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PCF8885

Capacitive 8-channel touch and proximity sensor with auto-calibration and very low power consumption

Rev. 3 — 17 March 2014

Product data sheet

1. General description

The integrated circuit PCF8885 is a capacitive 8-channel touch and proximity sensor that uses a patented (EDISEN) method to detect a change in capacitance on remote sensing plates. Changes in the static capacitances (as opposed to dynamic capacitance changes) are automatically compensated using continuous auto-calibration. Remote sensing plates (for example, conductive foils) can be connected to the IC¹ using coaxial cable. The eight input channels operate independently of each other. There is also a built-in option for a matrix arrangement of the sensors: interrupt generation only when two channels are activated simultaneously, suppression of additional channel outputs when two channels are already active.

2. Features and benefits

- Dynamic touch and proximity sensor with 8 sensor channels
- Support for matrix arrangement of sensors
- Sensing plates can be connected remotely
- Adjustable response time
- Adjustable sensitivity
 - ◆ Continuous auto-calibration
 - ◆ Digital processing method
 - ◆ Can cope with up to 6 mm of acrylic glass
- Direct and latching switch modes
- I²C Fast-mode Plus (Fm+) compatible interface
 - ◆ Two I²C-bus addresses
 - ◆ Cascading of two ICs possible
 - ◆ Interrupt signaling over I²C-bus
- Interrupt output
- Large voltage operating range ($V_{DD} = 2.5 \text{ V to } 5.5 \text{ V}$)
- Sleep mode ($I_{DD} < 100 \text{ nA}$)
- Low-power battery operation possible ($I_{DD} \sim 10 \text{ } \mu\text{A}$)
- Operating temperature range ($T_{amb} = -40 \text{ } ^\circ\text{C to } +85 \text{ } ^\circ\text{C}$)
- Available in TSSOP28 and SOIC28 package

1. The definition of the abbreviations and acronyms used in this data sheet can be found in [Section 22 on page 38](#).



3. Applications

- Replacing mechanical switches
- Hermetically sealed keys on a keyboard
- Switches for medical applications
- Switches for use in explosive environments
- Audio control: on/off, channel, volume
- Sliders and wheel-switches
- Vandal proof switches
- Switches in or under the upholstery, leather, handles, mats, carpets, tiles and glass
- Switches for home automation
- Use of standard metal sanitary parts (for example a tap) as switch
- Portable communication and entertainment units
- White goods control panel

4. Ordering information

Table 1. Ordering information

Type number	Package		
	Name	Description	Version
PCF8885TS	TSSOP28	plastic small outline package; 28 leads; body width 4.4 mm	PCF8885TS

4.1 Ordering options

Table 2. Ordering options

Product type number	Orderable part number	Sales item (12NC)	Delivery form	IC revision
PCF8885TS/1	PCF8885TS/1,118	935296171118	tape and reel, 13 inch	1

5. Marking

Table 3. Marking codes

Type number	Marking code
PCF8885TS/1	PCF8885TS

6. Block diagram

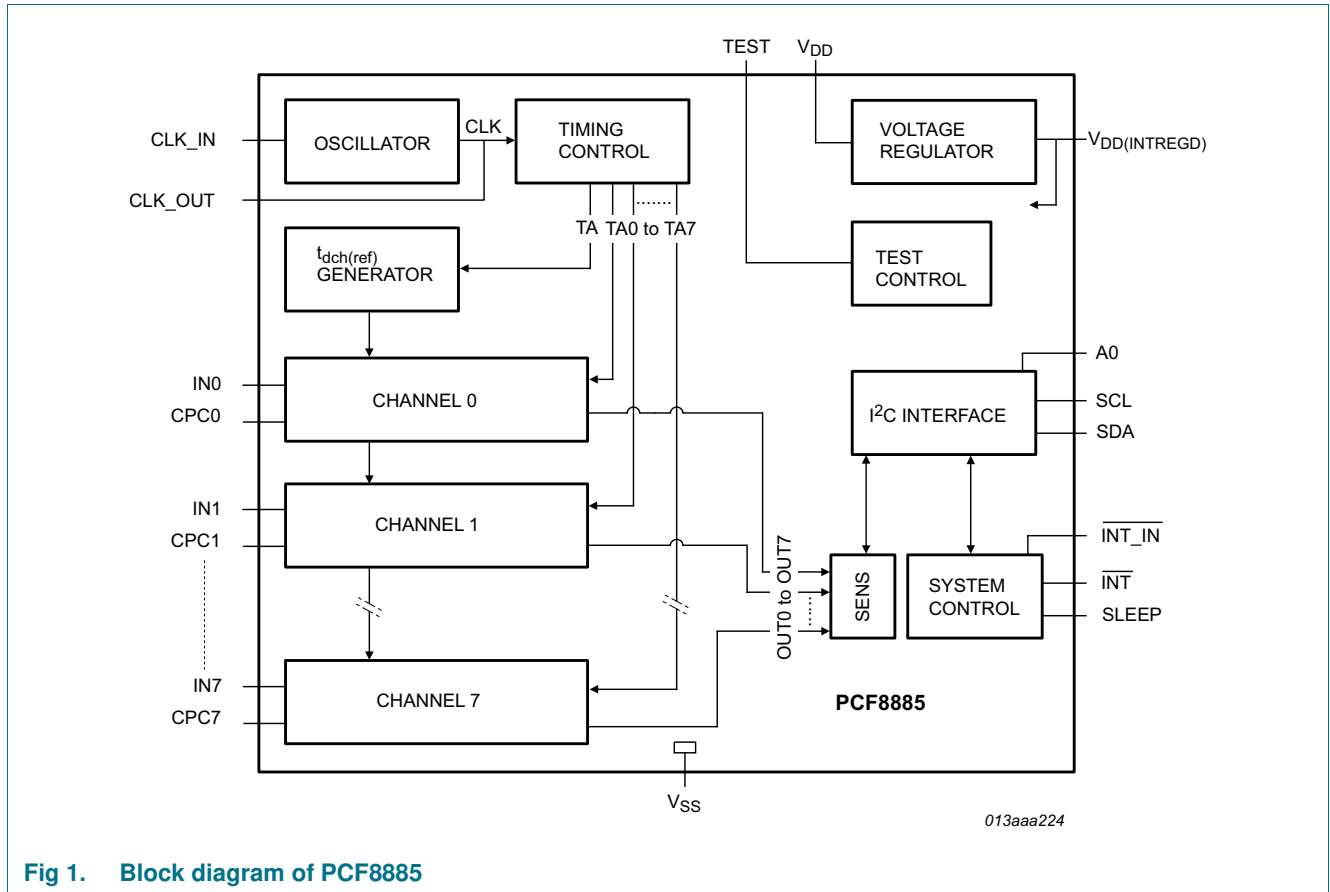
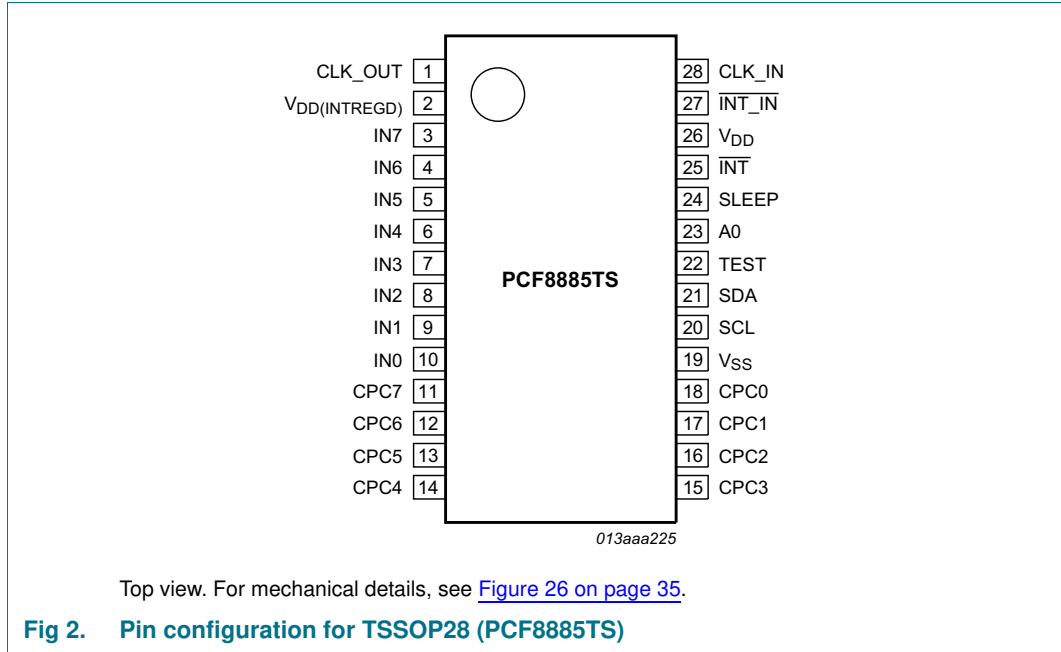


Fig 1. Block diagram of PCF8885

7. Pinning information

7.1 Pinning



7.2 Pin description

Table 4. Pin description

Input or input/output pins must always be at a defined level (V_{SS} or V_{DD}) unless otherwise specified.

Symbol	Pin	Type	Description
	PCF8885TS		
CLK_OUT	1	output	clock output for chip cascading and synchronization
$V_{DD}(\text{INTREGD})$ ^[1]	2	supply	internal regulated supply reference voltage
IN7 to IN0	3 to 10	analog input/output	sensor input, channel 0 to 7 ^[2]
CPC7 to CPC0	11 to 18	analog input/output	reservoir capacitor, channel 0 to 7 ^[2]
V_{SS}	19 ^[3]	supply	ground supply voltage
SCL	20	input	serial clock line
SDA	21	input/output	serial data line
TEST	22	input	test pin; must be connected to V_{SS}
A0	23	input	I ² C subaddress LSB ^[4]
SLEEP	24	input	sleep mode; connect to V_{DD} to force the circuit into low-power sleep mode
$\overline{\text{INT}}$	25	output	interrupt output

Table 4. Pin description ...continued

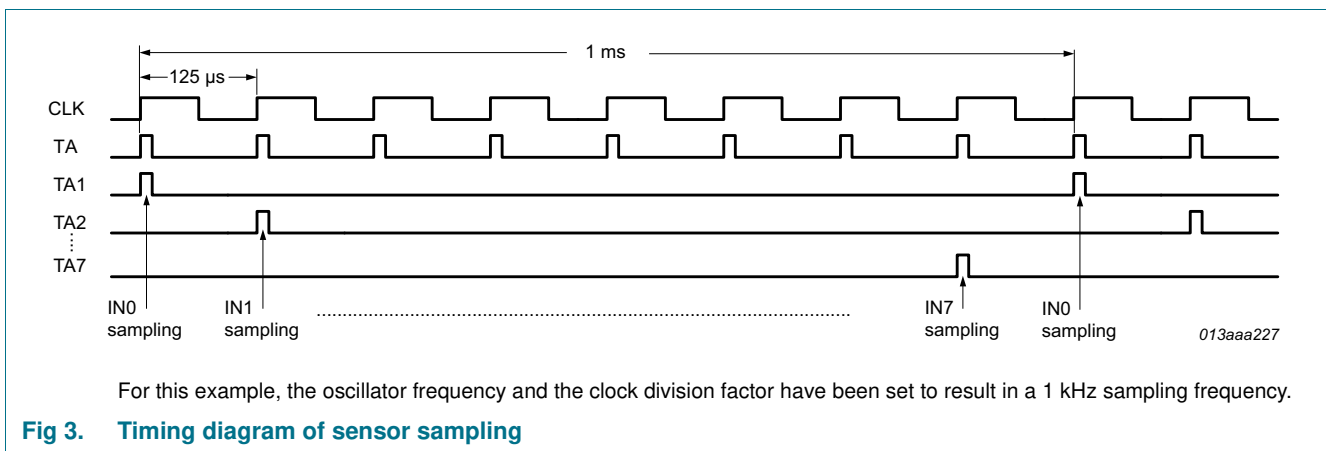
Input or input/output pins must always be at a defined level (V_{SS} or V_{DD}) unless otherwise specified.

Symbol	Pin	Type	Description
	PCF8885TS		
V_{DD}	26	supply	supply voltage
$\overline{\text{INT_IN}}$	27	input	interrupt input for chip cascading; connect to V_{DD} if not used
CLK_IN	28	input	clock input; for the secondary chip when the primary chip provides the clock signal

- [1] The internal regulated supply voltage output must be decoupled with a decoupling capacitor to V_{SS} .
- [2] If a channel is not used, the appropriate sensor input line has to be left open, the corresponding CPCn has to be connected to V_{SS} and the channel should be disabled in the MASK register (see [Table 11 on page 15](#)).
- [3] The die paddle (exposed pad) is connected to V_{SS} and should be electrically isolated.
- [4] Used to address two devices, for example: low address 3Ah, high address 3Bh.

8. Functional description

The sensing plates have to be connected to the sensor input pins IN0 to IN7. The discharge times (t_{dch}) on the sensor input pins, are compared to the discharge time ($t_{dch(ref)}$) of an internal RC timing element. The comparison is done sequentially for each sensor input pin. The RC timing circuits are periodically charged from $V_{DD(INTREGD)}$ and then discharged via a resistor to V_{SS} . The charge-discharge cycle for each channel is governed by the sampling rate (f_s). The channels are sampled sequentially, while the reference element is activated at the sampling point of each channel (see timing diagram in [Figure 3](#)).



When the voltage of an RC combination falls below the level V_{ref} , the appropriate comparator output changes. The logic following the comparators determines which comparator switched first. If the reference comparator switched first, then a pulse is given on CUP. If the sensor comparator switched first, then a pulse is given on CDN. [Figure 4](#) illustrates the functional principle of the PCF8885.

The pulses control the charge on the external capacitors C_{CPC} on pins CPC0 to CPC7. Every time a pulse is given on CUP, the capacitor C_{CPC} is charged through a current source (I_{source}) from $V_{DD(INTREGD)}$ for a fixed time causing the voltage on C_{CPC} to rise by a small increment. Likewise when a pulse occurs on CDN, capacitor C_{CPC} is discharged through a current sink (I_{sink}) towards ground for a fixed time, causing the voltage on C_{CPC} to fall by a small decrement. The voltage on C_{CPC} controls an additional current sink (I_{CPC}) that causes the capacitance attached to the input pins IN[0:7] to be discharged more quickly. This arrangement constitutes a closed loop control system, that constantly tries to equalize the discharge time (t_{dch}) with the reference discharge time ($t_{dch(ref)}$). In the equilibrium state, the discharge times are nearly equal and the pulses alternate between CUP and CDN.

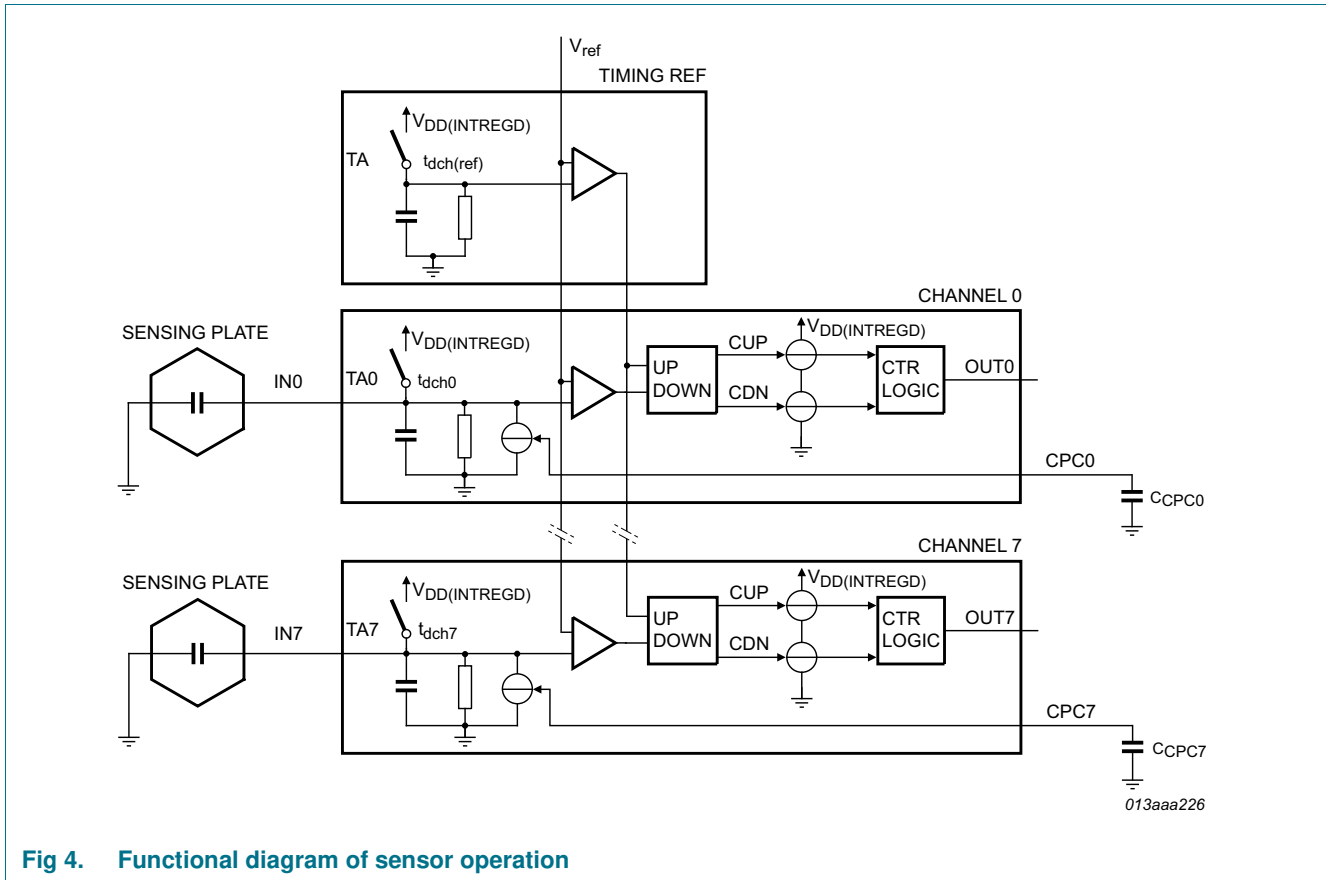


Fig 4. Functional diagram of sensor operation

The counter following this logic counts the pulses CUP or CDN respectively. The counter is reset every time the pulse sequence changes from CUP to CDN or the other way round. The outputs OUT0 to OUT7 are only activated when 64 consecutive pulses occurred on CUP. 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.

The sampling rate (f_s) is derived from the internally generated oscillator frequency. The oscillator frequency can be adjusted within a specified range by programming the CLKREG register (see [Table 10 on page 14](#)).

The status of the output signals OUT0 to OUT7 is stored in the SENS register (see [Table 9 on page 13](#)). An interrupt is generated on changes of the sensor states.

9. Commands

The operation of the PCF8885 can be controlled by 12 commands and four configuration- and status-registers (see [Section 10 on page 10](#)). Several configuration settings can be programmed using single commands without associated data transfer. The configuration register can however also be written using the write-config command. The clock and mask registers can only be programmed using the write-clock and write-mask commands.

9.1 Command overview

Table 5. Commands of PCF8885

Command	Operation code	Description	Transfer type	Reference
soft-reset	00000000	brings chip to reset state	command	Section 9.2 , Section 10.2.2.2
clear- $\overline{\text{INT}}$	00000011	deactivates interrupt generation on pin $\overline{\text{INT}}$	command	Section 10.2.2.1
sleep	00000101	enter sleep mode	command	Section 9.3
wake-up	00000110	enter active mode	command	
write-config	00110000	write configuration register	write 1 byte	Section 10.2
read-config	00110011	read configuration register	read 1 byte	
write-clock	00110101	write clock setting register	write 1 byte	Section 10.4
read-clock	00110110	read clock setting register	read 1 byte	
write-mask	00111001	write the mask register	write 1 byte	Section 10.5
read-mask	00111010	read the mask register	read 1 byte	
int-over-I ² C	00111100	put the device in int-over-I ² C mode	command	Section 10.2.2.1
read-sensor	-	read sensor state register and clears the $\overline{\text{INT}}$ line	direct read	Section 9.4 , Section 10.2.2.1

9.2 Command: soft-reset

Reset takes place during power-on of the circuit. There is no external hardware reset input.

During operation, the device can be reset using the soft-reset command. The sensor channels and all registers are reset to the default values and the int-over-I²C mode is terminated. It does not affect the state of the analog section except for those functions that are controlled by configuration bits.

9.3 Commands: Sleep and wake-up

Sleep mode is implemented to save power during periods where no sensor activity is expected or supported.

In sleep mode, most of the circuit parts are put in power-down mode, in particular all analog blocks consuming static and dynamic power. This includes the oscillator, thus no internal activity remains. Also the voltage regulator is powered down, to reduce its standalone power consumption.

During sleep mode, the register configuration is maintained and the device remains responsive to I²C commands. The charges in the CPC capacitors however cannot be guaranteed, as there is no limitation on the duration of the sleep mode. Therefore the analog part has to perform a normal start-up phase, including the fast start procedure for the CPC capacitor charging.

Sleep mode is entered when the sleep command is received from the system controller or when the SLEEP pin is set to HIGH. Resume is done by the wake-up command, or by setting the SLEEP pin to LOW.

The hardware sleep mechanism using the SLEEP pin and the software sleep mechanism using the sleep or wake-up commands are independent of each other:

- If the device was put to sleep using the sleep command, a wake-up command resumes the operation. It cannot be resumed by activating the SLEEP pin.
- If the device was put to sleep by setting pin SLEEP to HIGH, then pin SLEEP must be set to LOW to resume operation. It cannot be resumed with the wake-up command.

9.4 Command: read-sensor

The read-sensor command is the main transaction to read the actual state information of the sensor state register SENS.

If the $\overline{R/W}$ bit (LSB of the I²C slave address byte, see [Table 12 on page 20](#)) is set logic 1 the PCF8885 regards the transaction as the read-sensor command. The read-sensor command transaction supports a repeated reading of the SENS register (see [Section 10.3 on page 13](#)). When two circuits are used in a cascaded configuration, they alternately return their SENS register content in a single transaction

The protocols for the repeated read mode and the alternating read mode are described in [Section 13.7 on page 21](#).

10. Registers

The PCF8885 has four registers storing the configuration and the status information of the device.

10.1 Register overview

Table 6. Register overview

The bit position labeled as *x* is not relevant; if read, it can be either logic 0 or logic 1.

Register name	Bit								Default value	
	7	6	5	4	3	2	1	0		
CONFIG	OPM[1:0]		SWM	KM[1:0]		VROF	INTM	MSKMODE		00000000
SENS	CH[7:0]									00000000
CLKREG	CLO	CLI	x	FRQC[1:0]		FRQF[2:0]				00x01100
MASK	MSK[7:0]									11111111

10.2 Register: CONFIG

Table 7. CONFIG - configuration register bit description

Bit	Symbol	Value	Description	Reference
7 to 6	OPM[1:0]		main operation mode	Section 10.2.1.1
		00 ^[1]	stand-alone device	
		01	secondary-chip in a cascade	
		10	primary-chip in a cascade	
		11	unused	
5	SWM		switching mode	Section 10.2.1.2
		0 ^[1]	direct switching mode: sensor release clears the corresponding bit in the SENS register	
		1	latching mode: reading SENS register clears bits in the SENS register	
4 to 3	KM[1:0]		key-press mode	Section 10.2.1.3
		00 ^[1]	N-key mode: each sensor activity is reflected in the SENS register	
		01	2-key mode: only first two keys are visible in the SENS register	
		10	1-key mode: only first key-press is visible in the SENS register	
		11	unused	

Table 7. CONFIG - configuration register bit description ...continued

Bit	Symbol	Value	Description	Reference
2	VROF		voltage regulation	Section 11
		0 ^[1]	voltage regulation on	
		1	voltage regulation off	
1	INTM		interrupt generation mode	Section 10.2.2
		0 ^[1]	an interrupt is generated by each bit changed in the SENS register (press and release)	
		1	an interrupt is generated by each bit set in the SENS register (press only)	
0	MSKMODE		channel masking mode	Section 10.5.1
		0 ^[1]	normal power: masked out channels remain operational	
		1	low power: masked out channels are powered down	

[1] Default value.

All bits in this register can be written and read with the write-config and read-config commands.

10.2.1 Operating modes

10.2.1.1 Main operating modes

The PCF8885 can operate in three operating modes: as a stand-alone device or in a cascade as a primary-chip or a secondary-chip (see [Table 8](#)).

Table 8. Main operating modes

Conditions of	Main operating modes		
	Stand-alone ^[1]	Primary-chip	Secondary-chip
clock source	internal oscillator	internal oscillator	clock input
oscillator	enabled	enabled	disabled
clock output pin CLK_OUT	disabled	enabled	disabled
clock input pin CLK_IN	disabled	disabled	enabled

[1] Default operating mode after power-on.

The operating modes are implemented to support the application of two PCF8885 in the system (see [Section 13.8 on page 22](#)).

10.2.1.2 Switching modes

There is a one to one relationship between the channels IN[0:7] and the bits in the SENS register. The indication of the switching status of each channel is controlled by the two switching modes supported:

Direct mode — In direct mode, the sensor state is directly reflected in the SENS register. When the sensor is activated, the corresponding bit in the SENS register is immediately set logic 1. When the sensor is released, the bit is cleared (set logic 0) again. The bits are even cleared if the SENS register has not yet been read by the system controller.

Latching mode — In latching mode, every activated sensor sets the corresponding bit in the SENS register logic 1. When the sensor is released, the SENS register is unaffected. Reading the SENS register clears (set logic 0) those bits, whose sensor is not activated anymore.

After reset, the PCF8885 is set to direct switching mode.

10.2.1.3 Key-press modes

There are three key-press modes implemented in the PCF8885: N-key, 1-key, and 2-key mode.

N-key mode — In N-key mode, each sensor activity is reflected in register SENS according to the configured switching mode. The N-key mode is the default key-press mode after reset.

1-key mode — In 1-key mode, only the first sensor activation sets the corresponding bit in register SENS. All further activations of the other sensors are suppressed at the SENS register boundary. In this way, sensors in a keypad are masked out, which are activated accidentally because they are arranged next to the activated sensor.

The 1-key mode supports sensor matrix arrangements with two PCF8885, where one chip is attached to the columns and one to the rows (primary-chip and secondary-chip). Sensor activation sets 1 bit for the column and 1 bit for the row in the SENS register of the appropriate chip. Each activation of a sensor raises an interrupt. The system controller must handle the situation where the $\overline{\text{INT}}$ is raised before the second sensor in the matrix has been activated.

2-key mode — In 2-key mode, only the two first sensor activations set the corresponding bits in register SENS. All further activations of the other sensors are suppressed at the SENS register boundary. This mode supports in particular the matrix arrangement of sensors using only one PCF8885, as illustrated in [Figure 25 on page 33](#). In this way, sensors in a matrix are masked out, which are activated accidentally because they are arranged next to the intended sensors. This mode properly handles a delay in sensor activation due to unequal sensor capacitance or area (non-centric sensor touching, and so on) as long as the intended sensors react before sensors which are activated accidentally. In 2-key mode, the $\overline{\text{INT}}$ output is only activated after 2 bits have been set in the SENS register.

10.2.2 Interrupt generation

The PCF8885 provides two mechanisms to inform the system controller that a sensor activity has been detected.

10.2.2.1 Interrupt output $\overline{\text{INT}}$

The PCF8885 has an interrupt output, $\overline{\text{INT}}$, to flag to the system controller that a capacitive event has been detected. The controller can then fetch the sensor state by reading the SENS register over the I²C-bus.

The interrupt generation is controlled by the INTM bit in the CONFIG register (see [Table 7 on page 10](#)).

- If INTM is logic 0 (default), then the change (set or clear) of each bit in register SENS activates the $\overline{\text{INT}}$ output.
- If INTM is logic 1, then only sensor press events, resulting in bits being set logic 1 in the SENS register, activate the $\overline{\text{INT}}$ output. Sensor release events, which cause the corresponding bit in SENS to be cleared (set logic 0), do not activate the $\overline{\text{INT}}$ output.

In 2-key mode, the $\overline{\text{INT}}$ output is only activated after 2 bits have been set in the SENS register.

The interrupt is automatically cleared when the system controller reads the SENS register. Alternatively the $\overline{\text{INT}}$ can be cleared by using the clear-INT command, without reading the actual sensor state.

10.2.2.2 Interrupt over the I²C-bus

In applications where the sensing plates are remote from the microcontroller, the interrupt line can be saved by enabling the interrupt over I²C-bus.

The PCF8885 provides the feature of interrupt over the I²C-bus. The PCF8885 then behaves like an I²C master with restricted functionality. The interrupt is signaled by setting a START condition immediately followed by a STOP condition. It is illustrated in Figure 5. No further I²C master capabilities are supported.

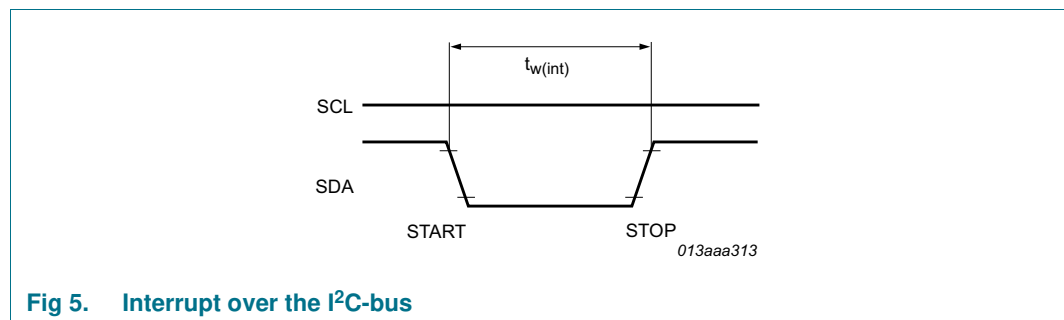


Fig 5. Interrupt over the I²C-bus

The system controller has to detect the START-STOP condition and react accordingly.

The interrupt over the I²C-bus can be enabled with the int-over-I²C command and disabled with the soft-reset command.

In interrupt over the I²C-bus mode, the functionality of the $\overline{\text{INT}}$ output continues to work as described in Section 10.2.2.1.

10.3 Register: SENS

Table 9. SENS - sensor state register bit description

Bit	Symbol	Value	Description
7 to 0	CH[7:0]	00000000 ^[1] to 11111111	sensor state of the respective channels IN7 to IN0

[1] Default value.

All bits in this register are read-only and can be read with the read-sensor command (see Section 9.4).

10.4 Register: CLKREG

Table 10. CLKREG - clock setting register bit description

Bit	Symbol	Value	Description
7	CLO		CLK_OUT switch
		0 ^[1]	CLK_OUT disabled (unless IC is in primary-chip mode)
		1	CLK_OUT enabled
6	CLI		CLK_IN switch
		0 ^[1]	CLK_IN disabled (unless IC is in secondary-chip mode)
		1	CLK_IN enabled, internal oscillator is powered down
5	-	- ^[2]	unused
4 to 3	FRQC[1:0]		clock frequency, coarse setting
		00	$f_{clk} = f_{osc}/64$
		01 ^[1]	$f_{clk} = f_{osc}/16$
		10	$f_{clk} = f_{osc}/4$
		11	$f_{clk} = f_{osc}$
2 to 0	FRQF[2:0]		oscillator tuning
		000	$f_{osc} = 0.5 \times f_{osc(nom)}$
		001	$f_{osc} = 0.625 \times f_{osc(nom)}$
		010	$f_{osc} = 0.75 \times f_{osc(nom)}$
		011	$f_{osc} = 0.875 \times f_{osc(nom)}$
		100 ^[1]	$f_{osc} = 1 \times f_{osc(nom)}$
		101	$f_{osc} = 1.25 \times f_{osc(nom)}$
		110	$f_{osc} = 1.5 \times f_{osc(nom)}$
		111	$f_{osc} = 1.75 \times f_{osc(nom)}$

[1] Default value.

[2] Should always be written with logic 0 and if read, it can be either logic 0 or logic 1.

All bits in this register can be written and read with the write-clock and read-clock commands.

10.4.1 Clock generation and frequency adjustment

The PCF8885 contains an integrated oscillator as main clock source. With the values of FRQF[2:0], the oscillator frequency can be tuned (see [Equation 1](#)).

$$f_{osc} = m \times f_{osc(nom)} \quad (1)$$

The values of m can be varied in the range $0.5 \leq m \leq 1.75$, where $m = 1.0$ corresponds to the default value of $FRQF[2:0] = 100$.

The internal clock frequency (f_{clk}) is derived from the oscillator frequency with [Equation 2](#):

$$f_{clk} = f_{osc} / n \tag{2}$$

where the values for n are 1, 4, 16, or 64 and can be selected with $FRQC[1:0]$. The sensor sampling frequency (f_s) is derived from the internal clock frequency with [Equation 3](#):

$$f_s = f_{clk} / 8 \tag{3}$$

The eight sensors are sampled sequentially, which results in a default sensor sampling rate f_s .

In secondary-chip mode, the internal clock generator is stopped, and the circuit is clocked from the CLK_IN input pin.

The tuning of the oscillator frequency and the programmable clock divider (see [Figure 6](#)) allows changing the sensor sampling rate, the adjustment of the reaction time and the power consumption of the PCF8885 over a wide range.

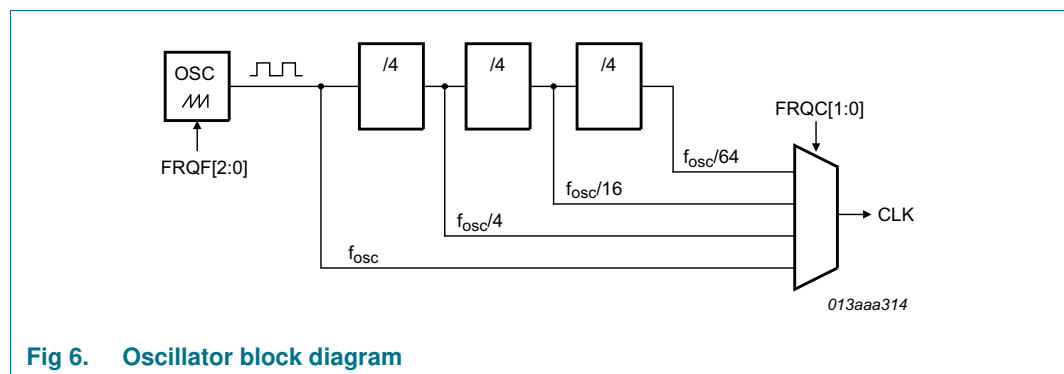


Fig 6. Oscillator block diagram

10.5 Register: MASK

Table 11. MASK - channel enable mask register bit description

Bit	Symbol	Value	Description
7 to 0	MSK[7:0]	00000000 to 11111111 ^[1]	enable or disable the respective sensor channels IN0 to IN7
		0	sensor channel is disabled
		1	sensor channel is enabled

[1] Default value.

All bits in this register can be written and read with the write-mask and read-mask commands.

10.5.1 Channel masking

The channel masking register MASK allows individual sensor channels to be enabled or disabled for particular applications or certain modes (for example only the on/off sensor should be active).

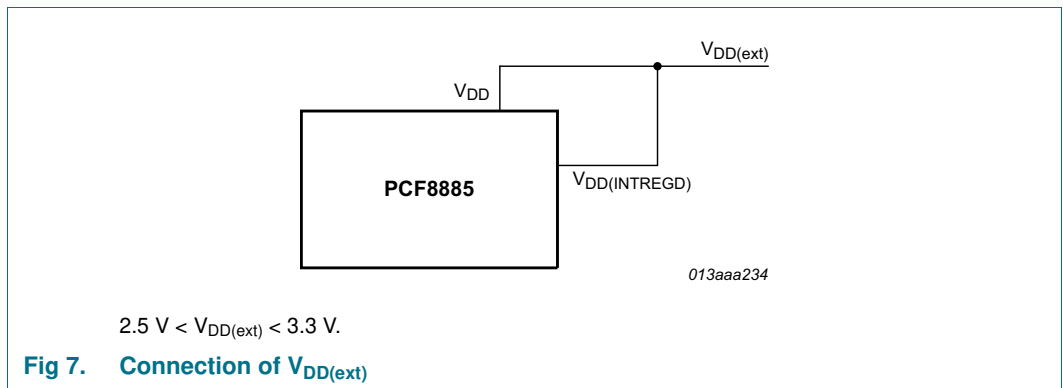
- When bit MSKMODE in register CONFIG (see [Table 7](#)) is set logic 0, then the disabled channels are continuously sampled, but switching events are not reflected in register SENS and do not cause interrupts.
- When bit MSKMODE in register CONFIG (see [Table 7](#)) is set logic 1, only channels which are enabled are sampled. Reducing the number of sampled channels also reduces the power consumption.

When a channel becomes newly enabled, the fast start-up method (see [Section 12](#)) is used to reach the functional state quickly.

11. Power architecture

The circuit has an integrated voltage regulator, supplied by pin V_{DD} . The regulator provides an internal $V_{DD(INTREGD)}$ supply of nominally 2.8 V.

If a stable and noise free external supply voltage with $2.5\text{ V} < V_{DD(ext)} < 3.3\text{ V}$ is available in the system, $V_{DD(INTREGD)}$ can be provided from an external source (see Figure 7). In this case V_{DD} and $V_{DD(INTREGD)}$ must both be connected to $V_{DD(ext)}$. To reduce the current consumption, the internal voltage regulator should be shut down by setting bit V_{ROF} logic 1 (see Table 7 on page 10).



While the analog part of the circuit is powered from $V_{DD(INTREGD)}$, the I²C interface and the registers are powered from V_{DD} . Therefore the I²C interface remains accessible in sleep mode, and the register values are maintained when $V_{DD(INTREGD)}$ is powered off.

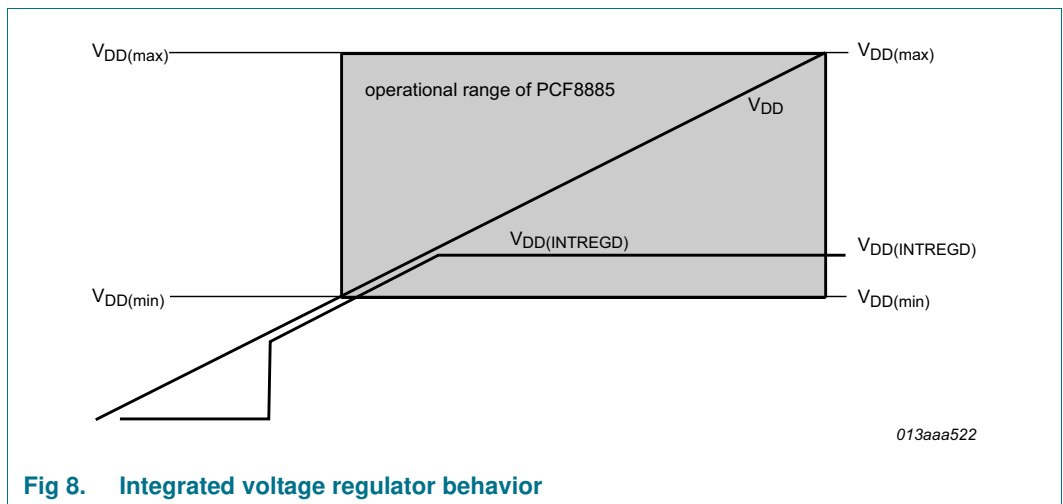


Figure 8 illustrates the behavior of the integrated voltage regulator. The gray area covers the operational range of the PCF8885. The analog part of the circuit and the switch logic is powered from $V_{DD(INTREGD)}$. The I²C interface and the registers are powered from V_{DD} . Therefore the I²C interface remains accessible in sleep mode, and the register values are maintained when $V_{DD(INTREGD)}$ is powered off.

12. Start-up procedure

After power-on the registers in the V_{DD} domain are reset, which includes the VROF bit controlling the voltage regulator. The regulator is therefore enabled, and the $V_{DD(INTREGD)}$ domain is powered on. As soon as a sufficient $V_{DD(INTREGD)}$ level is reached, the Power-On Reset (POR) is released.

After release of the POR in the $V_{DD(INTREGD)}$ domain, the circuit starts with the sensor sampling in the fast start mode (increased charge-pump currents quickly charge the CPC capacitors close to their target value). As soon as the capacitor voltages are close to the target value, the fast start phase is terminated, and the capacitors are charged in fine steps to the final value. When this state is reached, the logic enables the up and down counters, and the sensors are operational.

This start-up mechanism is executed independently for each channel.

13. Characteristics of the I²C-bus

The PCF8885 has an I²C serial interface which operates as a slave receiver or transmitter. SDA and SCL are the data I/O and clock lines for the serial I²C Interface. SDA is used as an input or as an open-drain output. SDA is actively pulled LOW and is passively held HIGH by the external pull-up resistor on the I²C-bus.

In order to provide high link robustness, the I²C interface of the PCF8885 is Fast-mode compatible and provides a robust addressing and command scheme.

13.1 Bit transfer

One data bit is transferred during each clock pulse. The data on the SDA line must remain stable during the HIGH period of the clock pulse as changes in the data line at this time are interpreted as a control signal (see [Figure 9](#)).

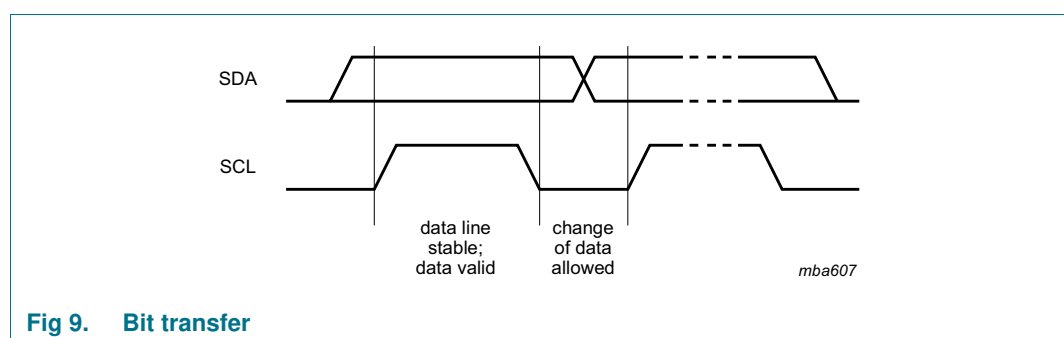


Fig 9. Bit transfer

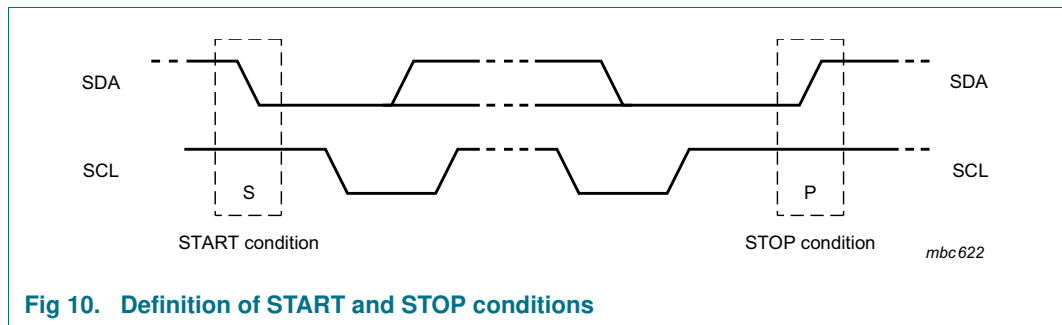
13.1.1 START and STOP conditions

Both data and clock lines remain HIGH when the bus is not busy.

A HIGH-to-LOW change of the data line, while the clock is HIGH, is defined as the START condition (S).

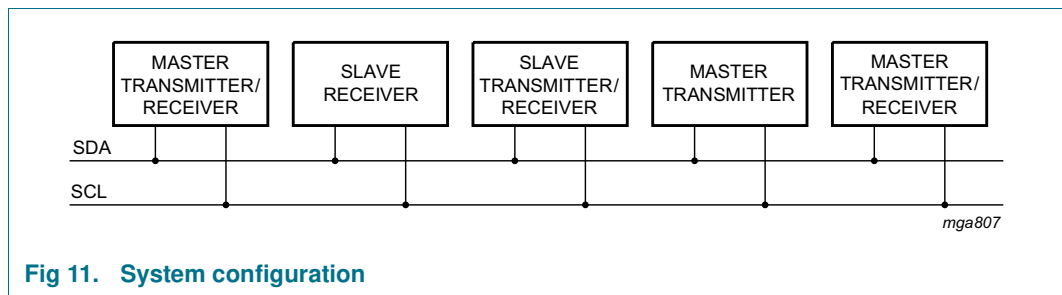
A LOW-to-HIGH change of the data line, while the clock is HIGH, is defined as the STOP condition (P).

The START and STOP conditions are shown in [Figure 10](#).



13.2 System configuration

A device generating a message is a transmitter; a device receiving a message is the receiver. The device that controls the message is the master; and the devices which are controlled by the master are the slaves. The system configuration is shown in [Figure 11](#).

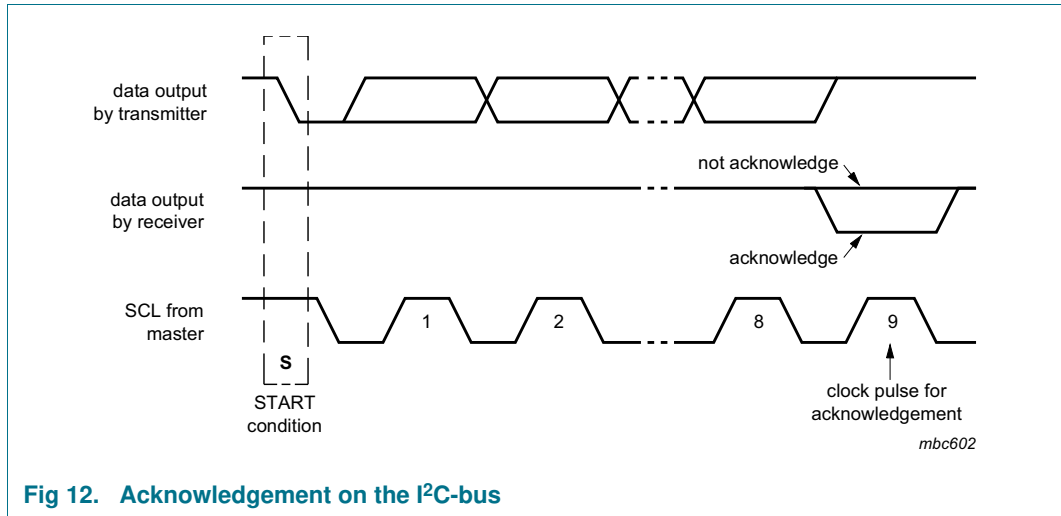


13.3 Acknowledge

The number of data bytes transferred between the START and STOP conditions from transmitter to receiver is unlimited. Each byte of 8 bits is followed by an acknowledge cycle.

- A slave receiver, which is addressed, must generate an acknowledge after the reception of each byte.
- A master receiver must generate an acknowledge after the reception of each byte that has been clocked out of the slave transmitter.
- The device that acknowledges must pull-down the SDA line during the acknowledge clock pulse, so that the SDA line is stable LOW during the HIGH period of the acknowledge related clock pulse (set-up and hold times must be considered).
- A master receiver must signal an end of data to the transmitter by not generating an acknowledge on the last byte that has been clocked out of the slave. In this event, the transmitter must leave the data line HIGH to enable the master to generate a STOP condition.

Acknowledgement on the I²C-bus is shown in [Figure 12](#).



13.4 I²C-bus subaddress

Device selection depends on the I²C-bus slave address, on the transferred command data, and on the hardware subaddress.

Two I²C-bus slave addresses are used to address the PCF8885 (see [Table 12](#)).

Table 12. I²C slave address byte

Bit	Slave address							
	7 MSB	6	5	4	3	2	1	0 LSB
Slave address	0	1	0	0	0	0	A0	R/W

The least significant bit of the slave address is bit R/W (see [Table 13](#)).

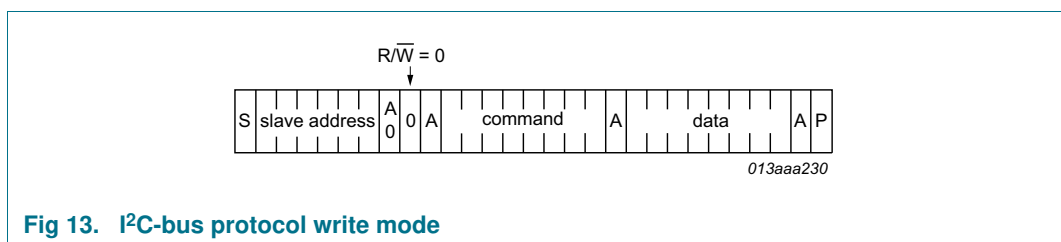
Table 13. R/W-bit description

R/W	Description
0	write data
1	read data

Bit 1 of the slave address is defined by connecting input A0 to either V_{SS} (logic 0) or V_{DD} (logic 1). Therefore, two instances of PCF8885 can be distinguished on the same I²C-bus.

13.5 I²C-bus protocol

The I²C-bus protocol is shown in [Figure 13](#). The sequence is initiated with a START condition (S) from the I²C-bus master which is followed by the slave address.



After acknowledgement, a command is sent, and after a further acknowledge a data byte is transmitted. After the last data byte, the I²C-bus master issues a STOP condition (P). Alternatively a START may be asserted to RESTART an I²C-bus access.

13.6 Fast-mode Plus (Fm+) support

The Fast-mode Plus specification is supported. Besides providing a high transmission speed, the main characteristic of Fast-mode Plus is the increased drive strength, allowing lower impedance buses to be driven, and therefore less noise sensitive. Details on the Fast-mode Plus specification are given in [Ref. 15 “UM10204”](#).

13.7 Reading sensor data

The PCF8885 supports direct reading of the sensor state from the SENS register. If - after sending the address - the R/W bit is immediately set to logic 1 without sending a command, the circuit recognizes that it must immediately return the content of the SENS register (see [Figure 14](#))

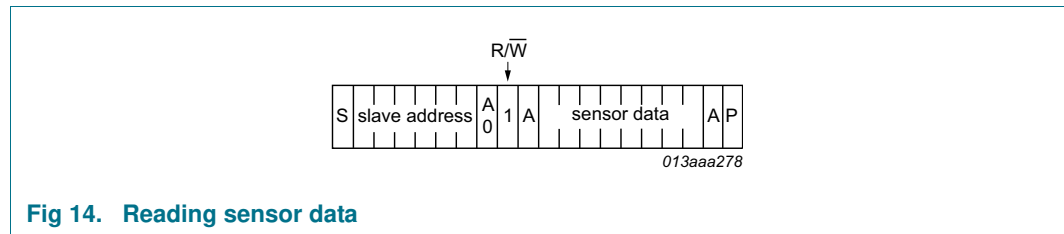


Fig 14. Reading sensor data

When the transaction, after reading the SENS register, is not terminated with a STOP bit, the PCF8885 repeatedly sends the content of SENS again. This provides a facility to observe the sensor activity continuously. This transaction is illustrated in [Figure 15](#).

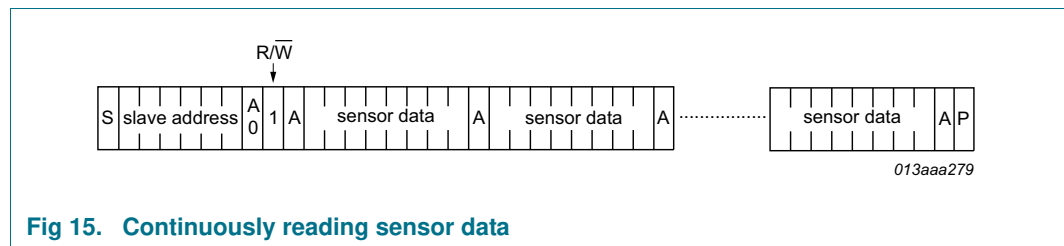


Fig 15. Continuously reading sensor data

Using two PCF8885 in a cascade (see [Section 13.8](#)), one has to be the primary-chip and the other the secondary-chip. When the direct read transaction is executed in a cascaded configuration, the primary-chip transmits its SENS content register immediately after the address byte, followed by the secondary-chip transmitting its SENS register content.

If the transaction - after reading the two SENS registers - is not terminated with a STOP bit, the primary-chip and the secondary-chip continue sending the content of the SENS registers alternately. Such a transaction is illustrated in [Figure 16](#).

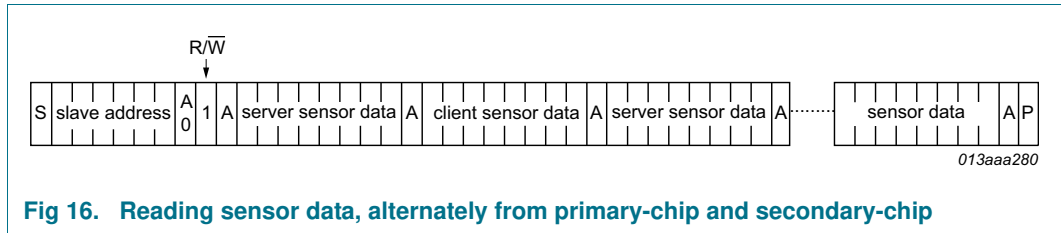


Fig 16. Reading sensor data, alternately from primary-chip and secondary-chip

It must be noted, that for this alternate data transfer only one PCF8885 has to be addressed. By definition the primary-chip must be addressed (A0 bit in the address set to logic 0). In this particular case, the secondary-chip reacts on the address of the primary-chip. For all other transactions targeting the secondary-chip, it must be properly addressed with A0 set to logic 1.

13.8 Device cascading

Two PCF8885 devices can be connected to the same I²C-bus, which facilitates up to 8 × 8 keypads.

The device provides the following features to guarantee robust operation and to simplify the system design using two devices:

- The 7-bit I²C address consists of 6 fixed bits and 1 selectable bit. The level externally applied to pin A0 (V_{DD} or V_{SS}) defines the LSB of the I²C slave address. In this way, two PCF8885 can be addressed on the same bus without the need for different hard coded I²C addresses.
- The sensor activity can be synchronized, so that interference between the sensors of the different chips is avoided. One chip is considered to be the primary-chip. It provides the sample clock on pin CLK_OUT. The other chip is considered to be the secondary-chip. It uses the clock provided by the primary-chip instead of the internal clock. The primary-chip samples the sensors on the rising edge of the internal sample clock. The CLK_IN signal is inverted to derive the sample clock in the secondary-chip. Therefore the secondary-chip samples its sensors on the negative edge of the sample clock of the primary-chip. In this way, no simultaneous sensor sampling occurs. Primary-chip or secondary-chip modes are enabled by programming the configuration register (see [Table 7 on page 10](#)).
- The interrupt signal can be cascaded. The $\overline{\text{INT}}$ output of the primary-chip can be connected to the INT_IN input of the secondary-chip. The INT output of the secondary-chip is then an OR'ed combination of the two interrupts.
- If two devices are cascaded and the int-over-I²C mode is desired, then it is sufficient to put the secondary-chip in int-over-I²C mode. The primary-chip still signals an interrupt over the INT output to the INT_IN input of the secondary-chip.

[Figure 25 on page 33](#) illustrates a typical example of an application using two PCF8885 circuits.

14. Internal circuitry

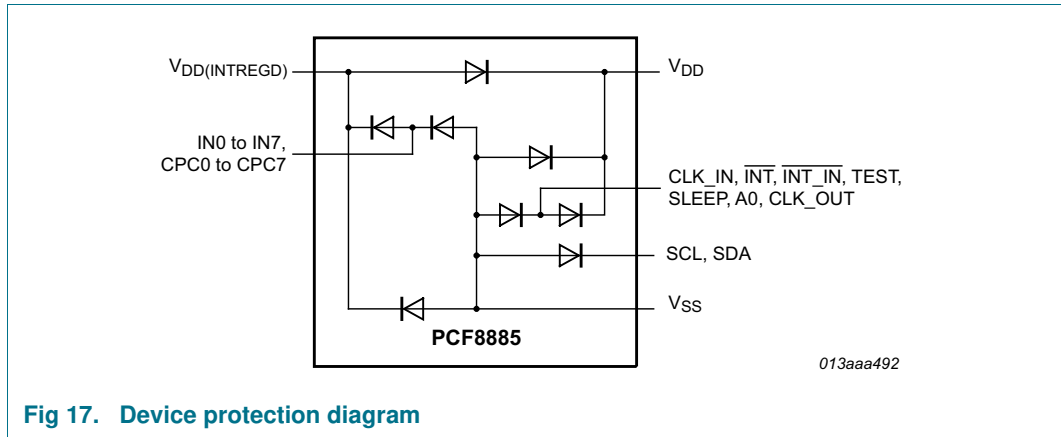


Fig 17. Device protection diagram

15. Safety notes

CAUTION



This device is sensitive to ElectroStatic Discharge (ESD). Observe precautions for handling electrostatic sensitive devices.

Such precautions are described in the *ANSI/ESD S20.20*, *IEC/ST 61340-5*, *JESD625-A* or equivalent standards.

16. Limiting values

Table 14. Limiting values

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

Symbol	Parameter	Conditions	Min	Max	Unit	
V _{DD}	supply voltage		-0.5	+8.0	V	
V _{DD(INTREGD)}	internal regulated supply voltage		-0.5	+6.5	V	
V _I	input voltage	on all input pins	-0.5	+6.5	V	
I _{SS}	ground supply current		-50	+50	mA	
I _{SDA}	current on pin SDA		-30	+30	mA	
I _{I/O(n)}	input/output current on any other pin		-10	+10	mA	
P _{tot}	total power dissipation		-	100	mW	
V _{ESD}	electrostatic discharge voltage	HBM	[1]	-	±2000	V
		CDM	[2]	-	±750	V
I _{Iu}	latch-up current		[3]	-	100	mA
T _{stg}	storage temperature		[4]	-60	+125	°C
T _{amb}	ambient temperature	operating device		-40	+85	°C

[1] Pass level; Human Body Model (HBM) according to [Ref. 10 "JESD22-A114"](#).

[2] Pass level; Charged-Device Model (CDM), according to [Ref. 11 "JESD22-C101"](#).

[3] Pass level; latch-up testing, according to [Ref. 12 "JESD78"](#) at maximum ambient temperature (T_{amb(max)}).

[4] According to the store and transport requirements (see [Ref. 17 "UM10569"](#)) the devices have to be stored at a temperature of +8 °C to +45 °C and a humidity of 25 % to 75 %.

17. Static characteristics

Table 15. Static characteristics

$V_{DD} = 2.5\text{ V to }5.5\text{ V}$, $V_{SS} = 0\text{ V}$, $T_{amb} = -40\text{ °C to }+85\text{ °C}$; unless otherwise specified; min and max values are not production tested, but verified on sampling basis.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{DD}	supply voltage		2.5	-	5.5	V
$V_{DD(ext)}$	external supply voltage	V_{DD} connected to $V_{DD(INTREGD)}$; internal regulator disabled	2.5	-	3.3	V
$V_{DD(INTREGD)}$	internal regulated supply voltage		[1]			
			2.5	2.9	3.3	V
		external supplied	2.5	-	3.3	V
I_{DD}	supply current	idle state; $f_s = 1\text{ kHz}$	[2]	10	20	μA
$I_{DD(sleep)}$	sleep mode supply current		-	100	500	nA
Digital inputs (CLK_IN, A0, INT_IN, TEST)						
V_{IL}	LOW-level input voltage		V_{SS}	-	$0.3V_{DD}$	V
V_{IH}	HIGH-level input voltage		$0.7V_{DD}$	-	V_{DD}	V
Digital outputs (INT, CLK_OUT)						
V_{OL}	LOW-level output voltage	$I_O = 0.5\text{ mA}$	V_{SS}	-	$0.2V_{DD}$	V
V_{OH}	HIGH-level output voltage	$I_O = 0.5\text{ mA}$	$0.8V_{DD}$	-	V_{DD}	V
Analog pins (IN0 to IN7 and CPC0 to CPC7)						
V_{CPC}	voltage on pin CPC	usable control range	$V_{SS} + 0.5$	-	$V_{DD(INTREGD)} - 0.5$	V
C_{in}	input capacitance	sensing plate and parasitic	10	-	40	pF
I²C interface pins (SDA, SCL)						
V_{IL}	LOW-level input voltage		-0.5	-	$0.3V_{DD}$	V
V_{IH}	HIGH-level input voltage		$0.7V_{DD}$	-	5.5	V
I_{OL}	LOW-level output current	$V_{DD} = 5.0\text{ V}$; $V_{OL} = 0.4\text{ V}$	20	-	-	mA
I_L	leakage current		[3]	0	-	μA
C_i	capacitance for each I/O pin		-	-	10	pF
External components						
C_{CPC}	capacitance on pin CPC		[4]	100	470	nF
C_{dec}	decoupling capacitance	on pins $V_{DD(INTREGD)}$ and V_{DD} ; ceramic chip capacitor	-	100	-	nF

[1] See [Figure 8](#) for an illustration of the voltage regulation behavior and the related parameters.

[2] Idle state is the steady state after completed power-on, without any mode change and without any activity on the sensor plates, and the voltages on the reservoir capacitors C_{CPC} are settled.

[3] In case of an ESD event, the value may increase slightly.

[4] The insulation resistance of the capacitor should be at least 5 G Ω .