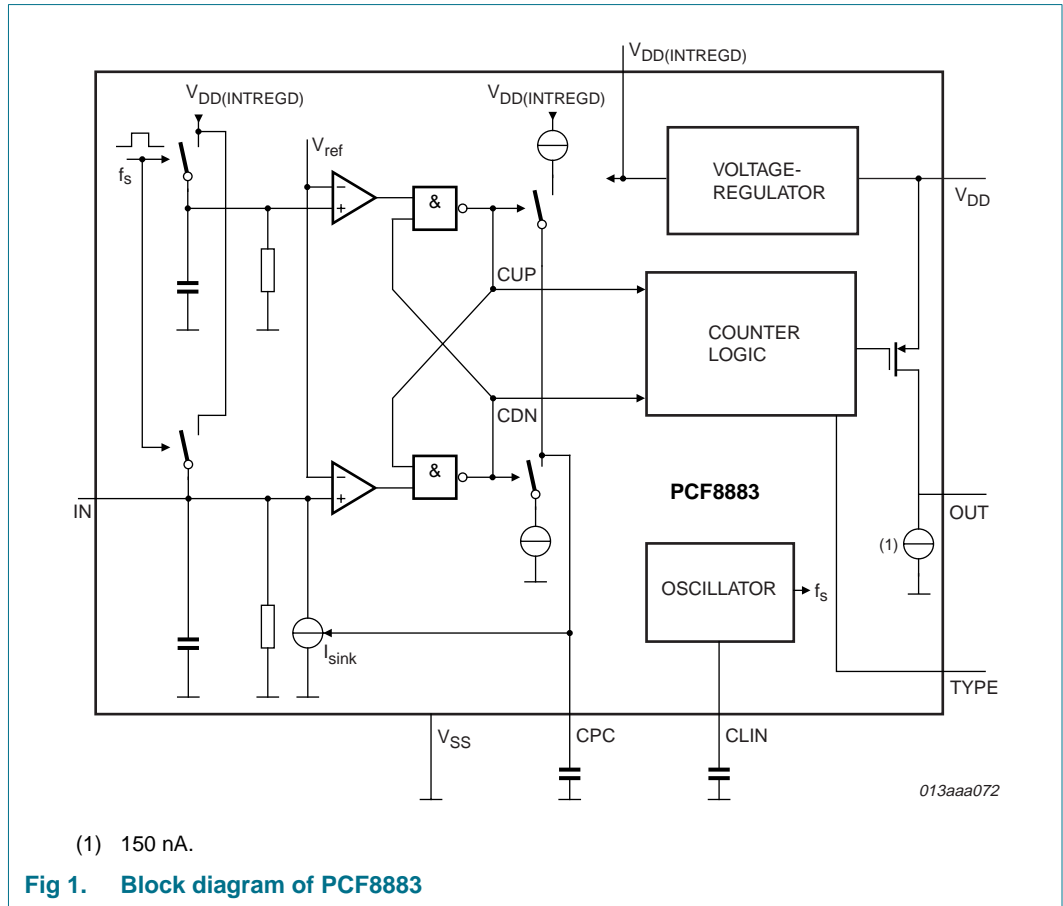
Type number	Package		
	Name	Description	Version
PCF8883T	SOIC8	plastic small outline package; 8 leads; body width 3.9 mm	PCF8883

### 5. Marking

Table 2. Marking codes

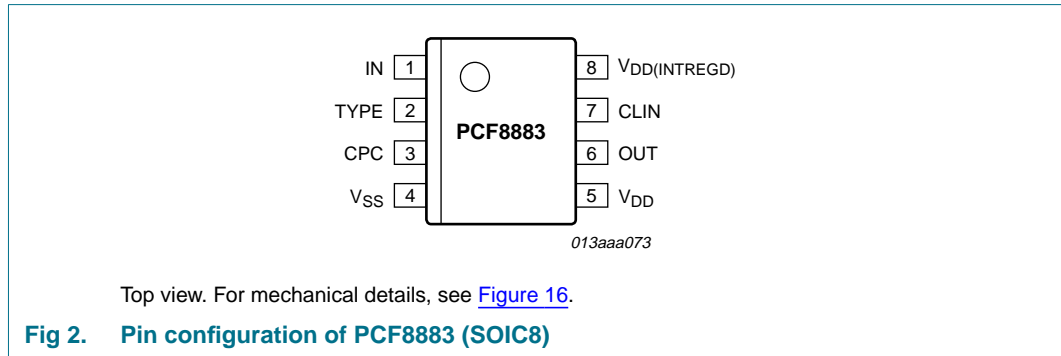
Type number	Marking code
PCF8883T	PCF8883

6. Block diagram



## 7. Pinning information

### 7.1 Pinning



### 7.2 Pin description

**Table 3. Pin description**

Symbol	Pin	Description
IN	1	sensor input
TYPE	2	pin OUT behavior configuration input
CPC	3	sensitivity setting
V <sub>SS</sub>	4	ground supply voltage
V <sub>DD</sub>	5	supply voltage
OUT	6	switch output
CLIN	7	sampling rate setting
V <sub>DD</sub> (INTREGD)	8	internal regulated supply voltage output

## 8. Functional description

Figure 3 and Figure 4 show the functional principle of the PCF8883. The discharge time ( $t_{dch}$ ) of a chip-internal RC timing circuit, to which the external sensing plate is connected via pin IN, is compared to the discharge time ( $t_{dch(ref)}$ ) of a second chip-internal reference RC timing circuit. Both RC timing circuits are periodically charged from  $V_{DD(INTREGD)}$  via identical switches and then discharged via a resistor to ground ( $V_{SS}$ ). Both switches are synchronized.

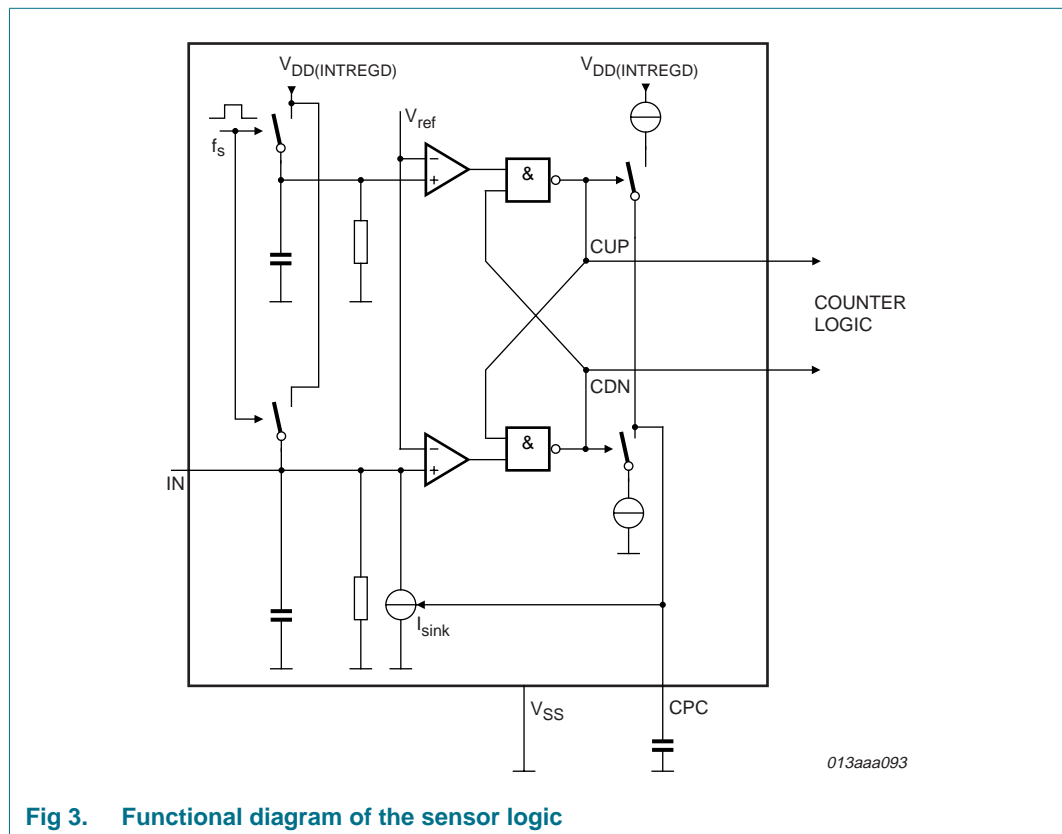


Fig 3. Functional diagram of the sensor logic

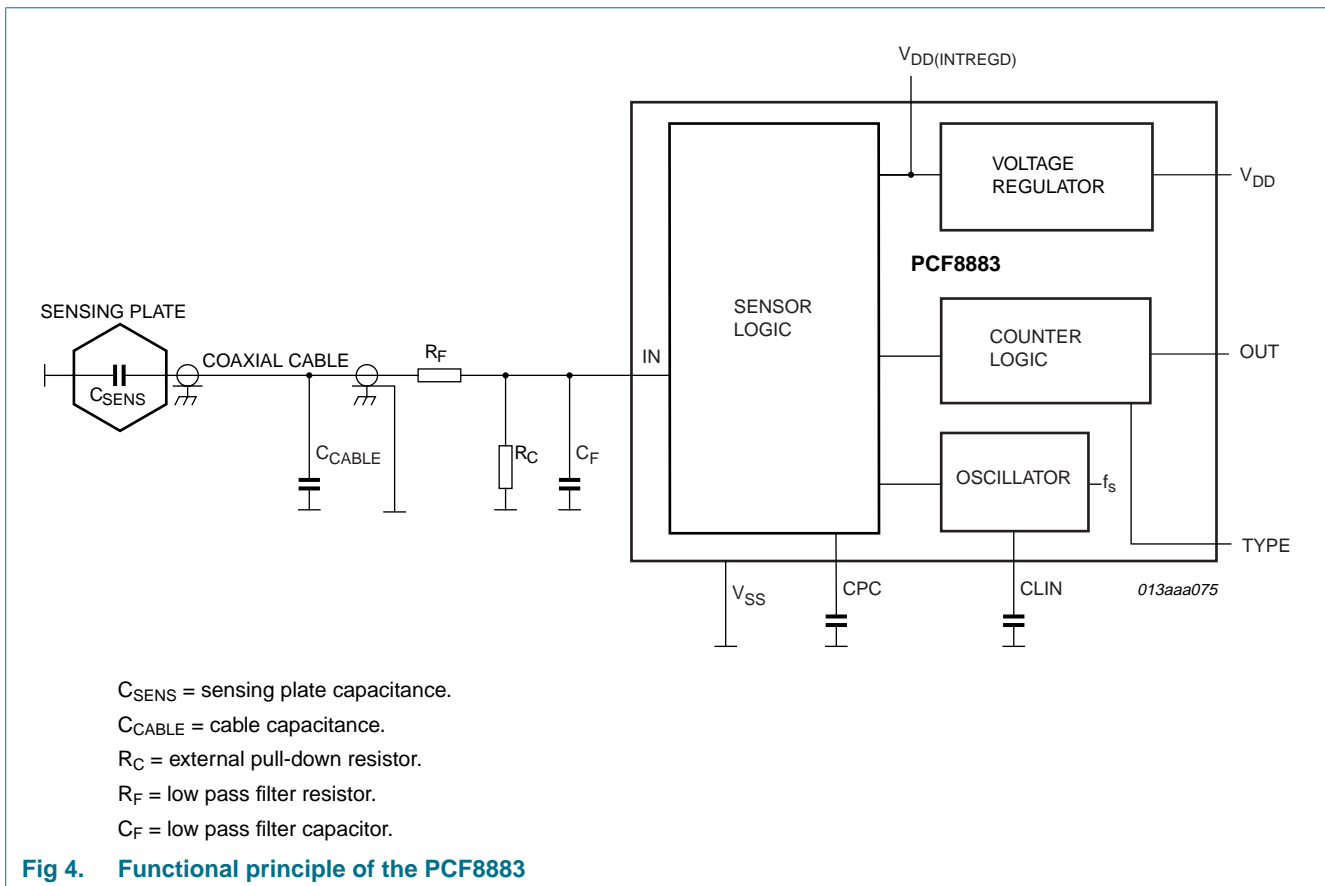
The charge-discharge cycle is governed by the sampling rate ( $f_s$ ). If the voltage of one of the RC timing circuits falls below the internal reference voltage  $V_{ref}$ , the respective comparator output will become LOW. The logic following the comparators determines which comparator switches first. If the upper (reference) comparator switches then a pulse is given on CUP. If the lower (input) comparator switches first then a pulse is given on CDN (see Figure 3).

The pulses control the charge on the external capacitor  $C_{CPC}$  on pin CPC. Every time a pulse is given on CUP, capacitor  $C_{CPC}$  is charged from  $V_{DD(INTREGD)}$  for a fixed time causing the voltage on  $C_{CPC}$  to rise. Likewise when a pulse occurs on CDN, capacitor  $C_{CPC}$  is connected to a current sink to ground for a fixed time causing the voltage on  $C_{CPC}$  to fall.

If the capacitance on pin IN increases, the discharge time  $t_{dch}$  increases too. Therefore it will take longer for the voltage on the corresponding comparator to drop below  $V_{ref}$ . Only once this happens, the comparator output will become LOW and this results in a pulse on CDN discharging the external capacitor  $C_{CPC}$  slightly. Thus most pulses will now be given by CUP. Without further action, capacitor  $C_{CPC}$  would then fully charge.

However, a chip-internal automatic calibration mechanism that is based on a voltage controlled sink current ( $I_{sink}$ ) connected to pin IN attempts to equalize the discharge time  $t_{dch}$  with the internal reference discharge time  $t_{dch(ref)}$ . The current source is controlled by the voltage on  $C_{CPC}$  which causes the capacitance on pin IN to be discharged more quickly in the case that the voltage on  $C_{CPC}$  is rising, thereby compensating for the increase in capacitance on input pin IN. This arrangement constitutes a closed-loop control system that constantly attempts to equalize the discharge time  $t_{dch}$  with  $t_{dch(ref)}$ . This allows compensating for slow changes in capacitance on input pin IN. Fast changes due to an approaching hand for example will not be compensated. In the equilibrium state the discharge times are equal and the pulses alternate between CUP and CDN.

From this also follows that an increase in capacitor value  $C_{CPC}$  results in a smaller voltage change per pulse CUP or CDN. Thus the compensation due to internal current sink source  $I_{sink}$  is slower and therefore the sensitivity of the sensor will increase. Likewise a decrease in capacitor  $C_{CPC}$  will result in a lower sensitivity. (For further information see [Section 13.](#))



The counter, following the sensor logic depicted in [Figure 3](#), counts the pulses of CUP or CDN respectively. The counter is reset every time the pulse sequence changes from CUP to CDN or vice versa. Pin OUT will only be activated when a sufficient number of consecutive CUP or CDN pulses occur. Low level interference or slow changes in the input capacitance do not cause the output to switch.

Various measures, such as asymmetrical charge and discharge steps, are taken to ensure that the output switches off correctly. A special start-up circuit ensures that the device reaches equilibrium quickly when the supply is attached.

Pin OUT is an open-drain output capable of pulling an external load  $R_{ext}$  (at maximum current of 20 mA) up to  $V_{DD}$ . The load resistor must be dimensioned appropriately, taking the maximum expected  $V_{DD}$  voltage into account. The output will be automatically deactivated (short circuit protection) for loads in excess of 30 mA. Pin OUT can also drive a CMOS input without connection of the external load.

A small internal 150 nA current sink  $I_{sink}$  enables a full voltage swing to take place on OUT, even if no load resistor is connected. This is useful for driving purely capacitive CMOS inputs. The falling slope can be fairly slow in this mode, depending on load capacitance.

The sampling rate ( $f_s$ ) corresponds to half of the frequency used in the RC timing circuit. The sampling rate can be adjusted within a specified range by selecting the value of  $C_{CLIN}$ . The oscillator frequency is internally modulated by 4 % using a pseudo random signal. This prevents interference caused by local AC-fields.

## 8.1 Output switching modes

The output switching behavior can be selected using pin TYPE (see [Figure 5](#))

- Push-button (TYPE connected to  $V_{SS}$ ): The output OUT is active as long as the capacitive event<sup>2</sup> lasts.
- Toggle (TYPE connected to  $V_{DD(INTREGD)}$ ): The output OUT is activated by the first capacitive event and deactivated by a following capacitive event.
- Pulse ( $C_{TYPE}$  connected between TYPE and  $V_{SS}$ ): The output OUT is activated for a defined time at each capacitive event. The pulse duration is determined by the value of  $C_{TYPE}$  and is approximately 2.5 ms/nF.

A typical value for  $C_{TYPE}$  is 4.7 nF which results in an output pulse duration of about 10 ms. The maximum value of  $C_{TYPE}$  is 470 nF which results in a pulse duration of about 1 s. Capacitive events are ignored that occur during the time the output is active.

[Figure 5](#) illustrates the switching behavior for the output switching modes. Additionally the graph illustrates, that short term disturbances on the sensor are suppressed by the circuit.

2. A capacitive event is a dynamic increase of capacitance at the sensor input pin IN.

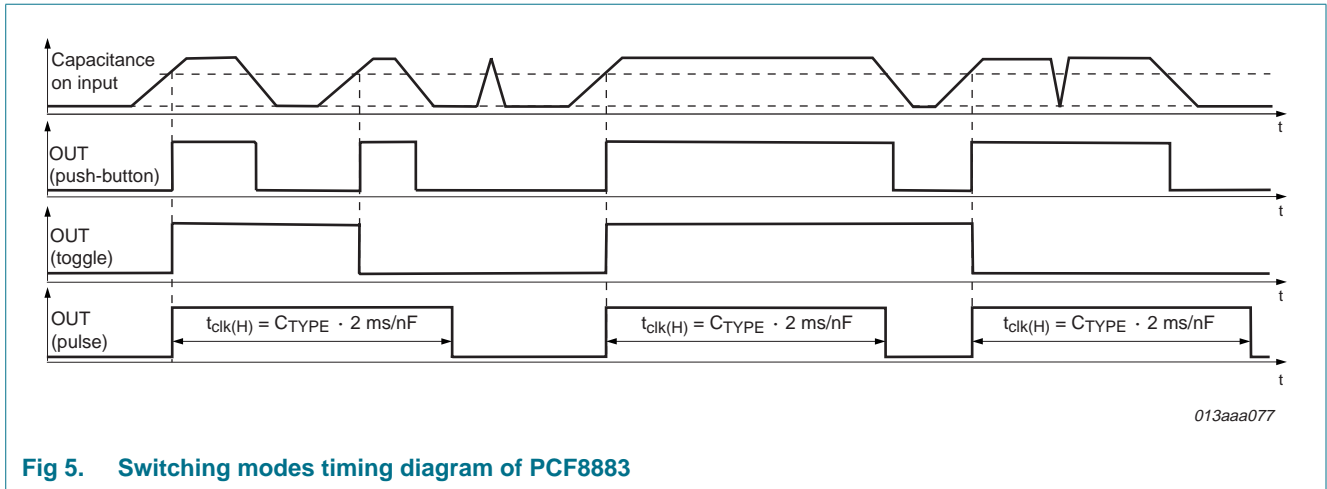


Fig 5. Switching modes timing diagram of PCF8883

### 8.2 Voltage regulator

The PCF8883 implements a chip-internal voltage regulator supplied by pin  $V_{DD}$  that provides an internal supply ( $V_{DD(INTREGD)}$ ), limited to a maximum of 4.6 V. The lock-in voltage  $V_{lockin}$  on  $V_{DD}$  is typically 4.0 V. The regulated supply is available at pin  $V_{DD(INTREGD)}$  and can be used to supply power to external electronic components (at a maximum current of 0.5 mA). Figure 4 shows the relationship between  $V_{DD}$  and  $V_{DD(INTREGD)}$ .

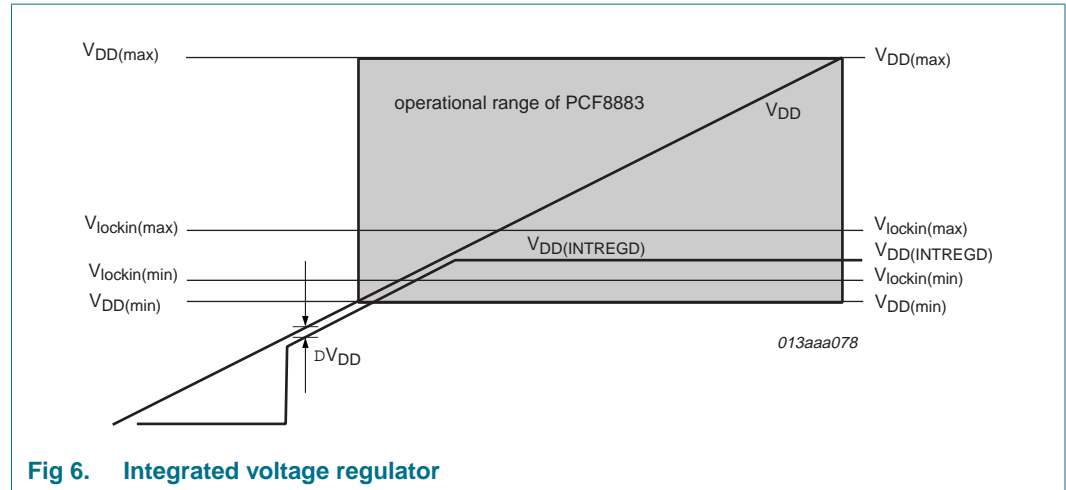


Fig 6. Integrated voltage regulator



## 9. Limiting values

**Table 4. Limiting values**

In accordance with the Absolute Maximum Rating System (IEC 60134).

Symbol	Parameter	Conditions	Min	Max	Unit
V <sub>DD</sub>	supply voltage		-0.5	+9	V
V <sub>I</sub>	input voltage	on pins IN, TYPE, CPC	-0.5	V <sub>DD(INTREGD)</sub> + 0.5	V
I <sub>O</sub>	output current	on pin OUT	-10	+50	mA
I <sub>SS</sub>	ground supply current		-10	+50	mA
I <sub>I</sub>	input current	on any other pin	-10	+10	mA
P <sub>tot</sub>	total power dissipation		-	100	mW
V <sub>ESD</sub>	electrostatic discharge voltage	HBM	[1] -	±2000	V
		MM	[2] -	±200	V
I <sub>lu</sub>	latch-up current		[3] -	100	mA
T <sub>stg</sub>	storage temperature		[4] -60	+125	°C

[1] Pass level; Human Body Model (HBM) according to [Ref. 6 "JESD22-A114"](#).

[2] Pass level; Machine Model (MM), according to [Ref. 7 "JESD22-A115"](#).

[3] Pass level; latch-up testing, according to [Ref. 8 "JESD78"](#) at maximum ambient temperature (T<sub>amb(max)</sub> = 85 °C).

[4] According to the NXP store and transport requirements (see [Ref. 10 "NX3-00092"](#)) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %. For long term storage products deviant conditions are described in that document.

## 10. Static characteristics

**Table 5. Static characteristics**
 $V_{DD} = 5\text{ V}$ ,  $T_{amb} = +25\text{ °C}$ ; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$V_{DD}$	supply voltage		[1] 3.0	-	9.0	V
$V_{lockin}$	lock-in voltage	no external load	-	4.0	-	V
$V_{DD(INTREGD)}$	internal regulated supply voltage	$V_{DD} > V_{lockin}$	3.0	4.0	4.6	V
$\Delta V_{DD(INTREGD)}$	internal regulated supply voltage variation	$V_{DD} < V_{lockin}$	-	10	50	mV
$I_{DD}$	supply current	idle state; $f_s = 1\text{ kHz}$	[2] -	3	5	$\mu\text{A}$
		idle state; $f_s = 1\text{ kHz}$ ; $V_{DD} = 3.0\text{ V}$	[2] -	2.2	3.5	$\mu\text{A}$
$I_{sink}$	sink current	internal constant current to $V_{SS}$	-	150	-	nA
$V_O$	output voltage	on pin OUT; pull-up voltage	0	$V_{DD}$	9.0	V
$I_O$	output current	P-MOS	[3] 0	10	20	mA
		short circuit protection $V_O \geq 0.6\text{ V}$	20	30	50	mA
$V_{sat}$	saturation voltage	on pin OUT; $I_O = +10\text{ mA}$	0.1	0.2	0.4	V
		on pin OUT; $I_O = +10\text{ mA}$ ; $V_{DD} = 3.0\text{ V}$	0.1	0.3	0.5	V
$C_{dec}$	decoupling capacitance	on pin $V_{DD(INTREGD)}$	[4] 100	-	220	nF
$V_I$	input voltage	on pin CPC	0.6	-	$V_{DD(INTREGD)} - 0.3$	V
$I_{LI}$	input leakage current	on pin CPC	-1	-	+1	nA
$T_{amb}$	ambient temperature		-40	-	+85	$^{\circ}\text{C}$

[1] When the input capacitance range is limited to  $10\text{ pF} \leq C_i \leq 40\text{ pF}$  or an external pull-down resistor  $R_C$  is used, the device can be operated down to  $V_{DD} = 3.0\text{ V}$  over the full temperature range.

[2] Idle state is the steady state after completed power-on without any activity on the sensor plate and the voltage on the reservoir capacitor  $C_{CPC}$  settled.

[3] For reliability reasons the average output current must be limited to 4.6 mA at 70 °C and 3.0 mA at 85 °C.

[4] External ceramic chip capacitor recommended (see [Figure 15](#)).

## 11. Dynamic characteristics

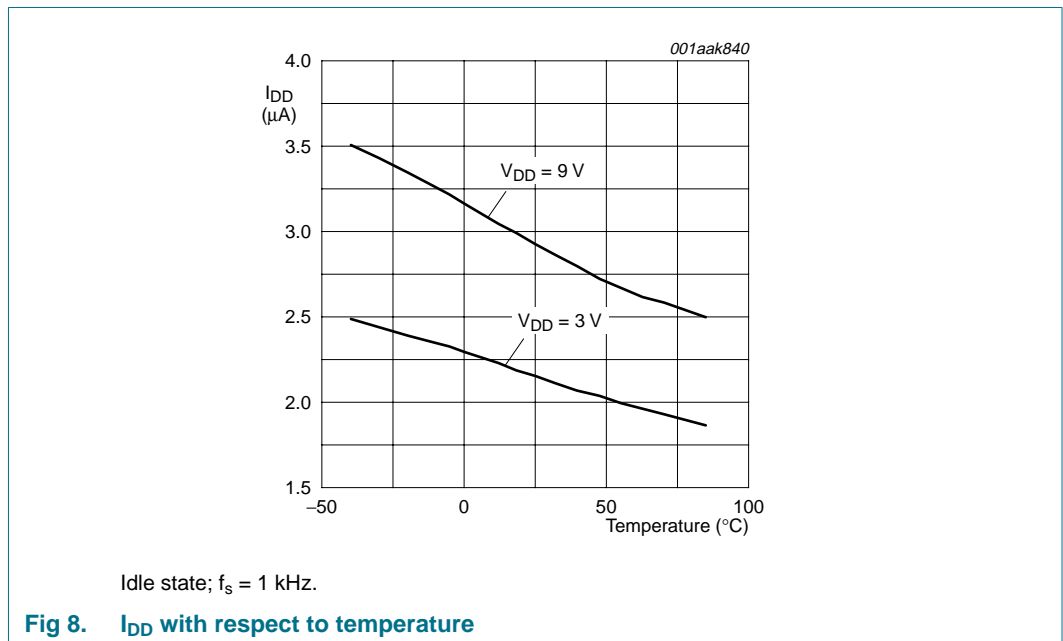
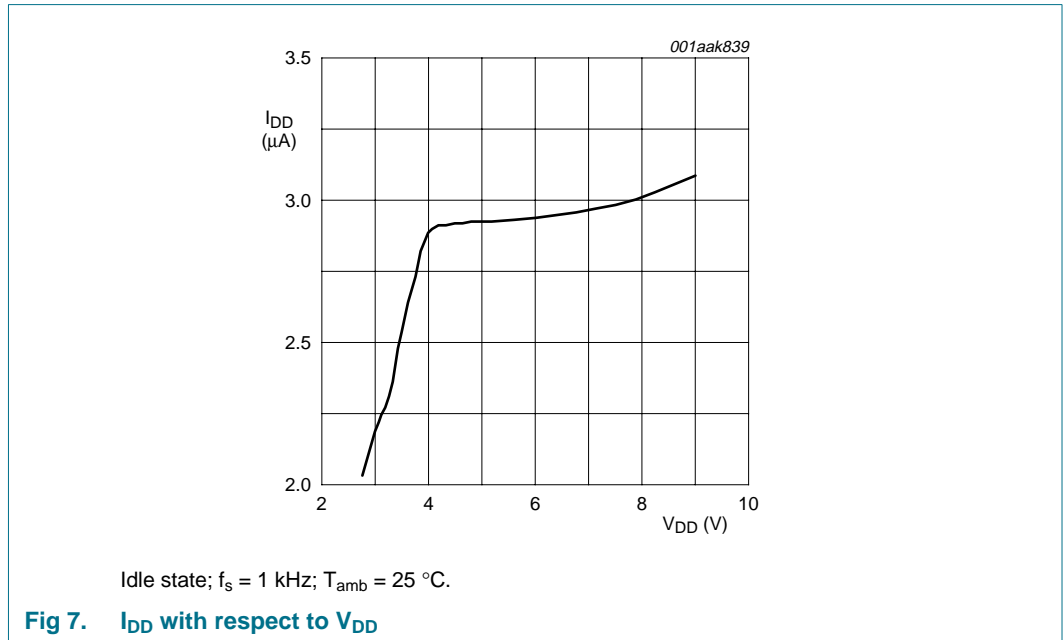
**Table 6. Dynamic characteristics**

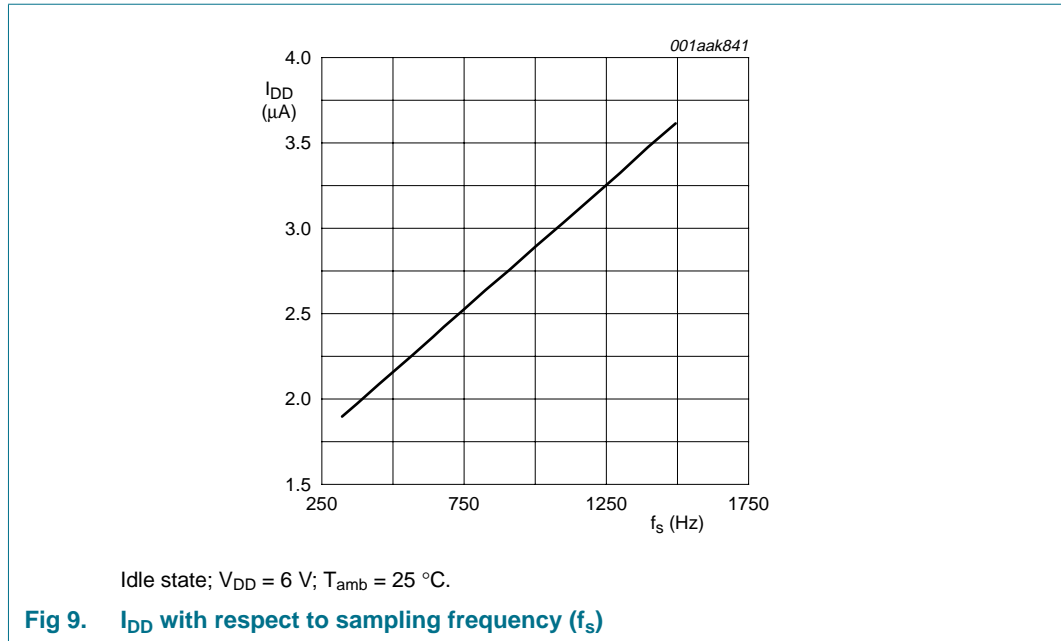
$V_{DD} = 5\text{ V}$ ,  $C_{CLIN} = 22\text{ pF}$ ,  $C_{CPC} = 470\text{ nF}$ ,  $T_{amb} = +25\text{ °C}$ ; unless otherwise specified.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
$C_{CLIN}$	capacitance on pin CLIN		0	22	100	pF
$C_{CPC}$	capacitance on pin CPC	X7R ceramic chip capacitor	90	470	2500	nF
$N_{res(dig)eq}$	equivalent digital resolution		-	14	-	bit
$C_{TYPE}$	capacitance on pin TYPE		0.1	-	470	nF
$C_i$	input capacitance	sensing plate and connecting cable	10	-	60	pF
		sensing plate and connecting cable; $T_{amb} = -40\text{ °C to }+85\text{ °C}$ ; $V_{DD} = 3.0\text{ V}$	10	-	40	pF
$R_{DSon}$	drain-source on-state resistance	internal pull-up on input	-	-	500	$\Omega$
$t_{ch}$	charge time	per sample	1.4	2.5	3.5	$\mu\text{s}$
$t_{dch}$	discharge time	per sample	-	1.0	-	$\mu\text{s}$
$t_{startup}$	start-up time	until normal operation is established	-	0.5	-	s
$t_p$	pulse duration	on pin OUT; in pulse mode; $C_{TYPE} \geq 10\text{ nF}$	-	2.5	-	ms/nF
$f_s$	sampling frequency	$C_{CLIN} = 0\text{ pF}$	-	3.3	-	kHz
		$C_{CLIN} = 22\text{ pF}$ (typical value)	-	1	-	kHz
		$C_{CLIN} = 100\text{ pF}$	-	275	-	Hz
$t_{sw}$	switching time	at $f_s = 1\text{ kHz}$	-	64	-	ms

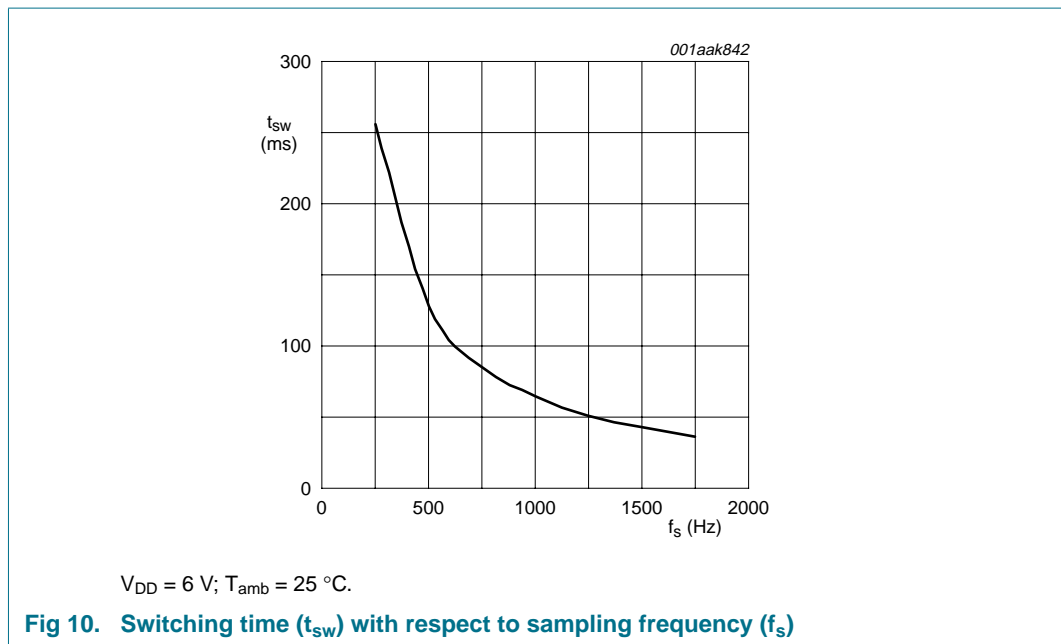
## 12. Characteristic curves

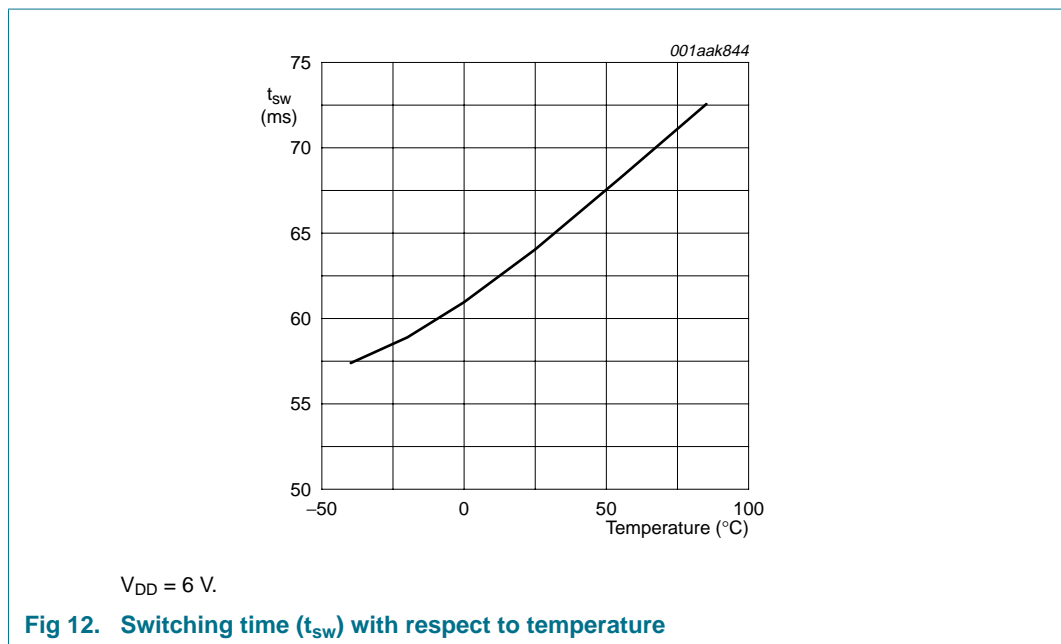
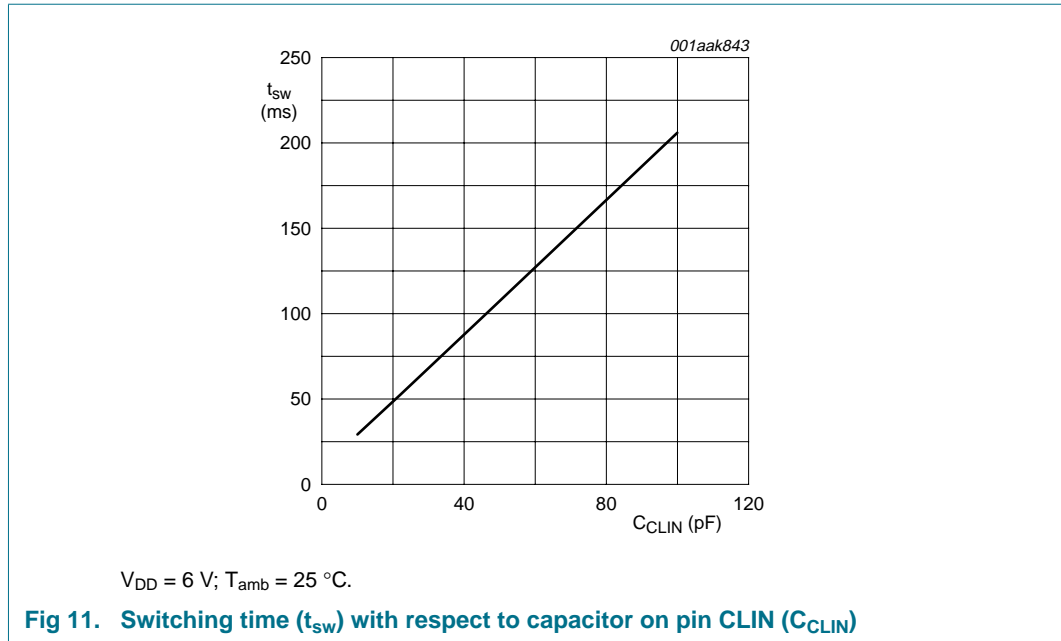
### 12.1 Power consumption



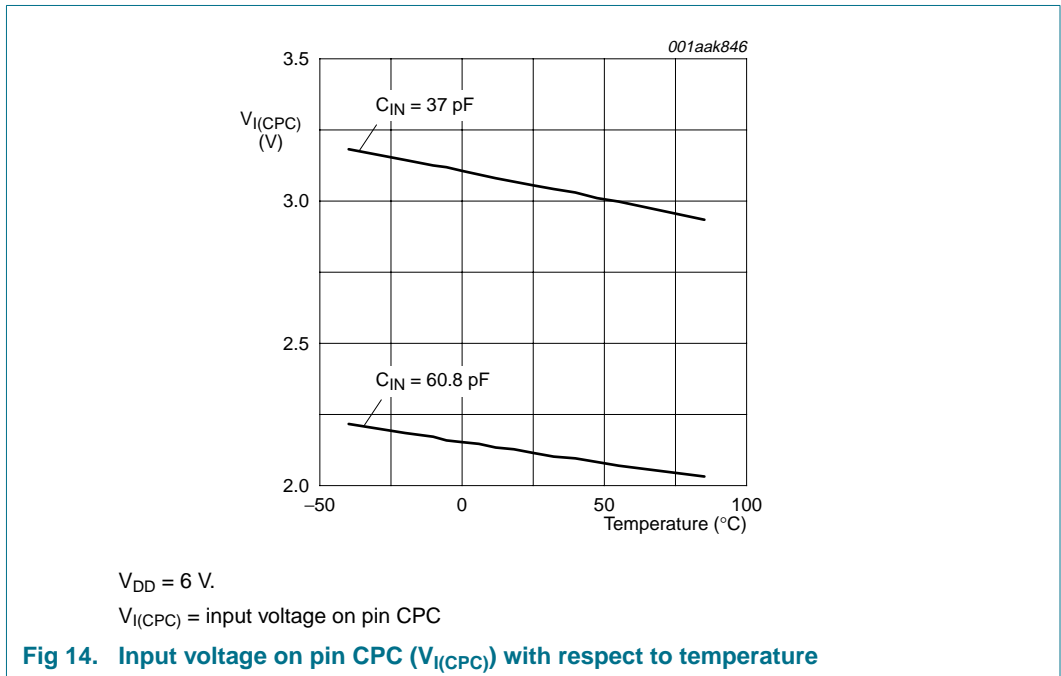
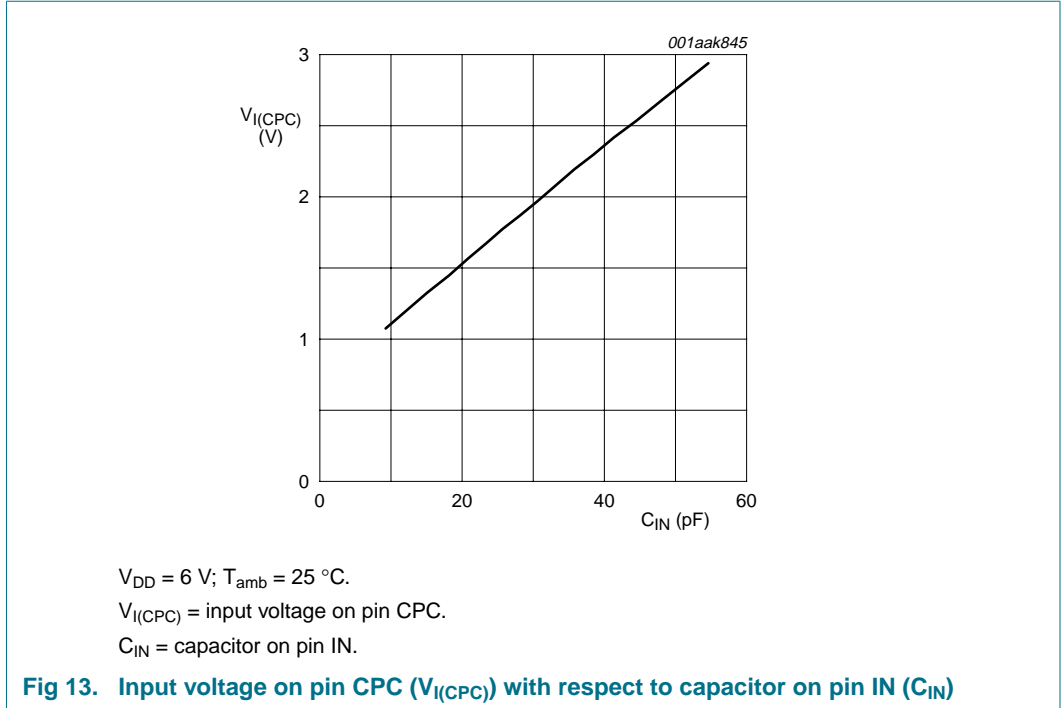


## 12.2 Typical reaction time



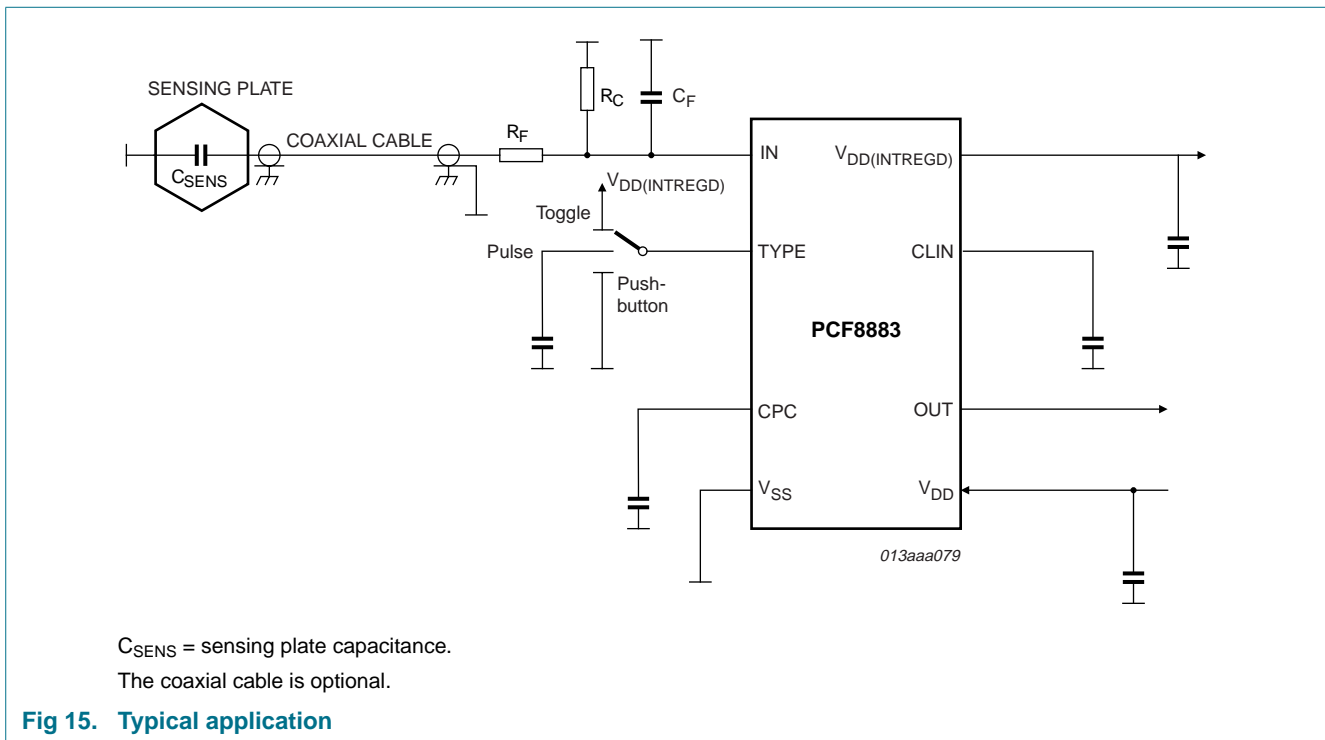


12.3 Reservoir capacitor voltage



### 13. Application information

Figure 15 shows the typical connections for a general application<sup>3</sup>. The positive supply is connected to pin V<sub>DD</sub>. It is recommended to connect smoothing capacitors to ground to both V<sub>DD</sub> and V<sub>DD(INTREGD)</sub> (values for C<sub>dec</sub>, see Table 5).



The sampling rate is determined by the capacitance C<sub>CLIN</sub> on pin CLIN. A higher sampling rate reduces the reaction time and increases the current consumption.

The sensing plate capacitance C<sub>SENS</sub> may consist of a small metal area, for example behind an isolating layer. The sensing plate can be connected to a coaxial cable (C<sub>CABLE</sub>) which in turn is connected to the input pin IN. Alternatively, the sensing plate can be directly connected to the input pin IN. An internal low pass filter is used to reduce RF interference. An additional low pass filter consisting of a resistor R<sub>F</sub> and capacitor C<sub>F</sub> can be added to the input to further improve RF immunity as required. For good performance, the total amount of capacitance on the input (C<sub>SENS</sub> + C<sub>CABLE</sub> + C<sub>F</sub>) should be in the proper range, the optimum point being around 30 pF. These conditions allow the control loop to adapt to the static capacitance on C<sub>SENS</sub> and to compensate for slow changes in the sensing plate capacitance. A higher capacitive input loading is possible provided that an additional discharge resistor R<sub>C</sub> is placed as shown in Figure 15. Resistor R<sub>C</sub> simply reduces the discharge time such that the internal timing requirements are fulfilled.

3. For further information see Ref. 2 "AN10832". Information about the appropriate evaluation board can be found in Ref. 11 "UM10370".



The sensitivity of the sensor can be influenced by the sensing plate area and capacitor  $C_{CPC}$ . The sensitivity is significantly reduced when  $C_{CPC}$  is reduced. When maximum sensitivity is desired  $C_{CPC}$  can be increased, but this also increases sensitivity to interference. Pin CPC has high-impedance and is sensitive to leakage currents. Therefore  $C_{CPC}$  should be a high quality foil or ceramic capacitor, for example an X7R type.

For the choice of proper component values for a given application, the component specifications in [Table 5](#) and [Table 6](#) must be followed.

14. Package outline

SOIC8: plastic small outline package; 8 leads; body width 3.9 mm

PCF8883

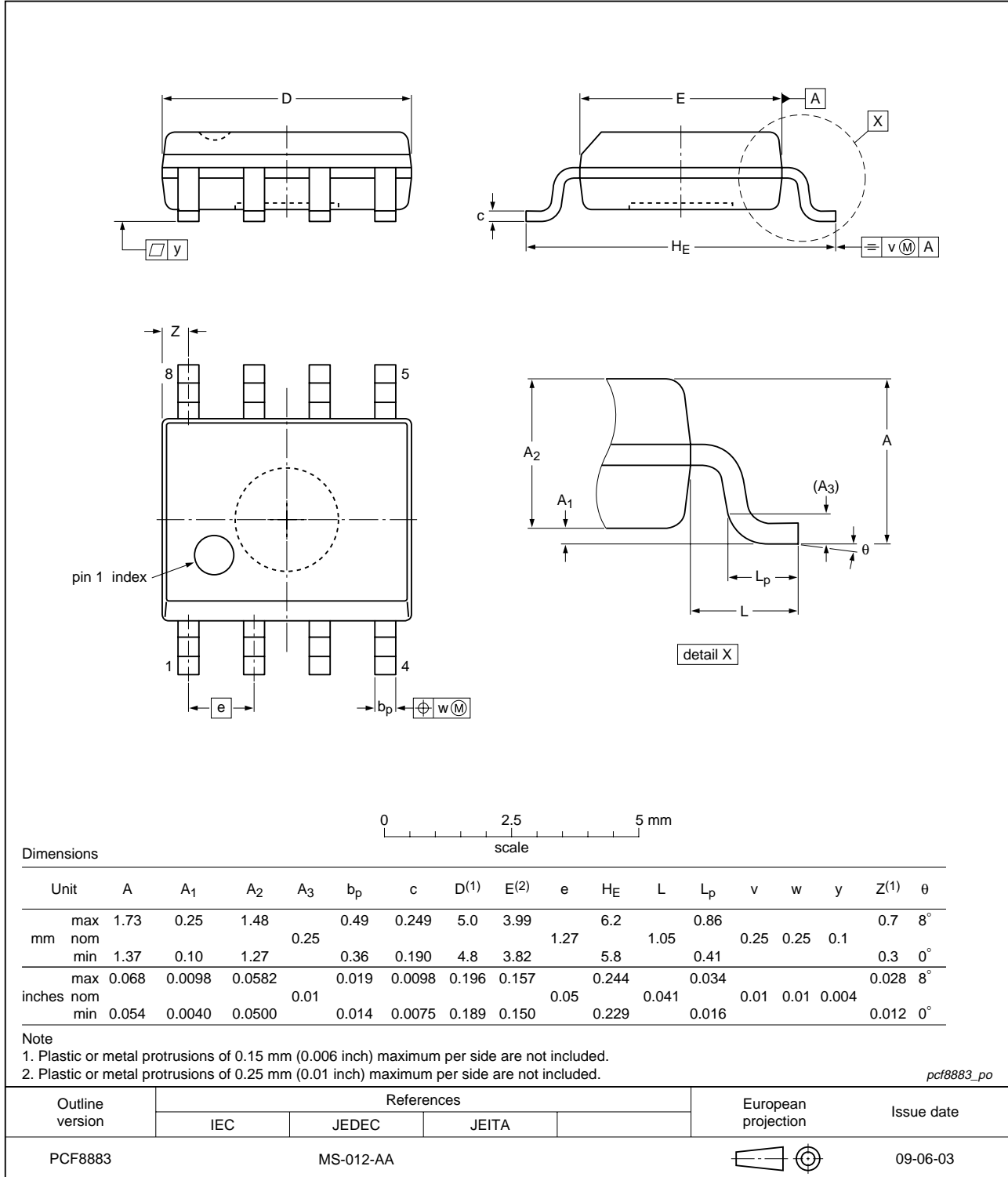


Fig 16. Package outline of PCF8883 (SOIC8)

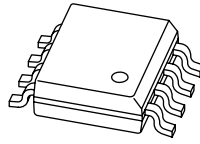


Fig 17. Three dimensional package drawing of PCF8883 (SOIC8)

## 15. Soldering of SMD packages

This text provides a very brief insight into a complex technology. A more in-depth account of soldering ICs can be found in Application Note *AN10365 "Surface mount reflow soldering description"*.

### 15.1 Introduction to soldering

Soldering is one of the most common methods through which packages are attached to Printed Circuit Boards (PCBs), to form electrical circuits. The soldered joint provides both the mechanical and the electrical connection. There is no single soldering method that is ideal for all IC packages. Wave soldering is often preferred when through-hole and Surface Mount Devices (SMDs) are mixed on one printed wiring board; however, it is not suitable for fine pitch SMDs. Reflow soldering is ideal for the small pitches and high densities that come with increased miniaturization.

### 15.2 Wave and reflow soldering

Wave soldering is a joining technology in which the joints are made by solder coming from a standing wave of liquid solder. The wave soldering process is suitable for the following:

- Through-hole components
- Leaded or leadless SMDs, which are glued to the surface of the printed circuit board

Not all SMDs can be wave soldered. Packages with solder balls, and some leadless packages which have solder lands underneath the body, cannot be wave soldered. Also, leaded SMDs with leads having a pitch smaller than ~0.6 mm cannot be wave soldered, due to an increased probability of bridging.

The reflow soldering process involves applying solder paste to a board, followed by component placement and exposure to a temperature profile. Leaded packages, packages with solder balls, and leadless packages are all reflow solderable.

Key characteristics in both wave and reflow soldering are:

- Board specifications, including the board finish, solder masks and vias
- Package footprints, including solder thieves and orientation
- The moisture sensitivity level of the packages
- Package placement
- Inspection and repair
- Lead-free soldering versus SnPb soldering

### 15.3 Wave soldering

Key characteristics in wave soldering are:

- Process issues, such as application of adhesive and flux, clinching of leads, board transport, the solder wave parameters, and the time during which components are exposed to the wave
- Solder bath specifications, including temperature and impurities

### 15.4 Reflow soldering

Key characteristics in reflow soldering are:

- Lead-free versus SnPb soldering; note that a lead-free reflow process usually leads to higher minimum peak temperatures (see [Figure 18](#)) than a SnPb process, thus reducing the process window
- Solder paste printing issues including smearing, release, and adjusting the process window for a mix of large and small components on one board
- Reflow temperature profile; this profile includes preheat, reflow (in which the board is heated to the peak temperature) and cooling down. It is imperative that the peak temperature is high enough for the solder to make reliable solder joints (a solder paste characteristic). In addition, the peak temperature must be low enough that the packages and/or boards are not damaged. The peak temperature of the package depends on package thickness and volume and is classified in accordance with [Table 7](#) and [8](#)

**Table 7. SnPb eutectic process (from J-STD-020C)**

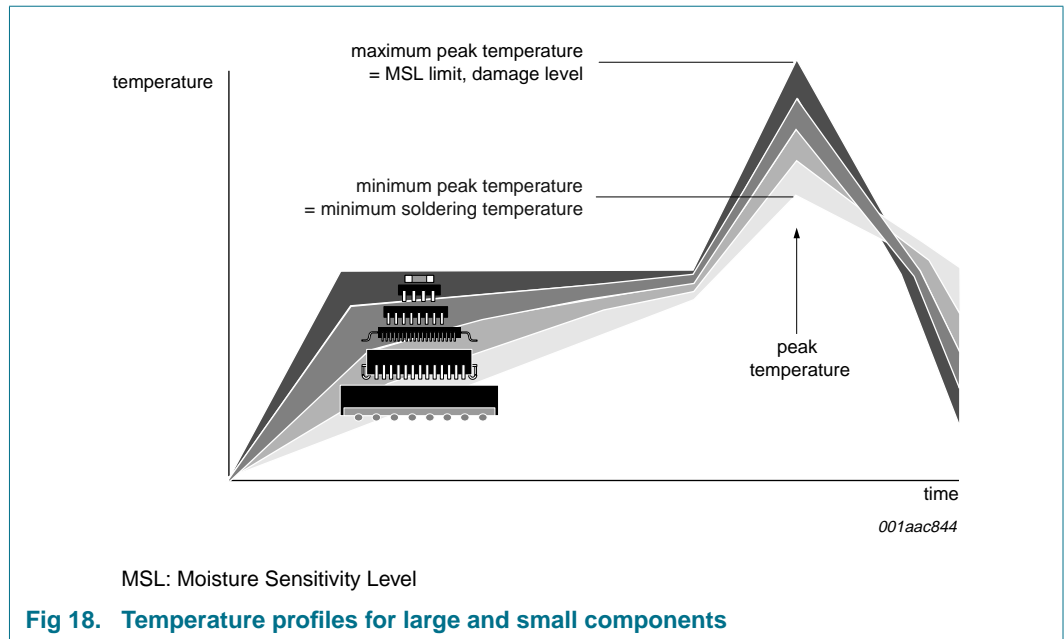
Package thickness (mm)	Package reflow temperature (°C)	
	Volume (mm <sup>3</sup> )	
	< 350	≥ 350
< 2.5	235	220
≥ 2.5	220	220

**Table 8. Lead-free process (from J-STD-020C)**

Package thickness (mm)	Package reflow temperature (°C)		
	Volume (mm <sup>3</sup> )		
	< 350	350 to 2000	> 2000
< 1.6	260	260	260
1.6 to 2.5	260	250	245
> 2.5	250	245	245

Moisture sensitivity precautions, as indicated on the packing, must be respected at all times.

Studies have shown that small packages reach higher temperatures during reflow soldering, see [Figure 18](#).



For further information on temperature profiles, refer to Application Note AN10365 “Surface mount reflow soldering description”.

## 16. Abbreviations

**Table 9. Abbreviations**

Acronym	Description
CMOS	Complementary Metal Oxide Semiconductor
HBM	Human Body Model
IC	Integrated Circuit
MM	Machine Model
MOS	Metal Oxide Semiconductor
MOSFET	Metal–Oxide–Semiconductor Field-Effect Transistor
MSL	Moisture Sensitivity Level
PCB	Printed-Circuit Board
RC	Resistance-Capacitance
RF	Radio Frequency
SMD	Surface Mount Device

## 17. References

- [1] **AN10365** — Surface mount reflow soldering description
- [2] **AN10832** — PCF8883 - capacitive proximity switch with auto-calibration
- [3] **IEC 60134** — Rating systems for electronic tubes and valves and analogous semiconductor devices
- [4] **IEC 61340-5** — Protection of electronic devices from electrostatic phenomena
- [5] **IPC/JEDEC J-STD-020D** — Moisture/Reflow Sensitivity Classification for Nonhermetic Solid State Surface Mount Devices
- [6] **JESD22-A114** — Electrostatic Discharge (ESD) Sensitivity Testing Human Body Model (HBM)
- [7] **JESD22-A115** — Electrostatic Discharge (ESD) Sensitivity Testing Machine Model (MM)
- [8] **JESD78** — IC Latch-Up Test
- [9] **JESD625-A** — Requirements for Handling Electrostatic-Discharge-Sensitive (ESDS) Devices
- [10] **NX3-00092** — NXP store and transport requirements
- [11] **UM10370** — PCF8883 evaluation board

## 18. Revision history

**Table 10.** Revision history

Document ID	Release date	Data sheet status	Change notice	Supersedes
PCF8883_1	20091016	Product data sheet	-	-

## 19. Legal information

### 19.1 Data sheet status

Document status <sup>[1][2]</sup>	Product status <sup>[3]</sup>	Definition
Objective [short] data sheet	Development	This document contains data from the objective specification for product development.
Preliminary [short] data sheet	Qualification	This document contains data from the preliminary specification.
Product [short] data sheet	Production	This document contains the product specification.

[1] Please consult the most recently issued document before initiating or completing a design.

[2] The term 'short data sheet' is explained in section "Definitions".

[3] The product status of device(s) described in this document may have changed since this document was published and may differ in case of multiple devices. The latest product status information is available on the Internet at URL <http://www.nxp.com>.

### 19.2 Definitions

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