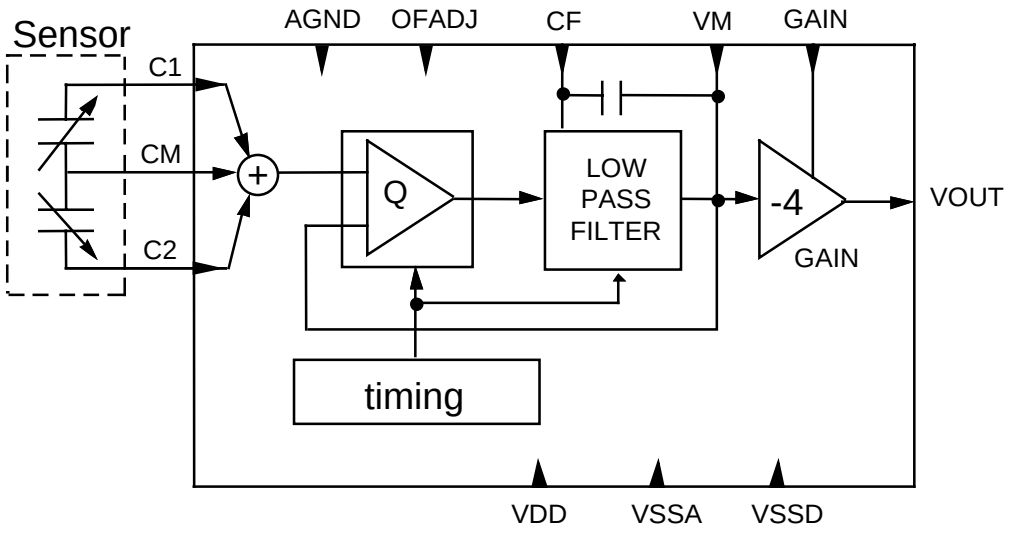
XEMICS

XE2003
Datasheet



XE2003

Capacitive Sensor Interface Circuit with Gain and Offset Adjustment

General Description

The XE2003 is a CMOS circuit designed to interface with capacitive-type sensors, such as pressure sensors, accelerometers, capacitive microphones and humidity sensors. The interface circuit is compact and easy-to-use since no external components are needed for a default setting of parameters. The low-noise low-drift design enables high precision measurements from DC up to the kHz range.

A high maximum sensitivity of 200 mV/pF can be obtained using a sensor with two nominal capacitances of 25 pF. The circuit is based on a charge compensation feedback loop. This approach guarantees a linear and low-drift transfer between a differential capacitance at the input and the analog output voltage.

For sensors with only one varying capacitance, an additional fixed capacitance with an equal nominal value can be used to form a quasi-differential sensor. The gain and offset adjustment can be used for adjustment of the sensor's sensitivity and offset.

Key Product Features

- Maximum sensitivity of 200 mV/pF
- Linear response to differential capacitances
- Designed for low drift & low noise
- Gain and offset adjustment possibility
- Dual ± 2.5 Volts or single 5 Volts power supply
- Low power consumption (17 mW max at 5 Volts)
- Frequency bandwidth DC to 17 kHz
- Output load on analog output: 50 pF and/or 10 kΩ
- Available in DIL16 (XE2003D), SO16 (XE2003S) or dice

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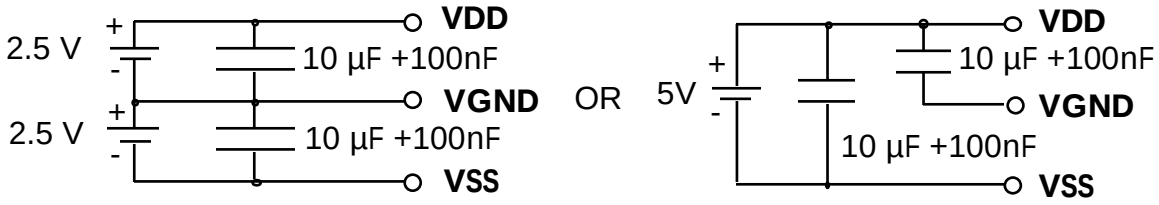
XE2003

Capacitive Sensor Interface Circuit

TYPICAL APPLICATION

A typical application of the XE2003 circuit is interfacing a sensor that is composed of two active capacitances that vary in a differential way.

The figure shows the simple connection of the circuit, with the optional Cfext. The supply voltages can be taken from a single 5 Volt source or two 2.5 Volt sources. OFADJ must be connected to AGND when the offset adjustment option is not used. VOUT must be measured with respect to AGND.



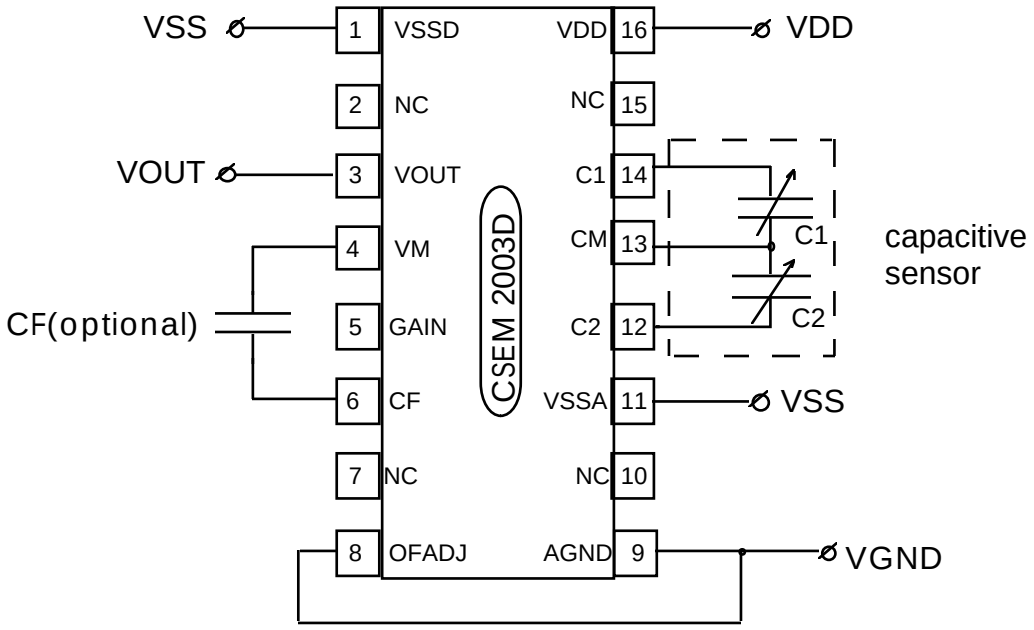


Fig. 3: Typical Connections of XE2003D circuit in DIL16 version without adjustment

XE2003

Capacitive Sensor Interface Circuit

PIN DESCRIPTION DIL16 and SO16 PACKAGE

DIL16 Pinout	SO16 Pinout	Name	Description
1	1	VSSD	Digital negative supply voltage
3	4	VOUT	Output of the interface circuit after gain stage
4	5	VM	Unbuffered output of the charge compensation loop
5	6	GAIN	Gain adjustment
6	7	CF	A capacitance Cfext for bandwidth adjustment may be connected between pins CF and VM
8	8	OFADJ	Offset adjustment or connected to AGND
9	9	AGND	Internally generated GROUND signal (R_{int} = 3kΩ). Its value is 0.5(VDD+VSSA)
11	10	VSSA	Analog negative supply voltage
12	11	C2	To be connected to the lower sensor electrode
13	12	CM	To be connected to the common sensor electrode
14	13	C1	To be connected to the upper sensor electrode
16	16	VDD	Positive supply voltage
2,7,10,15	2,3,14,15	NC	Not connected

Electrical Characteristics

(VSS=VSSA=VSSD, VDD-VSS=5V, Temperature = -40..85 °C, C1 = C2 = 50 pF unless otherwise stated)

Characteristic	Min	Type	Max	Unit
Sensor capacitances total value (C1+C2)	24		110	pF
Maximum capacitances relative difference (C1-C2)/(C1+C2)			±15	%
VOUT output dynamic range, measured with respect to AGND			±1.5	V
Gain (without trimming)	-3.75	-4	-4.25	
Offset voltage in VOUT, measured with respect to AGND.(without trimming)			±50	mV
Offset drift at VOUT output		±100	±150	μV/°C
White noise spectral density at VOUT, (de-coupled supplies).		-113	-110	dBV/√Hz
Flicker noise spectral density at VOUT, measured at 1 kHz (decoupled supplies)			-125	dBV/√Hz
Slope of flicker noise			-0.69	
THD measured at VOUT (VOUT=2V_p, f<10kHz)			-57	dB
External Cfext capacitance value	0		3	nF
External resistive load on VOUT	10			kΩ
External capacitive load on VOUT			50	pF
Start-up time		50	70	ms

OPERATING INFORMATION

Voltage output

The XE2003 interface circuit is a stand-alone IC, and converts the difference of two capacitances, relative to their sum, into an analog voltage. The ideal DC relationship between the input and output variables is:

$$OUT = -4Vo\frac{C1-C2}{C1+C2}$$

where:

VOUT is the output voltage, measured relative to AGND.

C1, C2 are the associated capacitances of the connected sensor.

Vo is half the supply voltage: 0.5·(VDD-VSSA), typically 2.5 V.

Bandwidth control

The transfer function of the circuit can be characterised as a first order low pass filter. The bandwidth of the equivalent filter may be programmed by inserting an optional external capacitance C_{fext} between pin VM and pin CF.

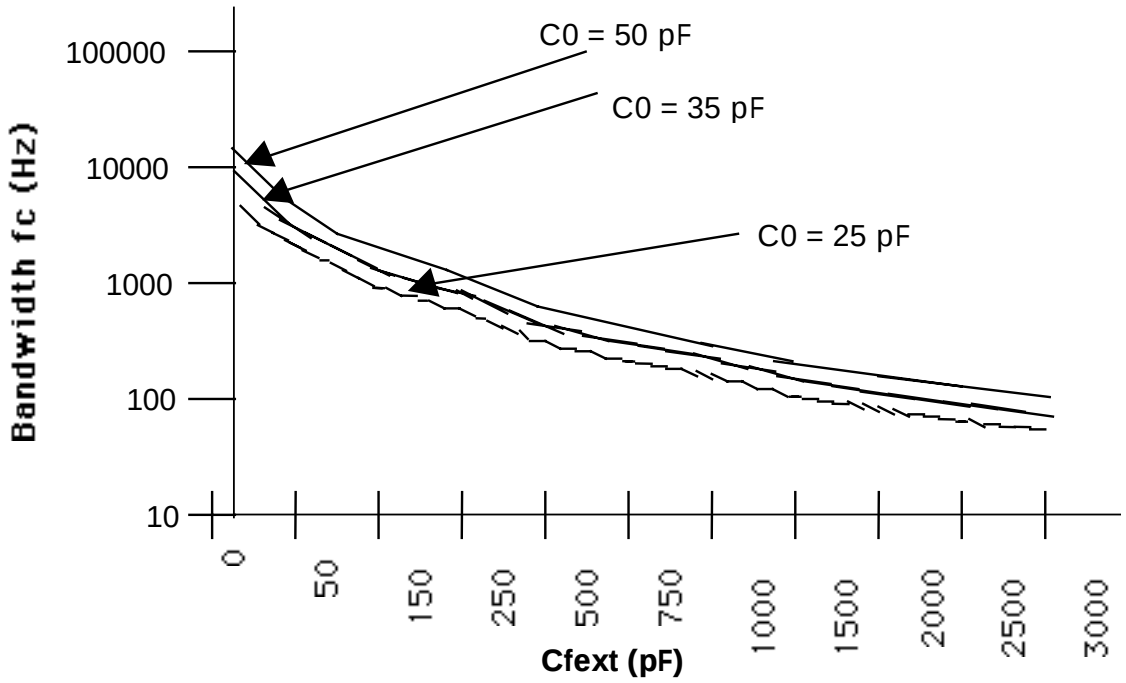


Fig.2: Band-width in function of external capacitance

An exact value for the bandwidth f_C (Hz) can be calculated from the following equation:

$$f_C = \frac{f_S}{\pi}\cdot\frac{1}{2.77\cdot\left(\frac{37+Cfext}{Co}\right)-1}$$

where:

fs is the internal loop clock frequency. Typically, fs=57 kHz at 25°C and VDD-VSSA=5 Volts.

Cfext is the optional external capacitance between pin CF and VM. The value is to be given in pF.

C0 is the nominal capacitance value of the connected sensor. We suppose that C0=C1=C2. The value is to be given in pF.

GAIN AND OFFSET ADJUSTMENT

Offset adjustment

The offset of sensor and circuit can be adjusted by applying a voltage to pin "OFADJ". The voltage can typically take values between 0 and ±1 Volt (with respect to VGND). The gain V_{OFFSET}/V_{OFADJ} varies from 1 (C1 and C2 min) to 0.5 (C1 and C2 max).A simple way to generate this voltage is using a variable resistor connected between VDD and VSS. During testing, a programmable voltage source referenced to VGND can be used. If the offset correction is not used, pin "OFADJ" must be connected to VGND.

Gain adjustment

The pin VM gives the **unbuffered** output voltage of the charge compensation loop:

$$M = 0.5 \cdot (VDD - VSS) \cdot \frac{C1 - C2}{C1 + C2}$$

The default gain factor of -4 (inverting amplifier) between the output VM and VOUT can be modified by connecting resistors R1 and R2 in parallel with integrated resistors 4*Rint and Rint, respectively (Rint = 14 kΩ), see Fig. 4 below.
If the nominal gain factor is denoted by G_{NOM}, then the modified gain, G_{MOD} factor can be found as:

$$G_{MOD} = G_{NOM} \cdot \left(\frac{1+\alpha_2}{1+\alpha_1}\right) \cdot \left(\frac{\beta+1+\alpha_1}{\beta+1+\alpha_2}\right)$$

$$\approx G_{NOM} \cdot \left(1 + \frac{\beta}{\beta+1}\alpha_2 - \frac{\beta}{\beta+1}\alpha_1\right)$$

where β = Rint / R
α_1 is the relative change in R1: R1 = 4R(1+ α_1),
α_2 is the relative change in R2: R2 = R(1+ α_2),
R is the nominal value of the external resistor R2,

The precision obtained depends on the precision of tuning R1 and/or R2. The maximum values for α_1 and α_2 are ±10 % .

Typical value could be 5.6 kΩ ± 10% for R1 and 1.4 kΩ ± 10% for R2 (β=10).

This feature is mainly used for adjustment of the gain of a module containing a sensor and the XE2003 circuit.

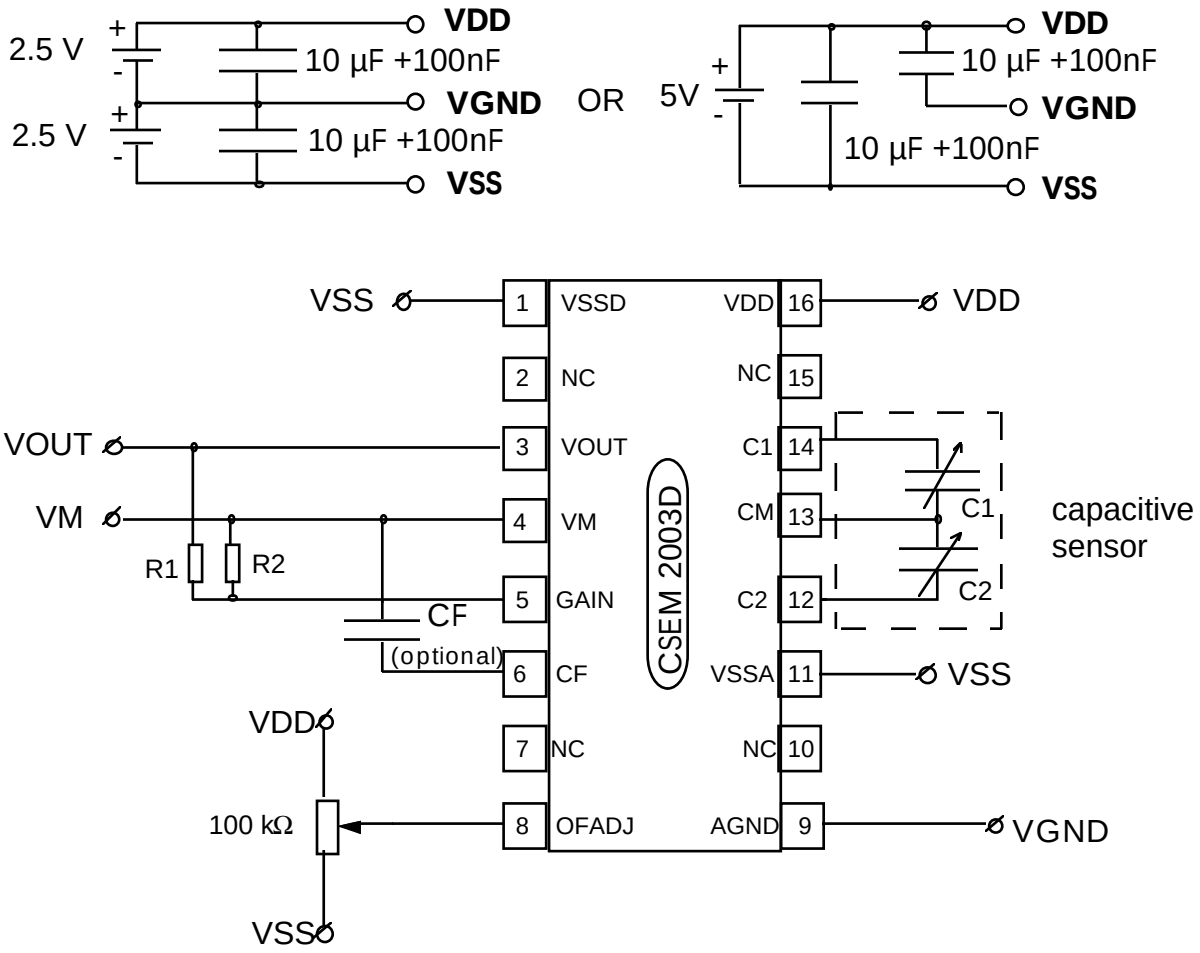


Fig. 4: Connection of XE2003D circuit in DIL16 version with gain and offset adjustment

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