FDC1004 4-Channel Capacitance-to-Digital Converter for Capacitive Sensing Applications

1 Features

- Input range: ±15pF
- Measurement resolution: 0.5fF
- Maximum offset capacitance: 100pF
- Programmable output rates: 100/200/400 S/s
- Maximum shield load: 400pF
- Supply voltage: 3.3V
- Temp range: –40° to 125°C
- Current consumption:
  - Active: 750µA
  - Standby: 29µA
- Interface: I^2C
- Number of channels: 4

2 Applications

- Proximity sensors
- Gesture recognition
- Automotive door / kick sensors
- Automotive rain sensors
- Remote and direct liquid level sensors
- High-resolution metal profiling
- Rain / fog / ice / snow sensors
- Material size detection
- Material stack height

3 Description

Capacitive sensing with grounded capacitor sensors is a very low-power, low-cost, high-resolution contact-less sensing technique that can be applied to a variety of applications ranging from proximity sensing and gesture recognition to material analysis and remote liquid level sensing. The sensor in a capacitive sensing system is any metal or conductor, allowing for low cost and highly flexible system design.

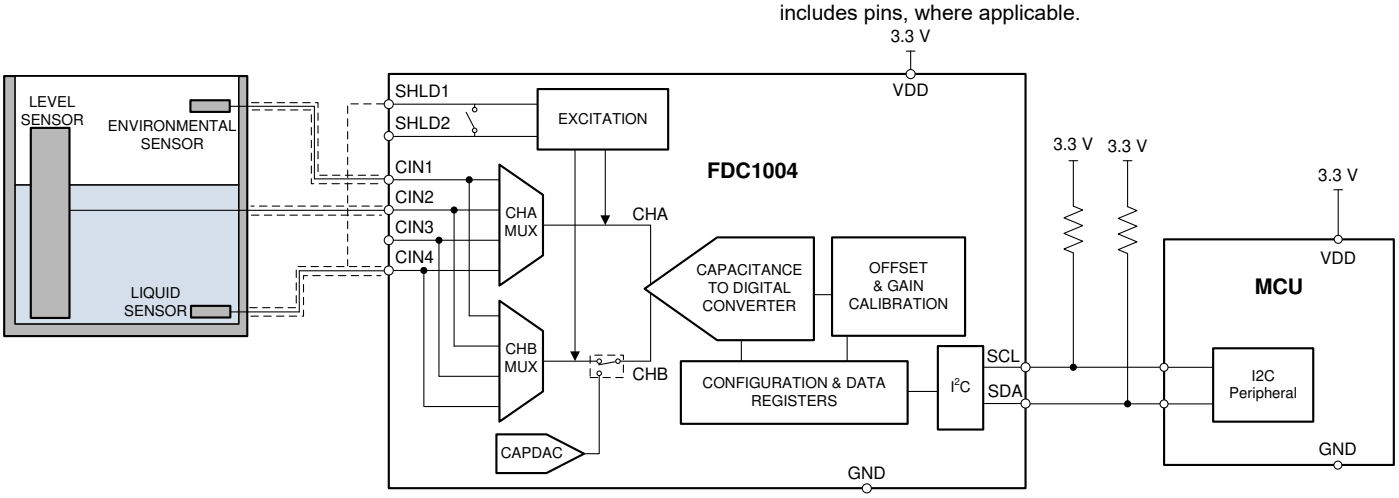
The FDC1004 is a high-resolution, 4-channel capacitance-to-digital converter for implementing capacitive sensing solutions. Each channel has a full scale range of ±15pF and can handle a sensor offset capacitance of up to 100pF, which can be either programmed internally or can be an external capacitor for tracking environmental changes over time and temperature. The large offset capacitance capability allows for the use of remote sensors.

The FDC1004 also includes shield drivers for sensor shields, which can reduce EMI interference and help focus the sensing direction of a capacitive sensor. The small footprint of the FDC1004 allows for use in space-constrained applications. The FDC1004 is available in a 10-pin WSON and VSSOP package and features an I^2C interface for interfacing to an MCU.

Package Information

PART NUMBER	PACKAGE(1)	PACKAGE SIZE(2)
FDC1004	DSC (WSON, 10)	3mm × 3mm
	DGS (VSSOP, 10)	3mm × 4.9mm

(1) For all available packages, see Section 10.
(2) The package size (length × width) is a nominal value and includes pins, where applicable.



Typical Application

An IMPORTANT NOTICE at the end of this data sheet addresses availability, warranty, changes, use in safety-critical applications, intellectual property matters and other important disclaimers. PRODUCTION DATA.

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4 Pin Configuration and Functions

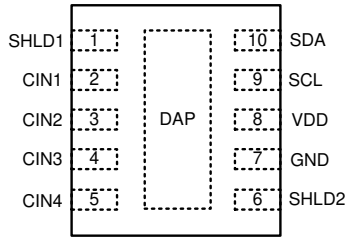


Figure 4-1. WSON (DSC) 10 Pins TOP

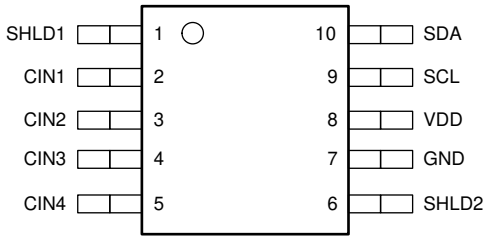


Figure 4-2. VSSOP (DGS) 10 Pins TOP

Table 4-1. Pin Functions

PIN		TYPE[1]	DESCRIPTION
NAME	NO.		
SHLD1	1	A	Capacitive Input Active AC Shielding.
CIN1	2	A	Capacitive Input. The measured capacitance is connected between the CIN1 pin and GND. If not used, leave this pin as an open circuit.
CIN2	3	A	Capacitive Input. The measured capacitance is connected between the CIN2 pin and GND. If not used, leave this pin as an open circuit.
CIN3	4	A	Capacitive Input. The measured capacitance is connected between the CIN3 pin and GND. If not used, leave this pin as an open circuit.
CIN4	5	A	Capacitive Input. The measured capacitance is connected between the CIN4 pin and GND. If not used, leave this pin as an open circuit.
SHLD2	6	A	Capacitive Input Active AC Shielding.
GND	7	G	Ground
VDD	8	P	Power Supply Voltage. Decouple this pin to GND, using a low impedance capacitor, for example in combination with a 1µF tantalum and a 0.1µF multilayer ceramic.
SCL	9	I	Serial Interface Clock Input. Connects to the controller clock line. Requires pullup resistor if not already provided elsewhere in the system.
SDA	10	I/O	Serial Interface Bidirectional Data. Connects to the controller data line. Requires a pullup resistor if not provided elsewhere in the system.
DAP[2]	-	N/A	Connect to GND

(1) P=Power, G=Ground, I=Input, O=Output, A=Analog, I/O=Bidirectional Input/Output
(2) There is an internal electrical connection between the exposed Die Attach Pad (DAP) and the GND pin of the device. Although the DAP can be left floating, for best performance the DAP should be connected to the same potential as the device's GND pin. Do not use the DAP as the primary ground for the device. The device GND pin must always be connected to ground.

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5 Specifications

5.1 Absolute Maximum Ratings

See (1)

		MIN	MAX	UNIT
Input voltage	VDD	–0.3	6	V
	SCL, SDA	–0.3	6	V
	at any other pin	–0.3	VDD+0.3	V
Input current	at any pin		3	mA
Junction temperature(2)			150	°C
Storage temperature	T_{STG}	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{\theta JA}$, and the ambient temperature, T_A. The maximum allowable power dissipation at any ambient temperature is $P_{DMAX} = (T_{J(MAX)} - T_A)/ R_{\theta JA}$. All numbers apply for packages soldered directly onto a PC board.

5.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge(1)	Human body model (HBM), per ANSI/ESDA/ JEDEC JS-001, all pins(2)	±1000	V
		Charged device model (CDM), per JEDEC specification -500 500 JESD22-C101, all pins(3)	±250	

(1) Electrostatic discharge (ESD) to measure device sensitivity and immunity to damage caused by assembly line electrostatic discharges in to the device.
(2) Level listed above is the passing level per ANSI, ESDA, and JEDEC JS-001. JEDEC document JEP155 states that 500V HBM allows safe manufacturing with a standard ESD control process.
(3) Level listed above is the passing level per EIA-JEDEC JESD22-C101. JEDEC document JEP157 states that 250V CDM allows safe manufacturing with a standard ESD control process.

5.3 Recommended Operating Conditions

Over operating temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
Supply voltage (VDD-GND)	3	3.3	3.6	V
Temperature	–40		125	°C

5.4 Thermal Information

THERMAL METRIC(1)		FDC1004		UNIT
		WSON (DSC)	VSSOP (DGS)	
		10 PINS		
$R_{\theta JA}$	Junction-to-ambient thermal resistance	46.8	46.8	°C/W
$R_{\theta JC}$	Junction-to-case(top) thermal resistance	46.7	48.7	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	21.5	70.6	°C/W

(1) For more information about traditional and new thermal metrics, see the *Semiconductor and IC Package Thermal Metrics* application note.

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5.5 Electrical Characteristics

Over recommended operating temperature range, V_{DD} = 3.3V, for T_A = 25°C (unless otherwise noted). (1)

PARAMETER		TEST CONDITION	MIN(2)	TYP(3)	MAX(2)	UNIT
POWER SUPPLY						
I_{DD}	Supply current	Conversion mode; Digital input to VDD or GND		750	950	µA
		Standby; Digital input to VDD or GND		29	70	µA
CAPACITIVE INPUT						
ICR	Input conversion range			±15		pF
C_{OMAX}	Max input offset capacitance	per channel, Series resistance at CINn n=1.4 = 0 Ω		100		pF
RES	Effective resolution (4)	Sample rate = 100S/s (5)		16		bit
EON	Output noise	Sample rate = 100S/s (5)		33.2		aF/√Hz
ERR	Absolute error	after offset calibration		±6		fF
TcC_{OFF}	Offset deviation over temperature	-40°C < T < 125°C		46		fF
G_{ERR}	Gain error			0.2		%
tcG	Gain drift vs temperature	-40°C < T < 125°C		-37.5		ppm/°C
PSRR	DC power supply rejection	3V < V_{DD} < 3.6V, single-ended mode (channel vs GND)		13.6		fF/V
CAPDAC						
FR_{CAPDAC}	Full-scale range			96.9		pF
$TcCOFF_{CAPDAC}$	Offset drift vs. temperature	-40°C < T < 125°C		30		fF
EXCITATION						
f	Frequency			25		kHz
V_{AC}	AC voltage across capacitance			2.4		Vpp
V_{DC}	Average DC voltage across capacitance			1.2		V
SHIELD						
DRV	Driver capability	*f* = 25kHz, SHLDn to GND, n = 1,2			400	pF

(1) Electrical Characteristics Table values apply only for factory testing conditions at the temperature indicated. Factor testing conditions result in very limited self-heating of the device such that TJ=TA. No guarantee of parametric performance is indicated in the electrical tables under conditions of internal self-heating where TJ>TA. Absolute Maximum Ratings indicate junction temperature limits beyond which the device can be permanently degraded, either mechanically or electrically.
(2) Limits are ensured by testing, design, or statistical analysis at 25Degree C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.
(3) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values can vary over time and also depend on the application and configuration. The typical values are not tested and are not guaranteed on shipped production material.
(4) Effective resolution is the ratio of converter full scale range to RMS measurement noise.
(5) No external capacitance connected.

5.6 I²C Interface Voltage Level

Over recommended operating free-air temperature range, V_{DD} = 3.3V, for T_A = T_J = 25°C (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{IH}	Input high voltage		0.7*V_{DD}			V
V_{IL}	Input low voltage				0.3*V_{DD}	V
V_{OL}	Output low voltage	Sink current 3 mA			0.4	V
HYS	Hysteresis (1)		0.1*V_{DD}			V

(1) This parameter is specified by design and/or characterization and is not tested in production.

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5.7 I²C Interface Timing

Over recommended operating free-air temperature range, V_{DD} = 3.3V, for $T_A = T_J$ = 25°C (unless otherwise noted).

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
f_{SCL}	Clock frequency(1)		10		400	kHz
t_{LOW}	Clock low time(1)		1.3			µs
t_{HIGH}	Clock high time(1)		0.6			µs
$t_{HD;STA}$	Hold time (repeated) START condition(1)	After this period, the first clock pulse is generated	0.6			µs
$t_{SU;STA}$	Set-up time for a repeated START condition(1)		0.6			µs
$t_{HD;DAT}$	Data hold time(1) (2)		0			ns
$t_{SU;DAT}$	Data setup time(1)		100			ns
t_f	SDA fall time(1)	IL ≤ 3mA; CL ≤ 400pF			300	ns
$t_{SU;STO}$	Set-up time for STOP condition(1)		0.6			µs
t_{BUF}	Bus free time between a STOP and START condition(1)		1.3			µs
$t_{VD;DAT}$	Data valid time(1)				0.9	ns
$t_{VD;ACK}$	Data valid acknowledge time(1)				0.9	ns
t_{SP}	Pulse width of spikes that must be suppressed by the input filter(1)				50	ns

(1) This parameter is specified by design and/or characterization and is not tested in production.
(2) The FDC1004 provides an internal 300ns minimum hold time to bridge the undefined region of the falling edge of SCL.

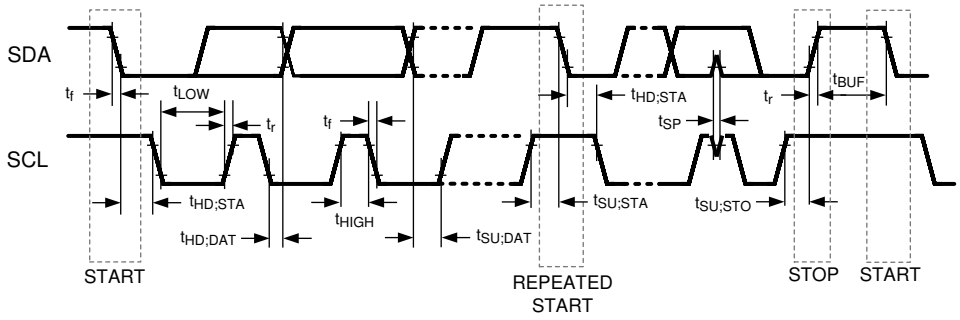


Figure 5-1. I²C Timing

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5.8 Typical Characteristics

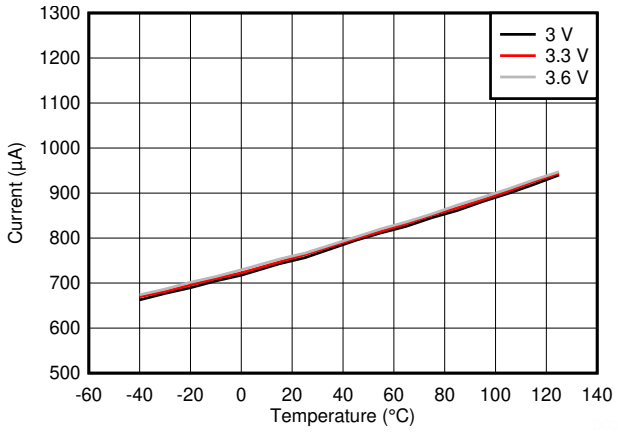


Figure 5-2. Active Conversion Mode Supply Current vs Temperature

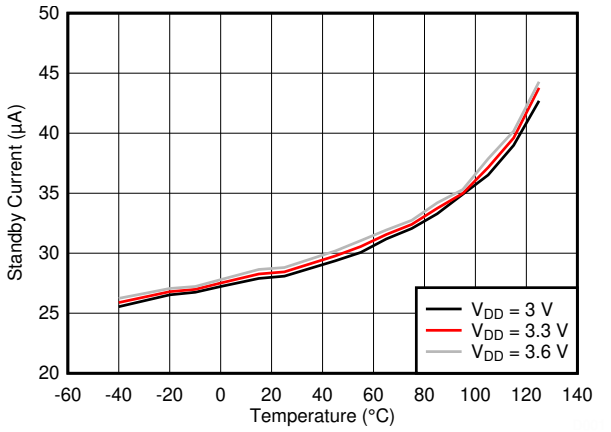


Figure 5-3. Stand-by Mode Supply Current vs Temperature

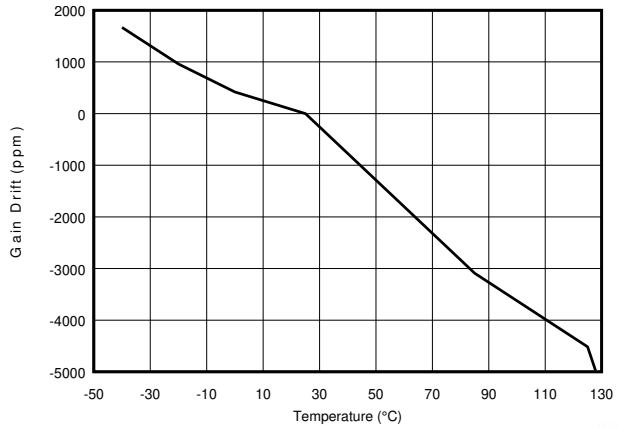
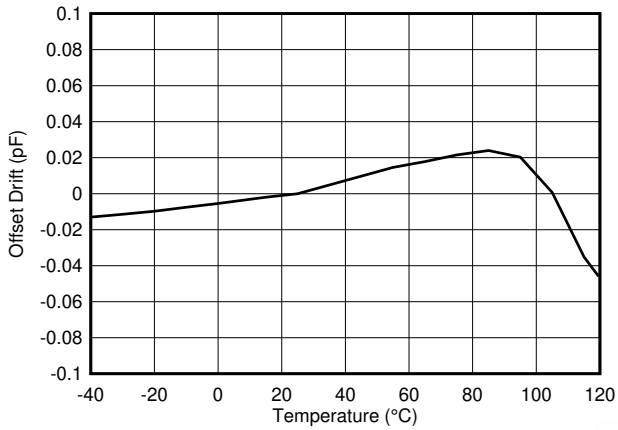
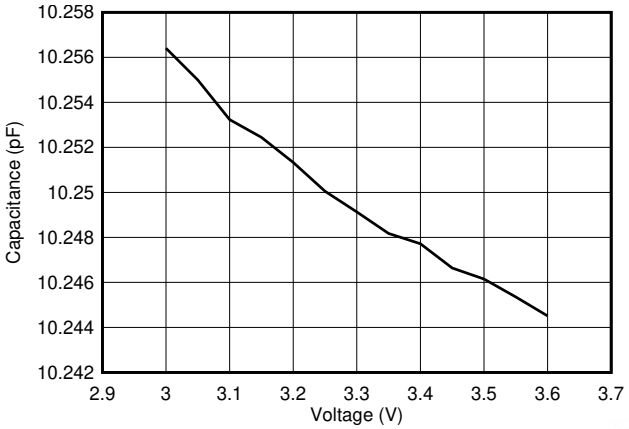


Figure 5-4. Gain Drift vs Temperature



CINn = open, where n = 1...4

Figure 5-5. Offset Drift vs Temperature



Capacitance Value = 10pF

Figure 5-6. Capacitance vs Voltage

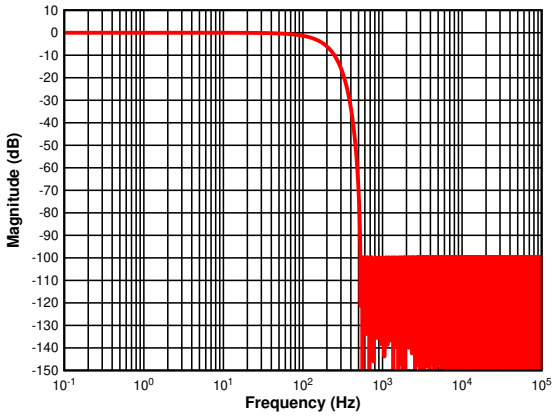


Figure 5-7. Frequency Response 100S/s

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5.8 Typical Characteristics (continued)

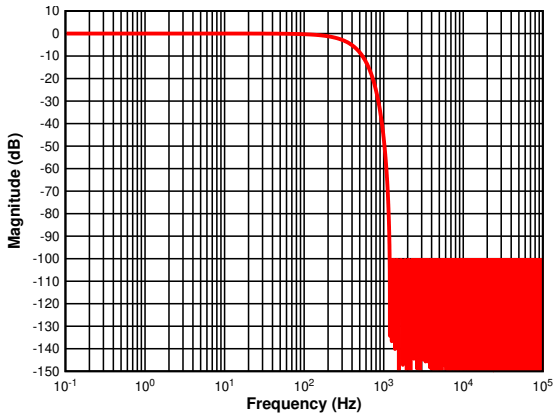


Figure 5-8. Frequency Response 200S/s

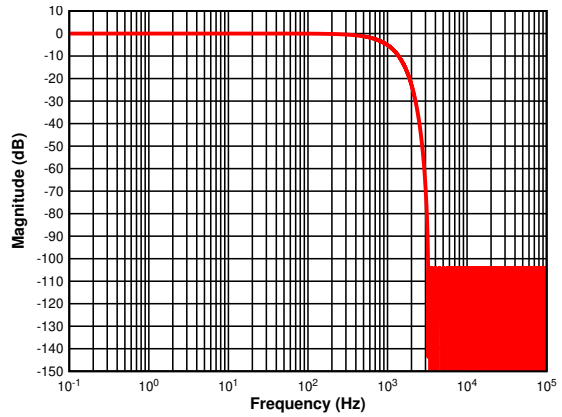


Figure 5-9. Frequency Response 400S/s

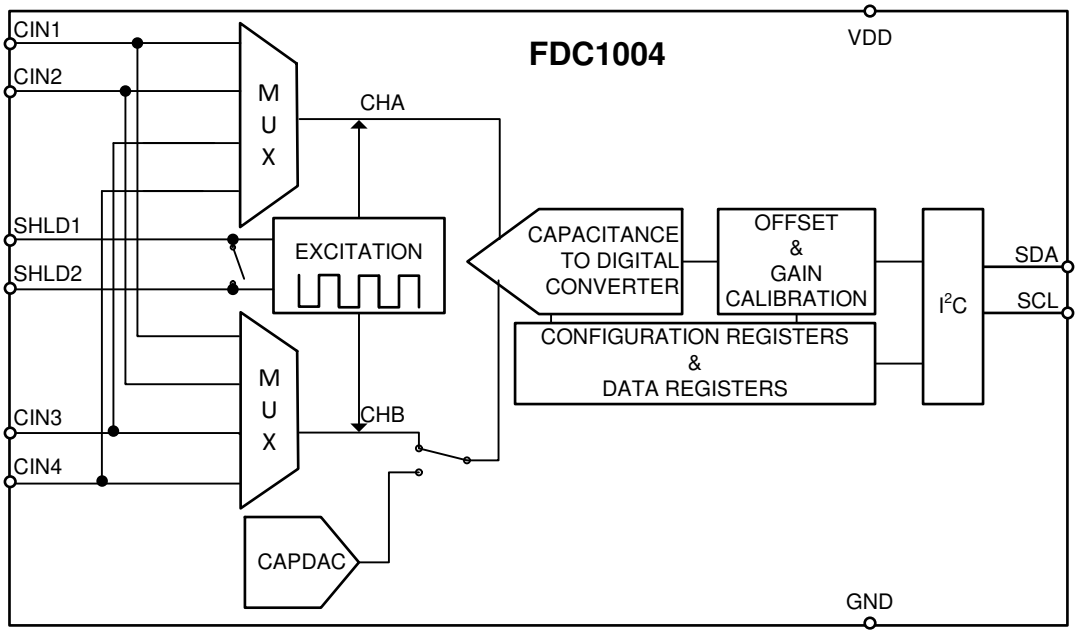
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6 Detailed Description

6.1 Overview

The FDC1004 is a high-resolution, 4-channel capacitance-to-digital converter for implementing capacitive sensing solutions. Each channel has a full scale range of ±15pF and can handle a sensor offset capacitance of up to 100pF, which can be either programmed internally or can be an external capacitor for tracking environmental changes over time and temperature. The large offset capacitance capability allows for the use of remote sensors. The FDC1004 also includes shield drivers for sensor shields, which can reduce EMI interference and help focus the sensing direction of a capacitive sensor. The small footprint of the FDC1004 allows for use in space-constrained applications. For more information on the basics of capacitive sensing and applications, refer to the *FDC1004: Basics of Capacitive Sensing and Applications* application note.

6.2 Functional Block Diagram



6.3 Feature Description

6.3.1 The Shield

The FDC1004 measures capacitance between CINn and ground. That means any capacitance to ground on signal path between the FDC1004 CINn pins and sensor is included in the FDC1004 conversion result.

In some applications, the parasitic capacitance of the sensor connections can be larger than the capacitance of the sensor. If that parasitic capacitance is stable, the capacitance can be treated as a constant capacitive offset. However, the parasitic capacitance of the sensor connections can have significant variation due to environmental changes (such as mechanical movement, temperature shifts, humidity changes). These changes are seen as drift in the conversion result and can significantly compromise the system accuracy.

To eliminate the CINn parasitic capacitance to ground, the FDC1004 SHLDx signals can be used for shielding the connection between the sensor and CINn. The SHLDx output is the same signal waveform as the excitation of the CINn pin; the SHLDx is driven to the same voltage potential as the CINn pin. Therefore, there is no current between CINn and SHLDx pins, and any capacitance between these pins does not affect the CINn charge transfer. Ideally, the CINn to SHLD capacitance does not have any contribution to the FDC1004 result.

In differential measurements, SHLD1 is assigned to CHn and SHLD2 is assigned to CHm, where n < m. For instance in the measurement CIN1 – CIN2, where CHA = CIN1 and CHB = CIN2 (see Table 6-4), SHDL1 is assigned to CIN1 and SHDL2 is assigned to CIN2.

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In a single-ended configuration, such as CINn versus GND, SHLD1 is internally shorted to SHLD2. In a single ended configuration, such as CINn versus GND with CAPDAC enabled, SHLD1 is assigned to the selected channel, SHLD2 is floating.

For best results, locate the FDC1004 as close as possible to the capacitive sensor. Minimize the connection length between the sensor and FDC1004 CINn pins and between the sensor ground and the FDC1004 GND pin. Shield the PCB traces to the CINn pins and connect the shielding to the FDC1004 SHLDx pins. In addition, if a shielded cable is used to connect the FDC1004 to the sensor, connect the shield to the appropriate SHLDx pin. In applications where only one SHLDx pin is used, the unused SHLDx pin can be left unconnected.

For more information on shielding, refer to *Capacitive Sensing: Ins and Outs of Active Sensing* application note.

6.3.2 The CAPDAC

The FDC1004 full-scale input range is ±15pF. The part can accept a higher capacitance on the input and the common-mode or offset (constant component) capacitance can be balanced by the programmable on-chip CAPDACs. The CAPDAC can be viewed as a negative capacitance connected internally to the CINn pin. The relation between the input capacitance and output data can be expressed as DATA = (CINn – CAPDAC), n = 1...4. The CAPDACs have a 5-bit resolution, monotonic transfer function, are well matched to each other, and have a defined temperature coefficient.

6.3.3 Capacitive System Offset Calibration

The capacitive offset can be due to many factors including the initial capacitance of the sensor, parasitic capacitances of board traces, and the capacitance of any other connections between the sensor and the FDC.

The parasitic capacitances of the FDC1004 are calibrated out at production. If there are other sources of offset in the system, it can be necessary to calibrate the system capacitance offset in the application. Any offset in the capacitance input larger than ½ LSB of the CAPDAC should first be removed using the on-chip CAPDACs. Any residual offset of approximately 1pF can then be removed by using the capacitance offset calibration register. The offset calibration register is reloaded by the default value at power-on or after reset. Therefore, if the offset calibration is not repeated after each system power-up, the calibration coefficient value should be stored by the host controller and reloaded as part of the FDC1004 setup.

6.3.4 Capacitive Gain Calibration

The gain is factory calibrated up to ±15pF in the production for each part individually. The factory gain coefficient is stored in a one-time programmable (OTP) memory.

The gain can be temporarily changed by setting the Gain Calibration Register (registers 0x11 to 0x14) for the appropriate CINn pin, although the factory gain coefficient is restored after power-up or reset.

The part is tested and specified for use only with the default factory calibration coefficient. Adjusting the Gain calibration can be used to normalize the capacitance measurement of the CINn input channels.

6.4 Device Functional Modes

6.4.1 Single Ended Measurement

The FDC1004 can be used for interfacing to a single-ended capacitive sensor. In this configuration, connect the sensor to the input CINn (n = 1..4) pins of the FDC1004 and GND. The capacitance-to-digital convertor (without using the CAPDAC, CAPDAC= 0pF) measures the positive (or the negative) input capacitance in the range of 0pF to 15pF. The CAPDAC can be used for programmable shifting of the input range. In this case it is possible to measure input capacitance in the range of 0pF to ±15pF which are on top of an offset capacitance up to 100pF. In single ended measurements with CAPDAC disabled SHLD1 is internally shorted to SHLD2 (see Figure 6-1); if CAPDAC is enabled SHLD2 is floating (see Figure 6-2). The single ended mode is enabled when the CHB register of the Measurements configuration registers (see Table 6-4) are set to b100 or b111.

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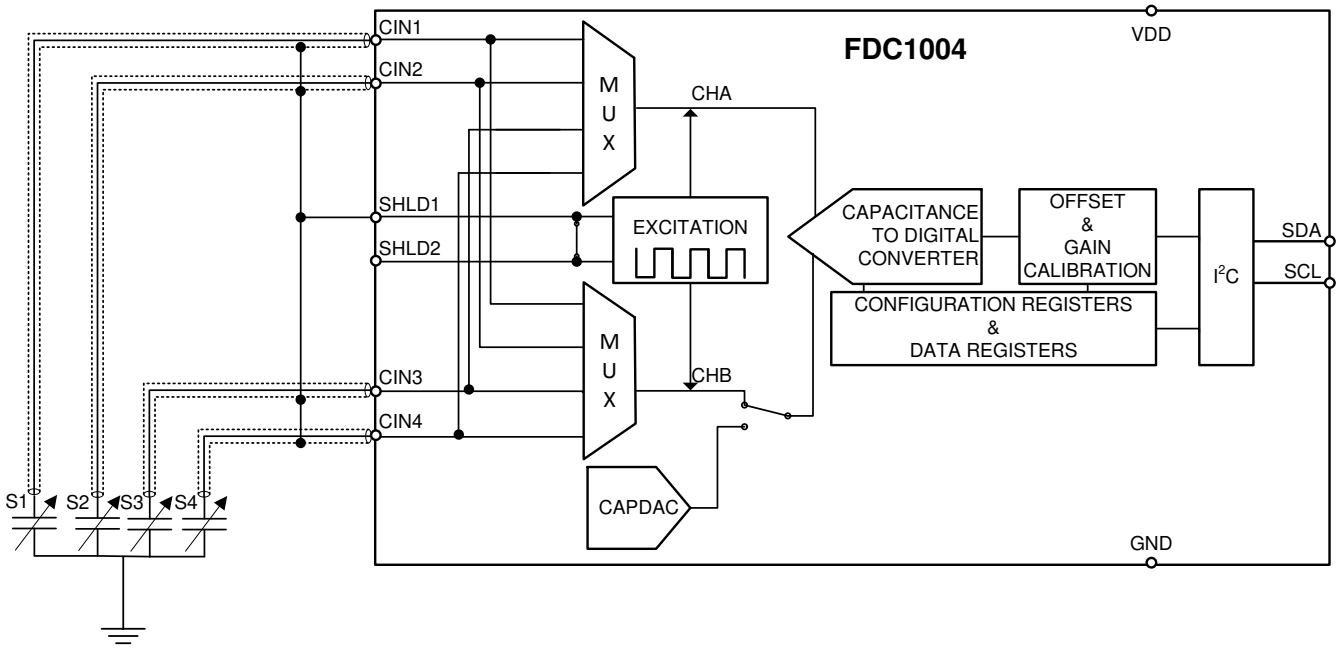


Figure 6-1. Single-Ended Configuration with CAPDAC Disabled

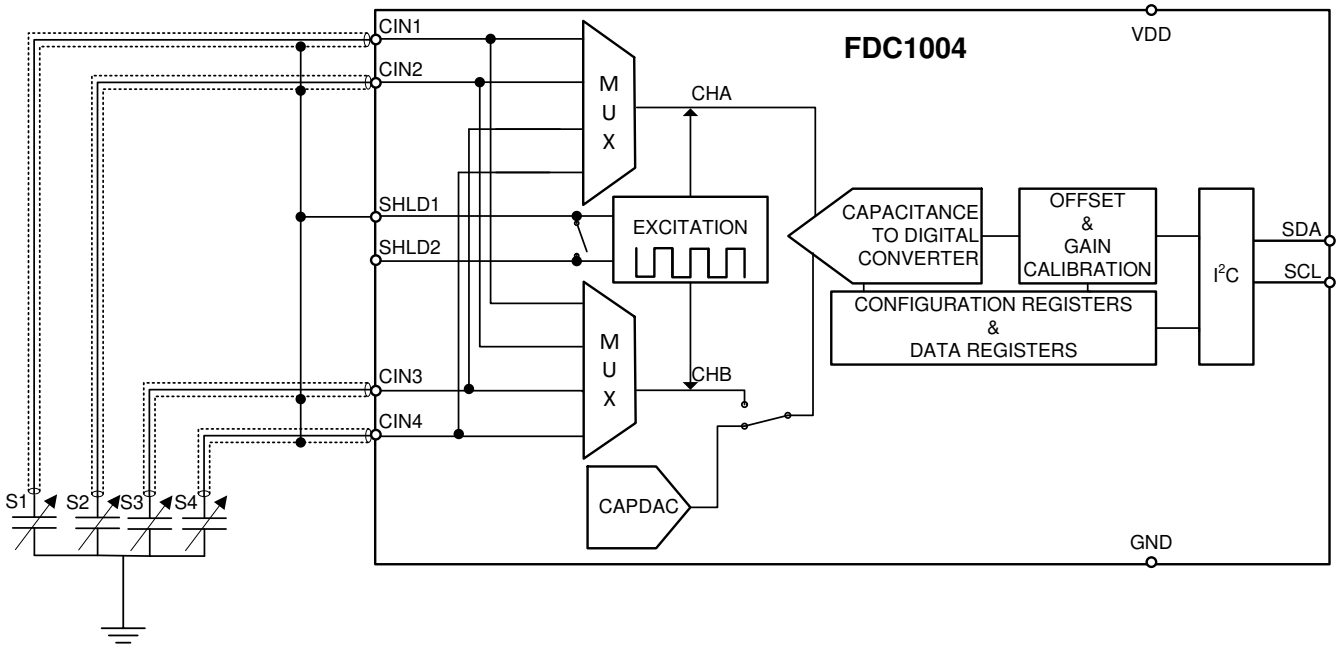


Figure 6-2. Single-Ended Configuration with CAPDAC Enabled

6.4.2 Differential Measurement

When the FDC1004 is used for interfacing to a differential capacitive sensor, each of the two input capacitances must be less than 115pF. In this configuration the CAPDAC is disabled. Keep the absolute value of the difference between the two input capacitances below 15pF to avoid introducing errors in the measurement. In differential measurements, SHLD1 is assigned to CHn and SHLD2 is assigned to CHm, where n < m. For instance in the measurement CIN1 – CIN2, where CHA = CIN1 and CHB = CIN2 (see Table 6-4), SHDL1 is assigned to CIN1 and SHDL2 is to CIN2. Differential sensors made with S1 versus S3 and S2 versus S4 is shown below in Figure 6-3. S1 and S2 are alternatively connected to CHA and the S3 and S4 are alternatively connected to CHB, the shield signals are connected as explained in previous paragraph. The FDC1004 performs a differential

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measurement when CHB field of the Measurements Configuration Registers (refer to Table 6-4) is less than to b100.

This configuration is very useful in applications where environment conditions need to be tracked. The differential measurement between the main electrode and the environment electrode makes the measurement independent of the environment conditions.

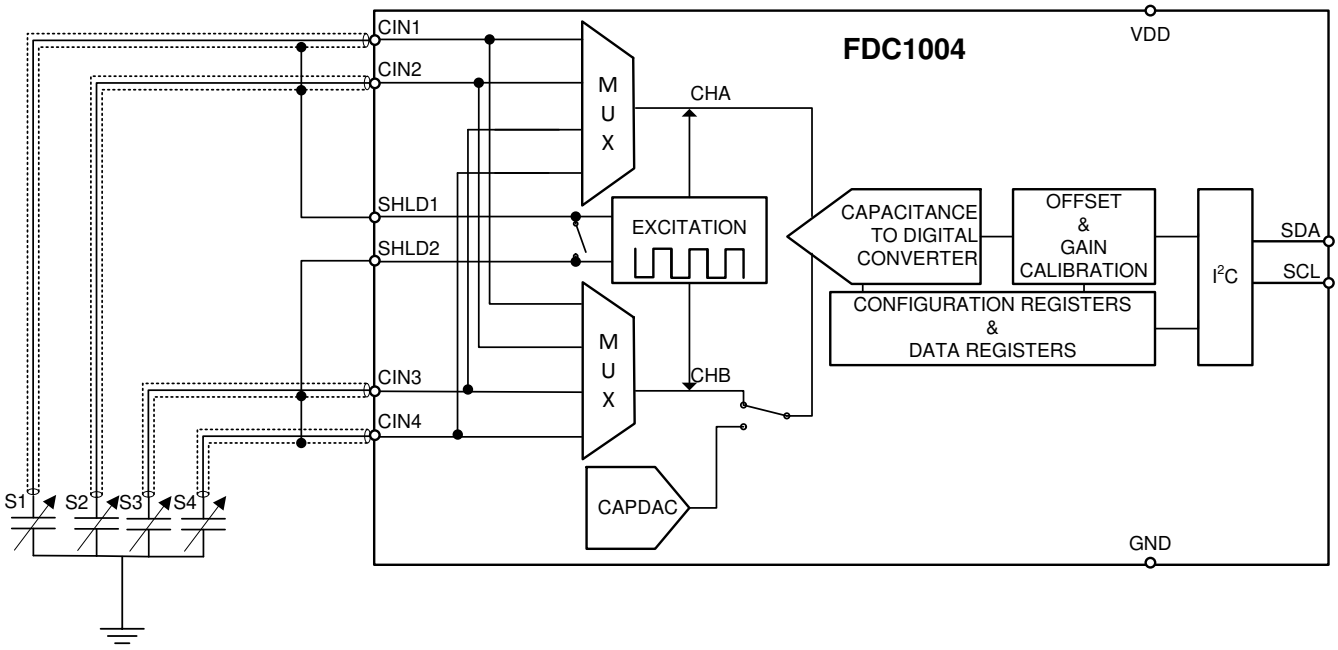


Figure 6-3. Differential Configuration

6.5 Programming

The FDC1004 operates only as a target device on the two-wire bus interface. Every device on the bus must have a unique address. Connection to the bus is made via the open-drain I/O lines, SDA, and SCL. The SDA and SCL pins feature integrated spike-suppression filters and Schmitt triggers to minimize the effects of input spikes and bus noise. The FDC1004 supports fast mode frequencies 10kHz to 400kHz. All data bytes are transmitted MSB first.

6.5.1 Serial Bus Address

To communicate with the FDC1004, the controller must first address target devices via a target address byte. The target address byte consists of seven address bits and a direction bit that indicates the intent to execute a read or write operation. The seven bit address for the FDC1004 is (MSB first): b101 0000.

6.5.2 Read/Write Operations

Access a particular register on the FDC1004 by writing the appropriate value to the Pointer Register. The pointer value is the first byte transferred after the target address byte with the R/W bit low. Every write operation to the FDC1004 requires a value for the pointer register. When reading from the FDC1004, the last value stored in the pointer by a write operation is used to determine which register is read by a read operation. To change the pointer register for a read operation, a new value must be written to the pointer. This transaction is accomplished by issuing the target address byte with the R/W bit low, followed by the pointer byte. No additional data is required. The controller can then generate a START condition and send the target address byte with the R/W bit high to initiate the read command. Note that register bytes are sent MSB first, followed by the LSB. A write operation in a read only registers such as MANUFACTURER ID or SERIAL ID returns a NACK after each data byte; read/write operation to unused address returns a NACK after the pointer; a read/write operation with incorrect I_2C address returns a NACK after the I^2C address.

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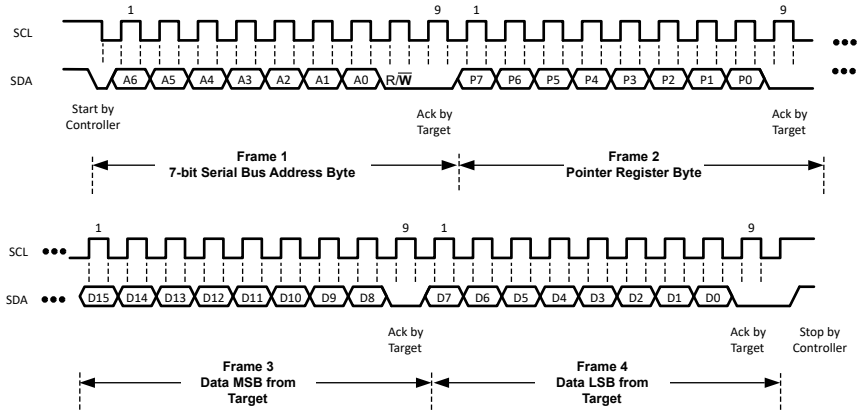


Figure 6-4. Write Frame

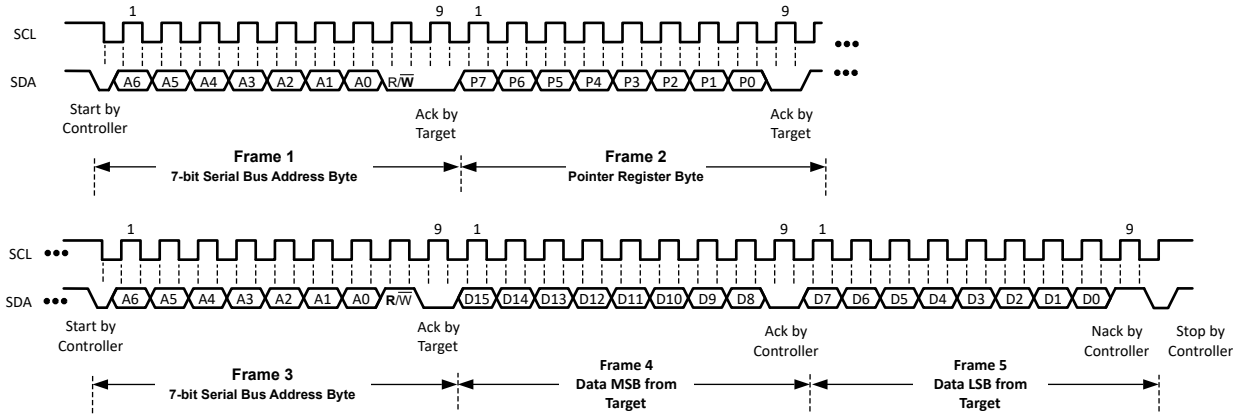


Figure 6-5. Read Frame

The I^{2}C interface of the FDC1004 is designed to operate with the standard I^{2}C transactions detailed in the I^{2}C specification; however it is not suitable for use in an I^{2}C system which supports early termination of transactions. A STOP condition or other early termination occurring before the normal end of a transaction (ACK) is not supported and can corrupt that transaction and/or the following transaction.

The device is also sensitive to any extraneous pulse on SDA during the SCL low period of the first bit position of the I^{2}C address byte. To ensure proper operation of the FDC1004, make sure the controller device does not transmit this type of waveform. An example of an unsupported I^{2}C waveform is shown in Figure 6-6.

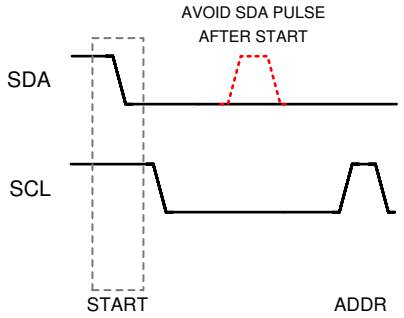


Figure 6-6. Extraneous Pulse on SDA between I^{2}C START and ADDR

6.5.3 Device Usage

The basic usage model of the FDC1004 is to simply follow these steps:

1. Configure measurements (for details, refer to *Measurement Configuration*).

2. Trigger a measurement set (for details, refer to *Triggering Measurements*).
3. Wait for measurement completion (for details, refer to *Wait for Measurement Completion*).
4. Read measurement data (for details, refer to *Read of Measurement Result*).

6.5.3.1 Measurement Configuration

Configuring a measurement involves setting the input channels and the type of measurement (single-ended or differential).

The FDC1004 can be configured with up to 4 separate measurements, where each measurement can be any valid configuration (that is, a specific channel can be used in multiple measurements). There is a dedicated configuration register for each of the 4 possible measurements (for example, MEAS_CONF1 in register 0x08 configures measurement 1, MEAS_CONF2 in register 0x09 configures measurement 2, ...). Configuring only one measurement is allowed, and it can be one of the 4 possible measurement configurations.

1. Setup the input channels for each measurement. Determine which of the 4 measurement configuration registers to use (registers 0x08 to 0x0A) and set the following:
   a. For single-ended measurement:
      i. Select the positive input pin for the measurement by setting the CHA field (bits[15:13]).
      ii. Set CAPDAC (bits[9:5]) if the channel offset capacitance is more than 15pF.
   b. For a differential measurement:
      i. Select the positive input pin for the measurement by setting the CHA field (bits[15:13]).
      ii. Select the negative input pin for the measurement by setting the CHB field (bits[12:10]). Note that the CAPDAC setting has no effect for a differential measurement.
2. Determine the appropriate sample rate. The sample rate sets the resolution of the measurement. Lower the sample rate higher is the resolution of the measurement.

6.5.3.2 Triggering Measurements

For a single measurement, trigger the desired measurement (that is, which one of the configured measurements) when needed by:

1. Setting REPEAT (Register 0x0C:bit[8]) to 0.
2. Setting the corresponding MEAS_x field (Register 0x0C:bit[7:4]) to 1.
   - For example, to trigger a single measurement of Measurement 2 at a rate of 100S/s, set Address 0x0C to 0x0540.

Note that, at a given time, only one measurement of the configured measurements can be triggered in this manner (that is, MEAS_1 and MEAS_2 cannot both be triggered in a single operation).

The FDC1004 can also trigger a new measurement on the completion of the previous measurement (repeated measurements). This is setup by:

1. Setting REPEAT (Register 0x0C:bit[8]) to 1.
2. Setting the corresponding MEAS_x field (Register 0x0C:bit[7:4]) to 1.

When the FDC1004 is setup for repeated measurements, multiple configured measurements (up to a maximum of 4) can be performed in this manner, but Register 0x0C must be written in a single transaction.

6.5.3.3 Wait for Measurement Completion

Wait for the triggered measurements to complete. When the measurements are complete, the corresponding DONE_x field (Register 0x0C:bits[3:0]) is set to 1.

6.5.3.4 Read of Measurement Result

Read the result of the measurement from the corresponding registers:

- 0x00/0x01 for Measurement 1
- 0x02/0x03 for Measurement 2
- 0x04/0x05 for Measurement 3
- 0x06/0x07 for Measurement 4

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The measurement results span 2 register addresses; both registers must be read to have a complete conversion result. The lower address (for example, 0x00 for Measurement 1) must be read first, then the upper address read afterwards (for example, 0x01 for Measurement 1).

When the measurement read is complete, the corresponding DONE_x field (Register 0x0C:bits[3:0]) returns to 0.

If an additional single triggered measurement is desired, simply perform the Trigger, Wait, Read steps again.

If the FDC1004 is set up for repeated measurements (Register 0x0C:bit[8]) = 1), the FDC1004 continuously measures until the REPEAT field (Register 0x0C:bit[8]) is set to 0, even if the results are not read back.

6.6 Register Maps

Table 6-1. Register Map

Pointer	Register Name	Reset Value	Description
0x00	MEAS1_MSB	0x0000	MSB portion of Measurement 1
0x01	MEAS1_LSB	0x0000	LSB portion of Measurement 1
0x02	MEAS2_MSB	0x0000	MSB portion of Measurement 2
0x03	MEAS2_LSB	0x0000	LSB portion of Measurement 2
0x04	MEAS3_MSB	0x0000	MSB portion of Measurement 3
0x05	MEAS3_LSB	0x0000	LSB portion of Measurement 3
0x06	MEAS4_MSB	0x0000	MSB portion of Measurement 4
0x07	MEAS4_LSB	0x0000	LSB portion of Measurement 4
0x08	CONF_MEAS1	0x1C00	Measurement 1 Configuration
0x09	CONF_MEAS2	0x1C00	Measurement 2 Configuration
0x0A	CONF_MEAS3	0x1C00	Measurement 3 Configuration
0x0B	CONF_MEAS4	0x1C00	Measurement 4 Configuration
0x0C	FDC_CONF	0x0000	Capacitance to Digital Configuration
0x0D	OFFSET_CAL_CIN1	0x0000	CIN1 Offset Calibration
0x0E	OFFSET_CAL_CIN2	0x0000	CIN2 Offset Calibration
0x0F	OFFSET_CAL_CIN3	0x0000	CIN3 Offset Calibration
0x10	OFFSET_CAL_CIN4	0x0000	CIN4 Offset Calibration
0x11	GAIN_CAL_CIN1	0x4000	CIN1 Gain Calibration
0x12	GAIN_CAL_CIN2	0x4000	CIN2 Gain Calibration
0x13	GAIN_CAL_CIN3	0x4000	CIN3 Gain Calibration
0x14	GAIN_CAL_CIN4	0x4000	CIN4 Gain Calibration
0xFE	Manufacturer ID	0x5449	ID of Texas Instruments
0xFF	Device ID	0x1004	ID of FDC1004 device

Registers from 0x15 to 0xFD are reserved and should not be written to.

6.6.1 Registers

The FDC1004 has an 8-bit pointer used to address a given data register. The pointer identifies which of the data registers should respond to a read or write command on the two-wire bus. This register is set with every write command. A write command must be issued to set the proper value in the pointer before executing a read command. The power-on reset (POR) value of the pointer is 0x00.

6.6.1.1 Capacitive Measurement Registers

The capacitance measurement registers are 24-bit result registers in binary format (the 8 LSBs D[7:0] are always 0x00). The result of the acquisition is always a 24 bit value, while the accuracy is related to the selected conversion time (refer to *Electrical Characteristics*). The result of the measurement can be calculated by the following formula:

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$$\text{Capacitance (pf)} = (\text{measurement [23:0]}) / 2^{19}) + C_{offset} \quad (1)$$

where

- C_{offset} is based on the CAPDAC setting.

Table 6-2. Measurement Registers Description (0x00, 0x02, 0x04, 0x06)

Field Name	Bits	Description
MSB_MEASn(1)	[15:0]	Most significant 16 bits of Measurement n (read only)

(1) MSB_MEAS1 = register 0x00, MSB_MEAS2 = register 0x02, MSB_MEAS3 = register 0x04, MSB_MEAS4 = register 0x06

Table 6-3. Measurement Registers Description (0x01, 0x03, 0x05, 0x07)

Field Name	Bits		Description
LSB_MEASn(1)	[15:8]		Least significant 8 bits of Measurement n (read only)
	[7:0]	Reserved	Reserved, always 0 (read only)

(1) LSB_MEAS1 = register 0x01, LSB_MEAS2 = register 0x03, LSB_MEAS3 = register 0x05, LSB_MEAS4 = register 0x07

6.6.1.2 Measurement Configuration Registers

These registers configure the input channels and CAPDAC setting for a measurement.

Table 6-4. Measurement Configuration Registers Description (0x08, 0x09, 0x0A, 0x0B)

Field Name	Bits			Description
CHA(1) (2)	[15:13]	Positive input channel capacitive to digital converter	b000	CIN1
			b001	CIN2
			b010	CIN3
			b011	CIN4
CHB(1) (2)	[12:10]	Negative input channel capacitive to digital converter	b000	CIN1
			b001	CIN2
			b010	CIN3
			b011	CIN4
			b100	CAPDAC
			b111	DISABLED
CAPDAC	[9:5]	Offset Capacitance	b00000	0pF (minimum programmable offset)
			- - - - -	Configure the single-ended measurement capacitive offset: C_{offset} = CAPDAC x 3.125pF
			b11111	96.875pF (maximum programmable offset)
RESERVED	[04:00]	Reserved		Reserved, always 0 (read only)

(1) **It is not permitted to configure a measurement where the CHA field and CHB field hold the same value (for example, if CHA=b010, CHB cannot also be set to b010).**
(2) **It is not permitted to configure a differential measurement between CHA and CHB where CHA > CHB (for example, if CHA= b010, CHB cannot be b001 or b000).**

6.6.1.3 FDC Configuration Register

This register configures measurement triggering and reports measurement completion.

Table 6-5. FDC Register Description (0x0C)

Field Name	Bits			Description
RST	[15]	Reset	0	Normal operation
			1	Software reset: write a 1 to initiate a device reset; after completion of reset, this field returns to 0
RESERVED	[14:12]	Reserved		Reserved, always 0 (read only)

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Table 6-5. FDC Register Description (0x0C) (continued)

Field Name	Bits			Description
RATE	[11:10]	Measurement Rate	b00	Reserved
			b01	100S/s
			b10	200S/s
			b11	400S/s
RESERVED	[9]	Reserved		Reserved, always 0 (read only)
REPEAT	[8]	Repeat Measurements	0	Repeat disabled
			1	Repeat enabled, all the enabled measurement are repeated
MEAS_1	[7]	Initiate Measurements	0	Measurement 1 disabled
			1	Measurement 1 enabled
MEAS_2	[6]	Initiate Measurements	0	Measurement 2 disabled
			1	Measurement 2 enabled
MEAS_3	[5]	Initiate Measurements	0	Measurement 3 disabled
			1	Measurement 3 enabled
MEAS_4	[4]	Initiate Measurements	0	Measurement 4 disabled
			1	Measurement 4 enabled
DONE_1	[3]	Measurement Done	0	Measurement 1 not completed
			1	Measurement 1 completed
DONE_2	[2]	Measurement Done	0	Measurement 2 not completed
			1	Measurement 2 completed
DONE_3	[1]	Measurement Done	0	Measurement 3 not completed
			1	Measurement 3 completed
DONE_4	[0]	Measurement Done	0	Measurement 4 not completed
			1	Measurement 4 completed

6.6.1.4 Offset Calibration Registers

These registers configure a digitized capacitance value in the range of -16pF to 16pF (max residual offset 250 aF) that can be added to each channel in order to remove parasitic capacitance due to external circuitry. In addition to the offset calibration capacitance which is a fine-tune offset capacitance, it is possible to support a larger offset by using the CAPDAC (for up to 100pF). These 16-bit registers are formatted as a fixed point number, where the first 5 bits represents the integer portion of the capacitance in Two's complement format, and the remaining 11 bits represent the fractional portion of the capacitance.

Table 6-6. Offset Calibration Registers Description (0x0D, 0x0E, 0x0F, 0x10)

Field Name	Bits		Description
OFFSET_CALn(1)	[15:11]	Integer part	Integer portion of the Offset Calibration of Channel CINn
	[10:0]	Decimal part	Decimal portion of the Offset Calibration of Channel CINn

(1) OFFSET_CAL1 = register 0x0D, OFFSET_CAL2 = register 0x0E, OFFSET_CAL3 = register 0x0F, OFFSET_CAL4 = register 0x10

6.6.1.5 Gain Calibration Registers

These registers contain a gain factor correction in the range of 0 to 4 that can be applied to each channel in order to remove gain mismatch due to the external circuitry. This 16-bit register is formatted as a fixed point number, where the 2 MSBs of the GAIN_CALn register correspond to an integer portion of the gain correction, and the remaining 14 bits represent the fractional portion of the gain correction. The result of the conversion represents a number without dimensions.

The Gain can be set according to the following formula:

$\text{Gain} = \text{GAIN_CAL}[15:0]/2^{14}$

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Table 6-7. Gain Calibration Registers Description (0x11, 0x12, 0x13, 0x14)

Field Name	Bits		Description
GAIN_CALn(1)	[15:14]	Integer part	Integer portion of the Gain Calibration of Channel CINn
	[13:0]	Decimal part	Decimal portion of the Gain Calibration of Channel CINn

(1) GAIN_CAL1 = register 0x11, GAIN_CAL2 = register 0x12, GAIN_CAL3 = register 0x13, GAIN_CAL4 = register 0x14

6.6.1.6 Manufacturer ID Register

This register contains a factory-programmable identification value that identifies this device as being manufactured by Texas Instruments. This register distinguishes this device from other devices that are on the same I^2C bus. The manufacturer ID reads 0x5449.

Table 6-8. Manufacturer ID Register Description (0xFE)

Field Name	Bits			Description
MANUFACTURER ID	[15:0]	Manufacturer ID	0x5449h	Texas instruments ID (read only)

6.6.1.7 Device ID Register

This register contains a factory-programmable identification value that identifies this device as a FDC1004. This register distinguishes this device from other devices that are on the same I2C bus. The Device ID for the FDC1004 is 0x1004.

Table 6-9. Device ID Register Description (0xFF)

Field Name	Bits			Description
DEVICE ID	[15:0]	Device ID	0x1004	FDC1004 Device ID (read only)

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7 Applications and Implementation

Note

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes, as well as validating and testing their design implementation to confirm system functionality.

7.1 Application Information

7.1.1 Liquid Level Sensor

The FDC1004 can be used to measure liquid level in non-conductive containers. Capacitive sensors can be attached to the outside of the container or be located remotely from the container, allowing for contactless measurements. The working principle is based on a ratiometric measurement; Figure 7-1 shows a possible system implementation which uses three electrodes. The Level electrode provides a capacitance value proportional to the liquid level. The Reference Environmental electrode and the Reference Liquid electrode are used as references. The Reference Liquid electrode accounts for the liquid dielectric constant and its variation, while the Reference Environmental electrode is used to compensate for any other environmental variations that are not due to the liquid itself. Note that the Reference Environmental electrode and the Reference Liquid electrode are the same physical size (h_{REF}).

For this application, single-ended measurements on the appropriate channels are appropriate, as the tank is grounded.

Use the following formula to determine the liquid level from the measured capacitances:

$$Level = h_{ref} \frac{C_{Lev} - C_{Lev}(0)}{C_{RL} - C_{RE}}$$

where

- C_{RE} is the capacitance of the Reference Environmental electrode,
- C_{RL} is the capacitance of the Reference Liquid electrode,
- C_{Lev} is the current value of the capacitance measured at the Level electrode sensor,
- $C_{Lev}(0)$ is the capacitance of the Level electrode when the container is empty, and
- h_{REF} is the height in the desired units of the Container or Liquid Reference electrodes.

7.1.2

The ratio between the capacitance of the level and the reference electrodes allows simple calculation of the liquid level inside the container itself. Very high sensitivity values (that is, many LSB/mm) can be obtained due to the high resolution of the FDC1004, even when the sensors are located remotely from the container.

For more information on a robust liquid level sensing technique, refer to the *Capacitive Sensing: Out-of-Phase Liquid Level Technique* application note and the *TIDA-00317 Capacitive-Based Liquid Level Sensing Sensor Reference Design*.

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7.2 Typical Application

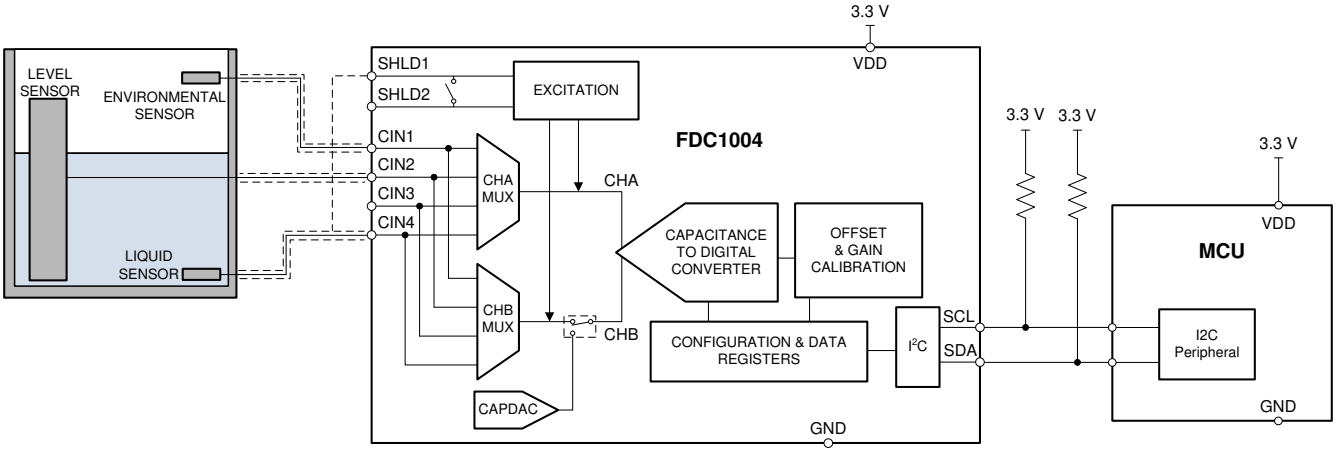


Figure 7-1. FDC1004 (Liquid Level Measurement)

7.2.1 Design Requirements

Make sure the liquid level measurement is independent of the liquid, which can be achieved using the 3-electrode design described above. Moreover, make sure the sensor is immune to environmental interferences such as a human body, other objects, or EMI. This can be achieved by shielding the side of the sensor which does not face the container.

7.2.2 Detailed Design Procedure

In capacitive sensing systems, the design of the sensor plays an important role in determining system performance and capabilities. In most cases the sensor is simply a metal plate that can be designed on the PCB.

The sensor used in this example is implemented with a two-layer PCB. On the top layer, which faces the tank, there are the 3 electrodes (Reference Environmental, Reference Liquid, and Level) with a ground plane surrounding the electrodes. The bottom layer is covered with a shield plane in order to isolate the electrodes from any external interference sources.

Depending on the shape of the container, the FDC1004 can be located on the sensor PCB to minimize the length of the traces between the input channels and the sensors and increase the immunity from EMI sources. In case the shape of the container or other mechanical constraints do not allow having the sensors and the FDC1004 on the same PCB, the traces which connect the channels to the sensor need to be shielded with the appropriate shield. In this design example all of the channels are shielded with SHLD1. For this configuration, the FDC1004 measures the capacitance of the 3 channels versus ground; and so the SHLD1 and SHLD2 pins are internally shorted in the FDC1004 (see *The Shield*).

7.2.3 Application Curve

The data shown below has been collected with the FDC1004EVM. A liquid level sensor with 3 electrodes like the one shown in the schematic was connected to the EVM. The plot shows the capacitance measured by the 3 electrodes at different levels of liquid in the tank. The capacitance of the Reference Liquid (the RF trace in the graph below) and Reference Environmental (the RE trace) sensors have a steady value when the liquid is above their height while the capacitance of the level sensor (Level) increases linearly with the height of the liquid in the tank.

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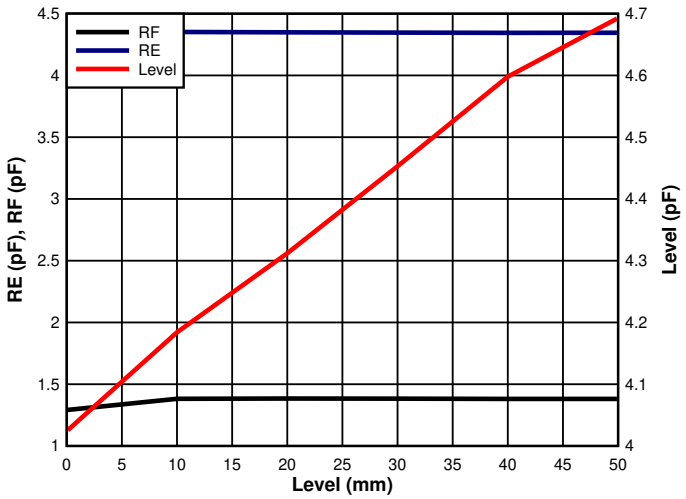


Figure 7-2. Electrode Capacitance vs Liquid Level

7.3 Best Design Practices

Avoid long traces to connect the sensor to the FDC1004. Short traces reduce parasitic capacitances between shield versus input channel and parasitic resistance between input channel versus GND and shield versus GND.

The sensor in many cases is simply a metal surface on a PCB, therefore the sensor must be protected with solder resist to avoid short circuits and limit any corrosion. Any change in the sensor can result in a change in system performance.

7.4 Initialization Set Up

At power on the device is in stand-by. It stays in this mode until a measurement is triggered.

7.5 Power Supply Recommendations

The FDC1004 requires a voltage supply within 3V and 3.6V. Two multilayer ceramic bypass X7R capacitors of 0.1 µF and 1µF, respectively between VDD and GND pin are recommended. Make sure the 0.1µF capacitor is closer to the VDD pin than the 1µF capacitor.

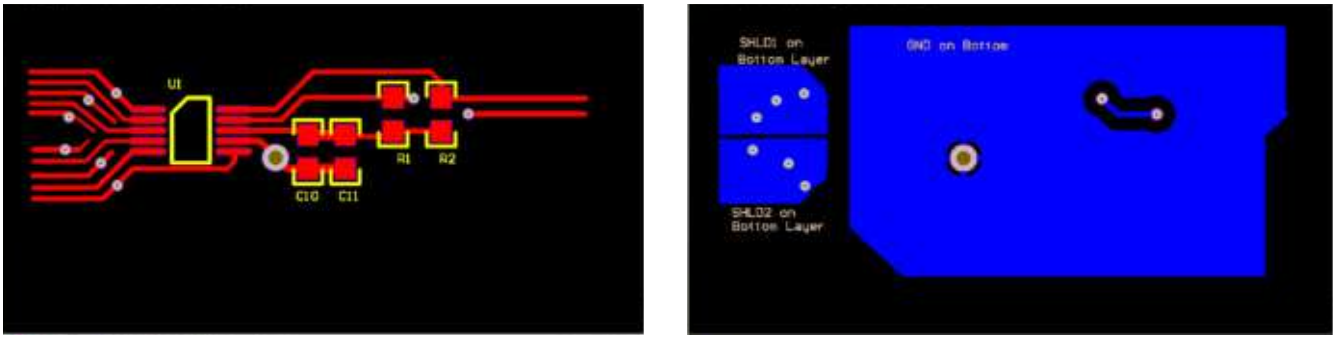
7.6 Layout

7.6.1 Layout Guidelines

The FDC1004 measures the capacitances connected between the CINn (n=1..4) pins and GND. To get the best result, locate the FDC1004 as close as possible to the capacitive sensor. Minimize the connection length between the sensor and FDC1004 CINn pins and between the sensor ground and the FDC1004 GND pin. If a shielded cable is used for remote sensor connection, connect the shield to the SHLDm (m=1...2) pin according to the configured measurement.

7.6.2 Layout Example

Figure 7-3 below is optimized for applications where the sensor is not too far from the FDC1004. Each channel trace runs between 2 shield traces. This layout allows the measurements of 4 single ended capacitance or 2 differential capacitance. The ground plane needs to be far from the channel traces, it is mandatory around or below the I2C pin.



TOP LAYER BOTTOM LAYER

Figure 7-3. Layout

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8 Device and Documentation Support

8.1 Documentation Support

8.1.1 Related Documentation

For related documentation, see the following:

- Texas Instruments, *Semiconductor and IC Package Thermal Metrics* application note
- Texas Instruments, *FDC1004: Basics of Capacitive Sensing and Applications* application note
- Texas Instruments, *Capacitive Sensing: Ins and Outs of Active Sensing* application note
- Texas Instruments, *Capacitive Sensing: Out-of-Phase Liquid Level Technique* application note
- Texas Instruments, *Capacitive Proximity Sensing Using the FDC1004* application note
- Texas Instruments, *Ice Buildup Detection Using TI's Capacitive Sensing Technology - FDC1004* application note
- Texas Instruments, *TIDA-00317 Capacitive-Based Liquid Level Sensing Sensor* reference design
- Texas Instruments, *TIDA-00506 Automotive Capacitive Proximity Kick to Open Detection* reference design
- Texas Instruments, *TIDA-00220 Capacitive-Based Human Proximity Detection for System Wake-Up & Interrupt* reference design
- Texas Instruments, *TIDA-00373 Backlight and Smart Lighting Control by Ambient Light and Proximity Sensor* reference design

8.2 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. Click on *Notifications* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

8.3 Support Resources

TI E2E™ support forums are an engineer's go-to source for fast, verified answers and design help — straight from the experts. Search existing answers or ask your own question to get the quick design help you need.

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8.4 Trademarks

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8.5 Electrostatic Discharge Caution



This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.6 Glossary

TI Glossary	This glossary lists and explains terms, acronyms, and definitions.

9 Revision History

Changes from Revision B (April 2015) to Revision C (October 2024)	Page
• Changed data sheet title from: FDC1004 4-Channel Capacitance-to-Digital Converter for Capacitive Sensing Solutions to: FDC1004 4-Channel Capacitance-to-Digital Converter for Capacitive Sensing Applications	1
• Updated the numbering format for tables, figures, and cross-references throughout the document	1
• Changed all instances of legacy terminology to controller and target where I^2C is mentioned	1
• Changed *Device Information* table to *Package Information*	1

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- Changed Equation 1 15

Changes from Revision A (October 2014) to Revision B (April 2015) **Page**

- Changed max temp range from 85C to 125C throughout 1
- Added VSSOP package type..... 1
- Deleted WSON DAP explicit assignment to GND in diagram..... 3
- Added VSSOP package diagram 3
- Changed table from Handling Ratings to ESD Ratings and moved Storage Temp to Absolute Maximum Ratings 4
- Added JA thermal resistance for VSSOP package 4
- Added JC thermal resistance for WSON package 4
- Added JC thermal resistance for VSSOP package 4
- Added JC thermal resistance for WSON package 4
- Added JB thermal resistance for VSSOP package 4
- Added note to Electrical Characteristics limits 5
- Changed TcC_{OFF} to "46" from "30"..... 5
- Changed G_{ERR} to "0.2" from "0.07" 5
- Changed gain error unit to "%" from "% of full scale"..... 5
- Changed tcG to "-37.5" from "2.1" 5
- Changed tcG unit to "ppm/°C" from "ppm of full scale/°C"..... 5
- Added testing for PSRR condition..... 5
- Changed PSRR to "13.6" from "11" 5
- Changed $FR_{CAPDAC}$to "96.9" from "96.875" 5
- Deleted CAPDAC resolution from EC table..... 5
- Changed $TcCOFF_{CAPDAC}$ to "30" from "1" 5
- Changed $TcCOFF_{CAPDAC}$to "fF" from "ppm of FS/°C" 5
- Changed DRV value of 400pF from typ and moved to max limit..... 5
- Added note to Electrical Characteristics table 5
- Changed plot for Active Supply Current vs Temperature due to change in temperature range 7
- Changed plot for Stand-by Supply Current vs Temperature due to change in temperature range 7
- Changed plot for Gain Drift vs Temperature due to change in temperature range and gain drift unit 7
- Changed plot for Offset Drift vs Temperature due to change in temperature range 7
- Added capacitance vs voltage plot 7
- Changed shield configuration example for differential mode from "CIN2-CIN1, where CHA=CIN2 and CHB=CIN1" to "CIN1-CIN2, where CHA=CIN1 and CHB=CIN2" 9
- Changed shield configuration example for differential mode from "CIN2-CIN1, where CHA=CIN2 and CHB=CIN1" to "CIN1-CIN2, where CHA=CIN1 and CHB=CIN2" 11
- Changed plot for Active Supply Current vs Temperature due to change in temperature range 15

Changes from Revision * (August 2014) to Revision A (October 2014) **Page**

- Added Parameter not tested in production 5
- Changed CINx to CINn throughout 9
- Added note for Applications and Implementation section..... 19

10 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

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PACKAGING INFORMATION

Orderable part number	Status (1)	Material type (2)	Package | Pins	Package qty | Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
FDC1004DGSR	Active	Production	VSSOP (DGS) | 10	3500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	ZBNX
FDC1004DGSR.A	Active	Production	VSSOP (DGS) | 10	3500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	ZBNX
FDC1004DGSR.B	Active	Production	VSSOP (DGS) | 10	3500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	ZBNX
FDC1004DGST	Obsolete	Production	VSSOP (DGS) | 10	-	-	Call TI	Call TI	-40 to 125	ZBNX
FDC1004DSCJ	Active	Production	WSON (DSC) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCJ.A	Active	Production	WSON (DSC) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCJ.B	Active	Production	WSON (DSC) | 10	4500 | LARGE T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCR	Active	Production	WSON (DSC) | 10	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCR.A	Active	Production	WSON (DSC) | 10	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCR.B	Active	Production	WSON (DSC) | 10	1000 | SMALL T&R	Yes	SN	Level-1-260C-UNLIM	-40 to 125	F1004
FDC1004DSCT	Obsolete	Production	WSON (DSC) | 10	-	-	Call TI	Call TI	-40 to 125	F1004

(1) **Status:** For more details on status, see our product life cycle.

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF FDC1004 :

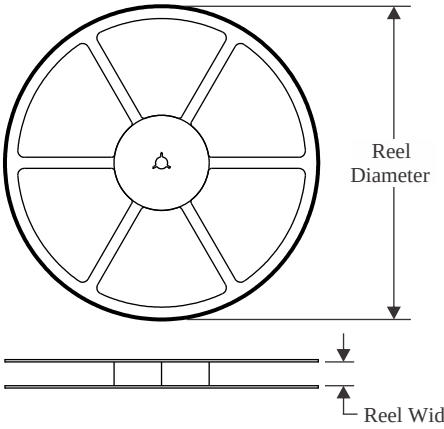
- Automotive : FDC1004-Q1

NOTE: Qualified Version Definitions:

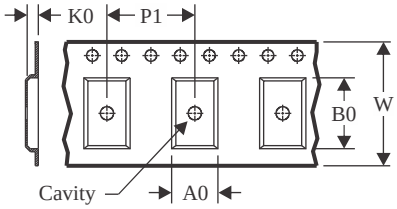
- Automotive - Q100 devices qualified for high-reliability automotive applications targeting zero defects

TAPE AND REEL INFORMATION

REEL DIMENSIONS

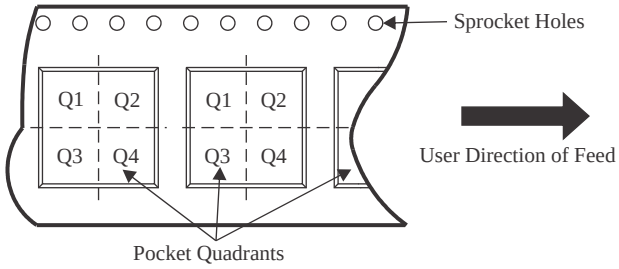


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

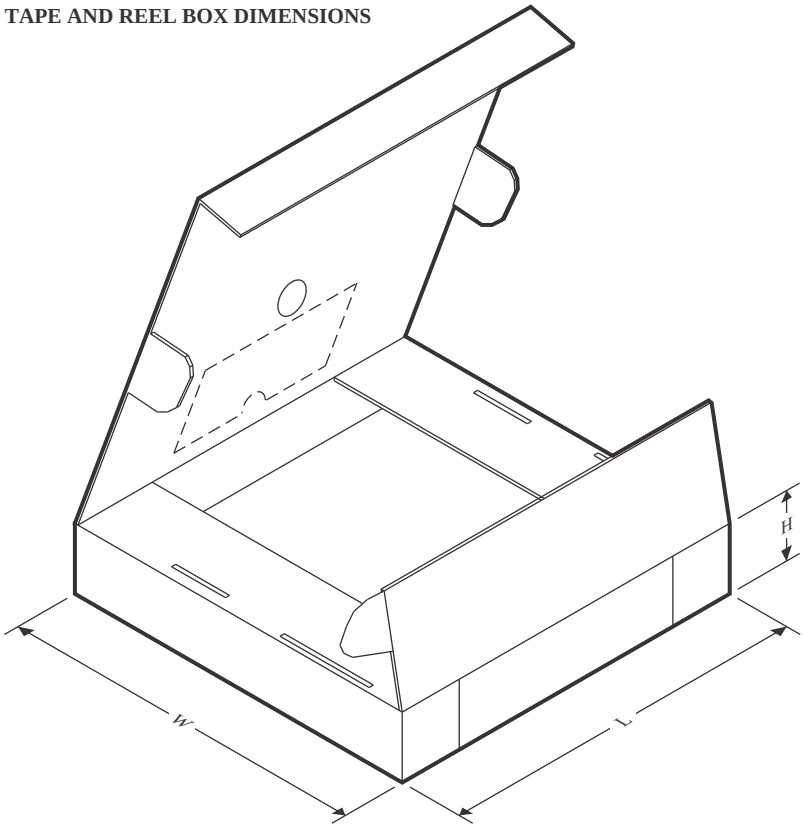
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
FDC1004DGSR	VSSOP	DGS	10	3500	330.0	12.4	5.3	3.4	1.4	8.0	12.0	Q1
FDC1004DSCJ	WSON	DSC	10	4500	330.0	12.4	3.3	3.3	1.0	8.0	12.0	Q1
FDC1004DSCR	WSON	DSC	10	1000	177.8	12.4	3.3	3.3	1.0	8.0	12.0	Q1

TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
FDC1004DGSR	VSSOP	DGS	10	3500	367.0	367.0	35.0
FDC1004DSCJ	WSON	DSC	10	4500	367.0	367.0	35.0
FDC1004DSCR	WSON	DSC	10	1000	210.0	185.0	35.0

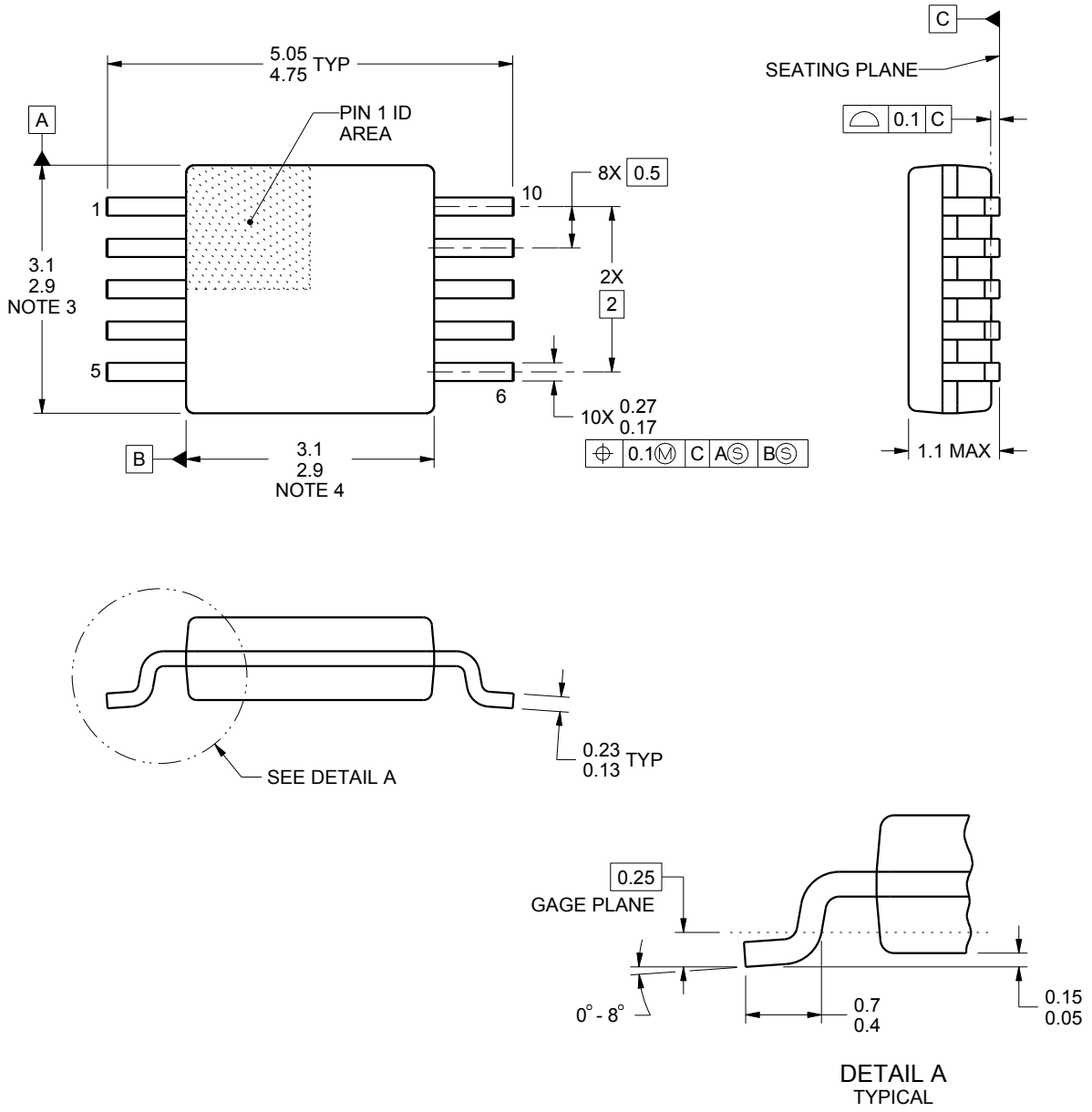


PACKAGE OUTLINE

DGS0010A

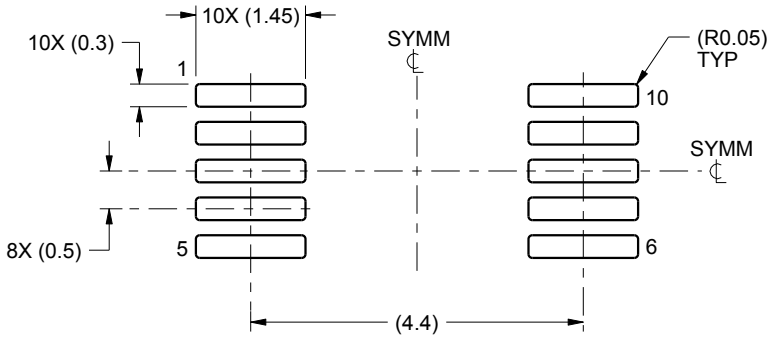
VSSOP - 1.1 mm max height

SMALL OUTLINE PACKAGE

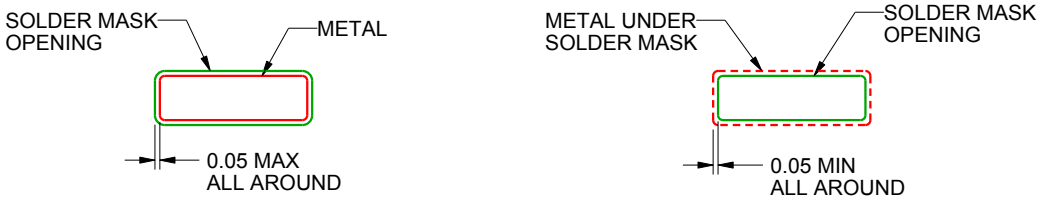


NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm per side.
5. Reference JEDEC registration MO-187, variation BA.



LAND PATTERN EXAMPLE
SCALE:10X

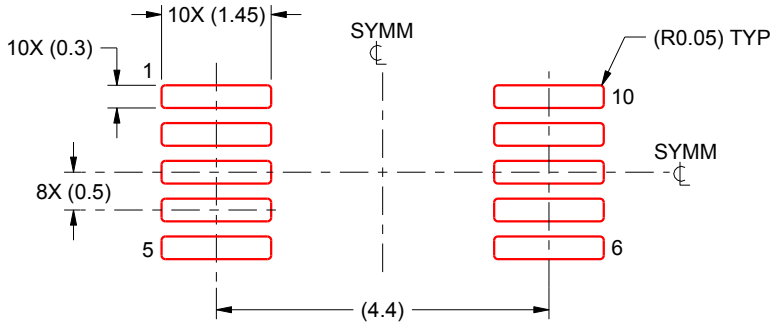


SOLDER MASK DETAILS
NOT TO SCALE

4221984/A 05/2015

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

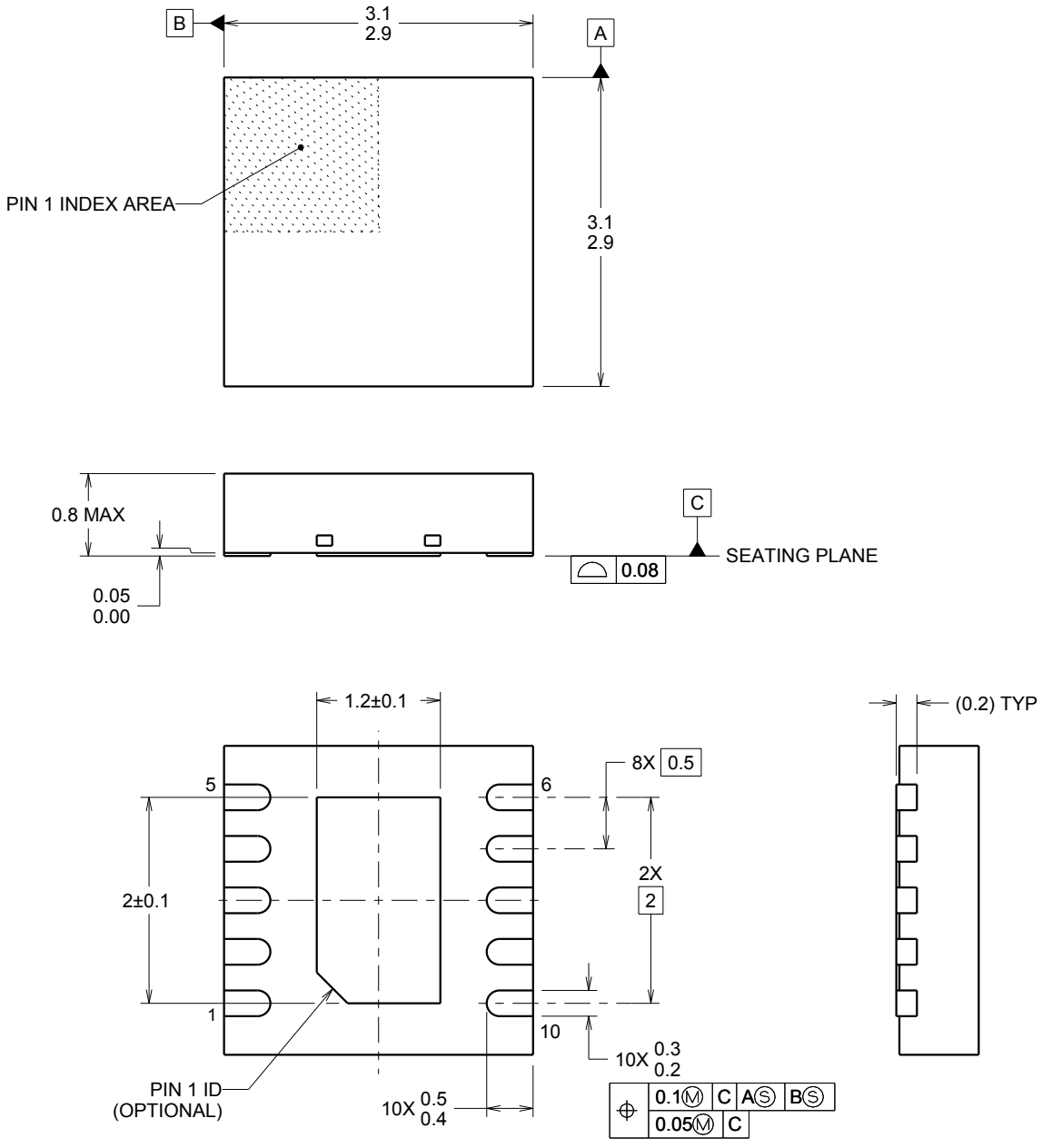


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:10X

4221984/A 05/2015

NOTES: (continued)

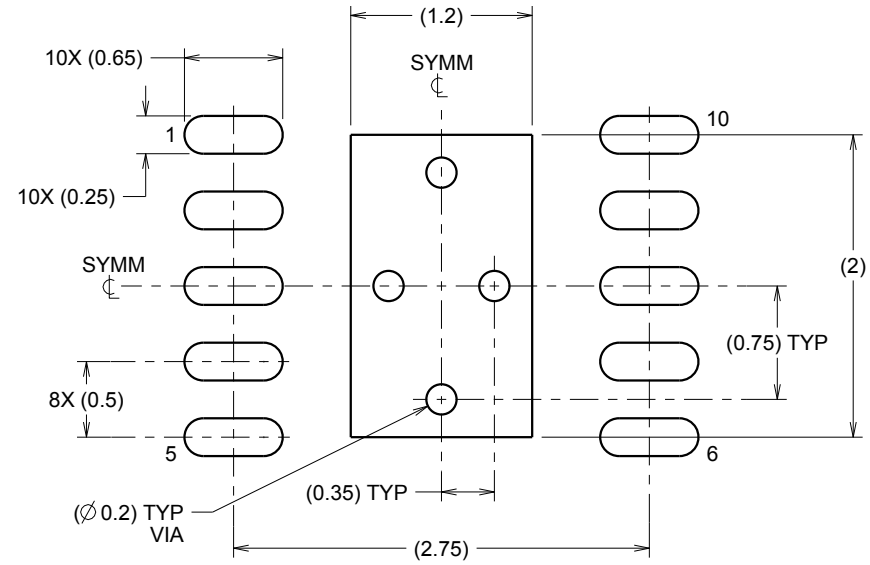
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.



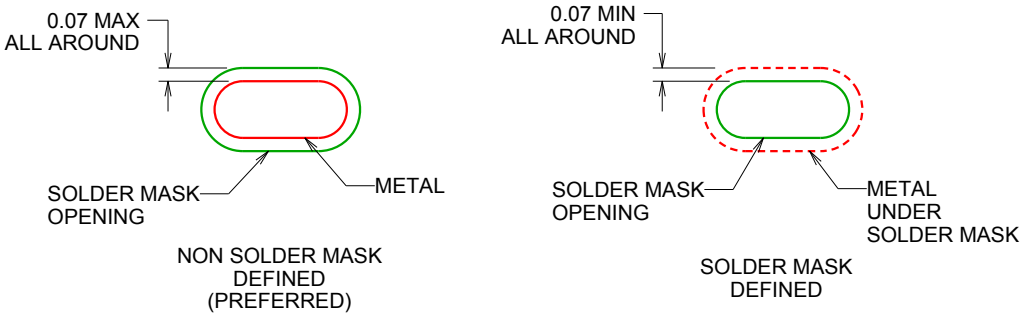
4214926/A 07/2014

NOTES:

1. All linear dimensions are in millimeters. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. The package thermal pad must be soldered to the printed circuit board for thermal and mechanical performance.



LAND PATTERN EXAMPLE
SCALE:20X

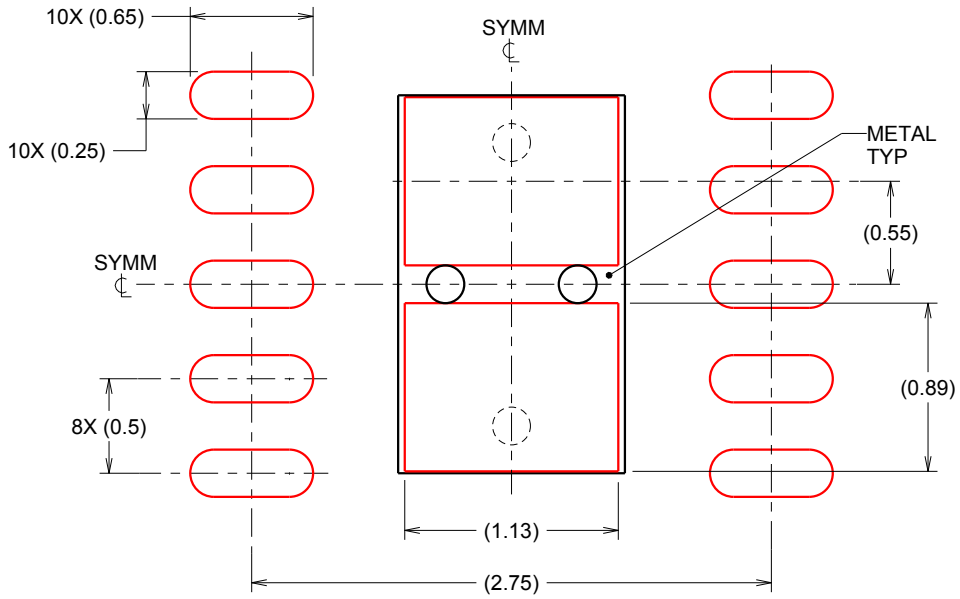


SOLDER MASK DETAILS

4214926/A 07/2014

NOTES: (continued)

4. This package is designed to be soldered to a thermal pad on the board. For more information, see Texas Instruments literature number SLUA271 (www.ti.com/lit/slua271).



SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL

EXPOSED PAD
84% PRINTED SOLDER COVERAGE BY AREA
SCALE:25X

4214926/A 07/2014

NOTES: (continued)

5. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.

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