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## WIRELESS & SENSING

### GENERAL DESCRIPTION

The SX9300 is the world's first dual channel capacitive Specific Absorption Rate (SAR) controller that accurately discriminates between an inanimate object and human body proximity.  The resulting detection is used in portable electronic devices to reduce and control radio-frequency (RF) emission power in the presence of a human body, enabling significant performance advantages for manufacturers of electronic devices with electro-magnetic radiation sources to meet stringent emission regulations' criteria and Specific Absorption Rate (SAR) standards.  Operating directly from an input supply voltage of 2.7 to 5.5V, the SX9300 outputs its data via a 1.65 – 5.5V host compatible I2C serial bus.

The I2C serial communication bus port is compatible with 1.8V host control to report body detection/proximity and to facilitate parameter settings adjustment.  Upon proximity detection, the NIRQ output asserts, enabling the user to either determine the relative proximity distance, or simply obtain an indication of detection.

The SX9300 includes an on-chip auto-calibration controller that regularly performs sensitivity adjustments to maintain peak performance over a wide variation of temperature, humidity and noise environments, providing simplified product development and enhanced performance.  A dedicated transmit enable (TXEN) pin is available to synchronize proximity measurements to RF transmission, enabling very low supply current and high noise immunity by only measuring proximity when requested.

### KEY PRODUCT FEATURES

♦ **2.7 – 5.5V Input Supply Voltage**
♦ **Dual SAR Capacitive Sensor Inputs**
   ❖ On-Chip SAR Engine For Body versus Inanimate Object Detection
   ❖ Down to 0.08 fF Capacitance Resolution
   ❖ Stable Proximity Sensing With Temperature
   ❖ 20mm detection distance
   ❖ Capacitance Offset Compensation up to 30pF
♦ **Active Sensor Guarding**
♦ **Automatic Calibration**
♦ **Ultra Low Power Consumption:**
   ❖ Active Mode:      170 uA
   ❖ Doze Mode:       18 uA
   ❖ Sleep Mode:      2.5 uA
♦ **400kHz I2C Serial Interface**
   ❖ Four  programmable I2C Sub-Addresses
   ❖ Input Levels Compatible with 1.8V Host Processors
♦ **Open Drain NIRQ Interrupt pin**
♦ **Three (3) Reset Sources: POR, NRST pin, Soft Reset**
♦ **-40°C to +85°C Operation**
♦ **Compact Size: 3 x 3mm Thin QFN package**
♦ **Pb & Halogen Free, RoHS/WEEE compliant**

### APPLICATIONS

- SAR Compliant Systems
- Notebooks
- Tablets
- Mobile Phones
- Mobile Hot Spots

### ORDERING INFORMATION

| Part Number | Package | Marking |
|---|---|---|
| SX9300IULTRT [1] | QFN-20 | ZM5C |
| SX9300EVKA | Eval. Kit | - |

[1] 3000 Units/reel

### TYPICAL APPLICATION CIRCUIT

## Table of Contents

## 1   GENERAL DESCRIPTION

### 1.1   Pin Diagram
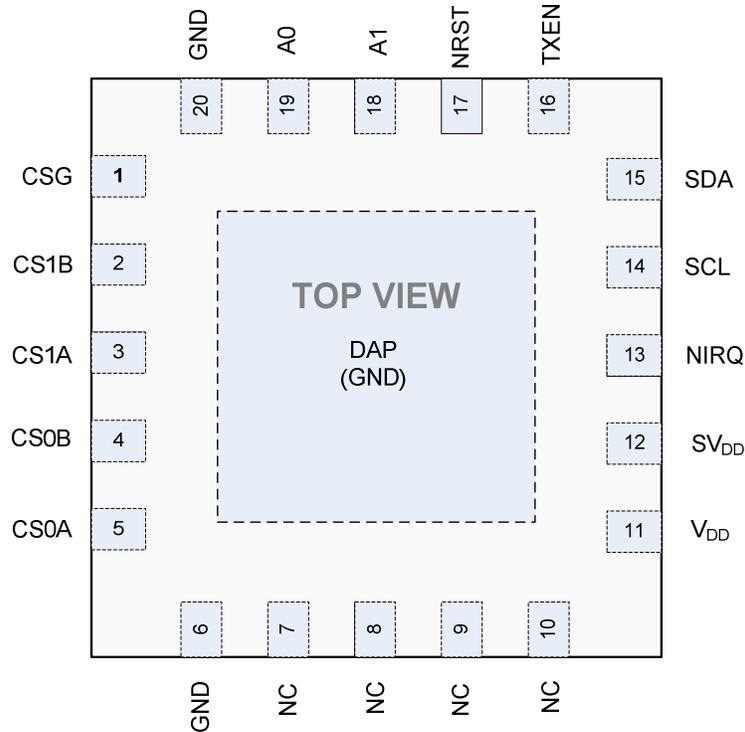


**Figure 1: Pin Diagram**

### 1.2   Marking Information
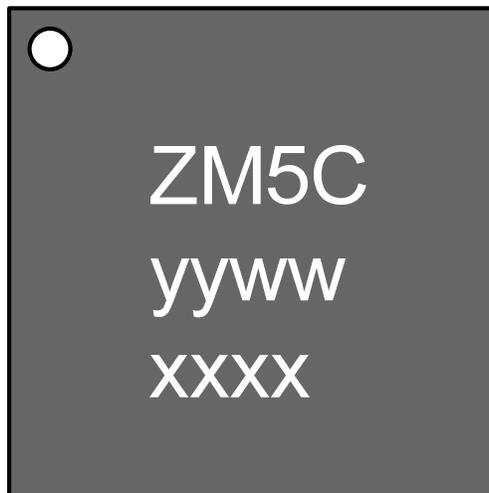


yyww= Date Code
xxxx =  Lot Number

**Figure 2: Marking Information**

## 1.3 Pin Description

| Number | Name | Type | Description |
|--------|------|------|-------------|
| 1 | CSG | Analog | Capacitive Sensor Guard/Shield |
| 2 | CS1B | Analog | Capacitive Sensor B (inner) of pair 1 |
| 3 | CS1A | Analog | Capacitive Sensor A (outer) of pair 1 |
| 4 | CS0B | Analog | Capacitive Sensor B (inner) of pair 0 |
| 5 | CS0A | Analog | Capacitive Sensor A (outer) of pair 0 |
| 6 | GND | Ground | Ground |
| 7 | NC | Not Used | Do Not Connect |
| 8 | NC | Not Used | Do Not Connect |
| 9 | NC | Not Used | Do Not Connect |
| 10 | NC | Not Used | Do Not Connect |
| 11 | $V_{DD}$ | Power | Core power supply |
| 12 | $SV_{DD}$ | Power | Host interface power supply.<br>Must be ≤$V_{DD}$ at all times (including during power-up and power-down) |
| 13 | NIRQ | Digital Output | Interrupt request, active LOW, requires pull-up resistor to $SV_{DD}$ |
| 14 | SCL | Digital Input | I2C Clock, requires pull-up resistor to $SV_{DD}$ |
| 15 | SDA | Digital I/O | I2C Data, requires pull-up resistor to $SV_{DD}$ |
| 16 | TXEN | Digital Input | Transmit Enable, active HIGH (Tie to $SV_{DD}$ if not used). |
| 17 | NRST | Digital Input | External reset, active LOW (Tie to $SV_{DD}$ if not used). |
| 18 | A1 | Digital Input | I2C Sub-Address, connect  to GND or $V_{DD}$ |
| 19 | A0 | Digital Input | I2C Sub-Address, connect  to GND or $V_{DD}$ |
| 20 | GND | Ground | Ground |
| DAP | GND | Ground | Exposed Pad.  Connect to Ground |

*Table 1: Pin Description*

## 1.4 Acronyms

DAP          Die Attach Paddle
SAR          Specific Absorption Rate
RF            Radio Frequency

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## 2   ELECTRICAL CHARACTERISTICS

### 2.1   Absolute Maximum Ratings

*Stresses above the values listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at these, or any other conditions beyond the "Operating Conditions", is not implied.  Exposure to Absolute Maximum Rating conditions for extended periods may affect device reliability and proper functionality.*

| Parameter | Symbol | Min | Max | Unit |
|---|---|---|---|---|
| Supply Voltage | $V_{DD}$ | -0.5 | 6.0 | V |
|  | $SV_{DD}$ | -0.5 | 6.0 |  |
| Input Voltage (non-supply pins) | $V_{IN}$ | -0.5 | $V_{DD}$+0.3 |  |
| Input Current (non-supply pins) | $I_{IN}$ | -10 | 10 | mA |
| Operating Junction Temperature | $T_{JCT}$ | -40 | 125 | °C |
| Reflow Temperature | $T_{RE}$ | - | 260 |  |
| Storage Temperature | $T_{STOR}$ | -50 | 150 |  |
| ESD HBM (Human Body model, to JESD22-A114) | $ESD_{HBM}$ | 8 | - | kV |

*Table 2: Absolute Maximum Ratings*

### 2.2   Operating Conditions

| Parameter | Symbol | Min | Max | Unit |
|---|---|---|---|---|
| Supply Voltage | $V_{DD}$ | 2.7 | 5.5 | V |
|  | $SV_{DD}$ | 1.65 | $V_{DD}$ |  |
| Ambient Temperature | $T_A$ | -40 | 85 | °C |

*Table 3: Operating Conditions*

Note: During power-up or power-down, SVDD must be less than or equal to VDD

### 2.3   Thermal Characteristics

| Parameter | Symbol | Typical | Unit |
|---|---|---|---|
| Thermal Resistance – Junction to Air  (Static Airflow) | $\theta_{JA}$ | 34 | °C/W |

*Table 4: Thermal Characteristics*

Note: $\theta_{JA}$ is calculated from a package in still air, mounted to 3" x 4.5", 4-layer FR4 PCB with thermal vias under exposed pad per JESD51 standards.

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### 2.4 Electrical Specifications

*All values are valid within the operating conditions unless otherwise specified.*
*Typical values are given for $T_A$= +25°C, VDD=SVDD=3.3V unless otherwise specified.*

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Current Consumption** | | | | | | |
| Sleep (no sensor enabled) | $I_{SLEEP}$ | Power down, all analog circuits shut down. (I2C listening) | - | 2.5 | - | |
| Doze (all sensors enabled) | $I_{DOZE}$ | SCANPERIOD = 200ms DOZEPERIOD = 2xSCANPERIOD FREQ = 167kHz RESOLUTION = Medium VDD = 5V | - | 18 | - | uA |
| Active (all sensors enabled) | $I_{ACTIVE}$ | SCANPERIOD = 30ms FREQ = 167kHz RESOLUTION = Medium VDD = 5V | - | 170 | - | |
| **Outputs: SDA, NIRQ** | | | | | | |
| Output Current at Output Low Voltage | $I_{OL}$ | VOL = 0.4V | 6 | - | - | mA |
| Maximum Output LOW Voltage | $V_{OL}(Max)$ | $SV_{DD}$ > 2V | - | - | 0.4 | V |
| | | $SV_{DD}$ ≤ 2V | - | - | 0.2 x $SV_{DD}$ | |
| **Inputs: SCL, SDA, TXEN** | | | | | | |
| Input logic high | $V_{IH}$ | | 0.8 x $SV_{DD}$ | - | $SV_{DD}$ + 0.3 | V |
| Input logic low | $V_{IL}$ | | -0.3 | - | 0.25 x $SV_{DD}$ | |
| Input leakage current | $I_L$ | CMOS input | -1 | - | 1 | uA |
| Hysteresis | $V_{HYS}$ | $SV_{DD}$ > 2V | - | 0.05x $SV_{DD}$ | - | V |
| | | $SV_{DD}$ ≤ 2V | - | 0.1x $SV_{DD}$ | - | |
| TXEN Delay | $TXEN_{ACTDLY}$ | Delay between TXEN rising edge and SX9300 starting measurements | - | 100 | - | µs |
| **Inputs: A0, A1** | | | | | | |
| Input logic high | $V_{IH}$ | | 0.7 x $V_{DD}$ | - | $V_{DD}$ + 0.3 | V |
| Input logic low | $V_{IL}$ | | -0.3 | - | 0.3 x $V_{DD}$ | |

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **Input: NRST** | | | | | | |
| Input logic high | $V_{IH}$ | $SV_{DD}$ > 2V | 0.7 x $SV_{DD}$ | - | $SV_{DD}$ + 0.3 | V |
| | | $SV_{DD}$ ≤ 2V | 0.75 x $SV_{DD}$ | - | | |
| Input logic low | $V_{IL}$ | $SV_{DD}$ > 2V | - | - | 0.6 | |
| | | $SV_{DD}$ ≤ 2V | - | - | 0.3 x $SV_{DD}$ | |
| NRST minimum pulse width | $T_{RESETPW}$ | | 2 | - | - | µs |
| **Start-up** | | | | | | |
| Power-up time | $T_{POR}$ | | - | 1 | - | ms |

*Table 5: Electrical Specifications*

**WIRELESS & SENSING**

| Parameter | Symbol | Conditions | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| **I2C Timing Specifications** (Cf. Figure 3 and Figure 4 below) | | | | | | |
| SCL clock frequency | $f_{SCL}$ | | - | - | 400 | kHz |
| SCL low period | $t_{LOW}$ | | 1.3 | - | - | |
| SCL high period | $t_{HIGH}$ | | 0.6 | - | - | |
| Data setup time | $t_{SU;DAT}$ | | 0.1 | - | - | |
| Data hold time | $t_{HD;DAT}$ | | 0 | - | - | |
| Repeated start setup time | $t_{SU;STA}$ | | 0.6 | - | - | us |
| Start condition hold time | $t_{HD;STA}$ | | 0.6 | - | - | |
| Stop condition setup time | $t_{SU;STO}$ | | 0.6 | - | - | |
| Bus free time between stop and start | $t_{BUF}$ | | 1.3 | - | - | |
| Input glitch suppression | $t_{SP}$ | Note 1 | - | - | 50 | ns |

Note 1: Minimum glitch amplitude is $0.7V_{DD}$ at High level and Maximum $0.3V_{DD}$ at Low level.

*Table 6: I2C Timing Specifications*
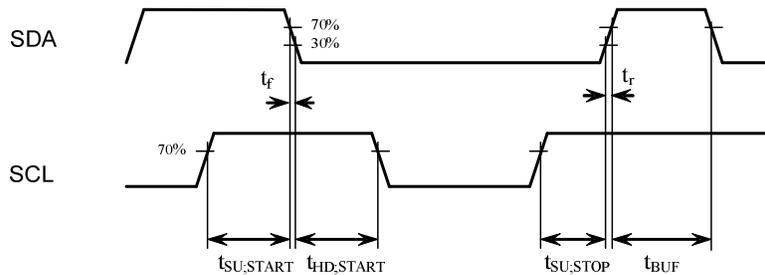


*Figure 3: I2C Start and Stop Timing*
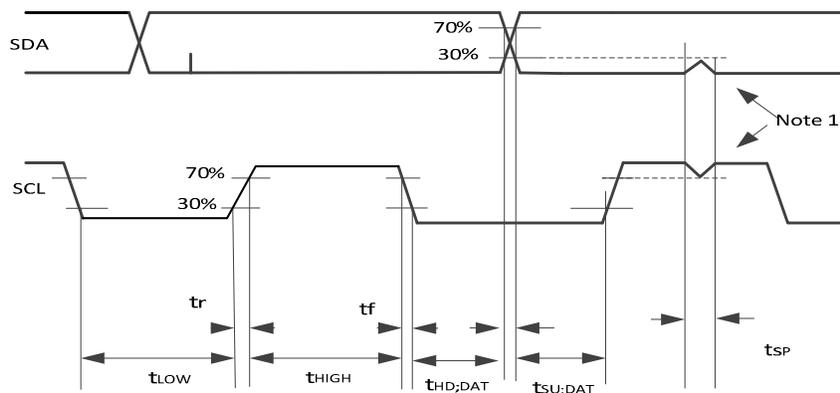


*Figure 4: I2C Data Timing*

## 3   PROXIMITY SENSING INTERFACE

### 3.1   Introduction

The purpose of the proximity sensing interface is to detect when a conductive object (usually a body part i.e. finger, palm, face, etc) is in the proximity of the system. Note that proximity sensing can be done thru the air or thru a solid (typically plastic) overlay (also called "touch" sensing).

The chip's proximity sensing interface is based on capacitive sensing technology. An overview is given in figure below.
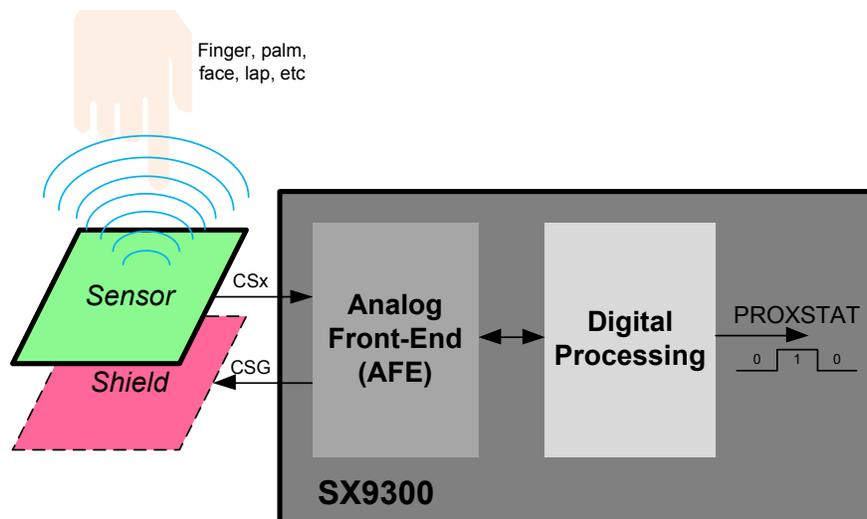


*Figure 5: Proximity Sensing Interface Overview*

- ❖ The sensor can be a simple copper area on a PCB or FPC for example. Its capacitance (to ground) will vary when a conductive object is moving in its proximity.

- ❖ The optional shield can be also be a simple copper area on a PCB or FPC below/under/around the sensor. It is used to protect the sensor against potential surrounding noise sources and improve its global performance. It also brings directivity to the sensing, for example sensing objects approaching from top only.

- ❖ The analog front-end (AFE) performs the raw sensor's capacitance measurement and converts it into a digital value. It also controls the shield. See §3.3 for more details.

- ❖ The digital processing block computes the raw capacitance measurement from the AFE and extracts a binary information PROXSTAT corresponding to the proximity status, i.e. object is "Far" or "Close". It also triggers AFE operations (compensation, etc). See §3.4 for more details.

### 3.2   Scan Period

To save power and since the proximity event is slow by nature, the chip will be waken-up regularly at every programmed scan period (SCANPERIOD) to first sense sequentially each of the enabled CSx pins and then process new proximity samples/info. The chip will be in idle mode most of the time. This is illustrated in figure below
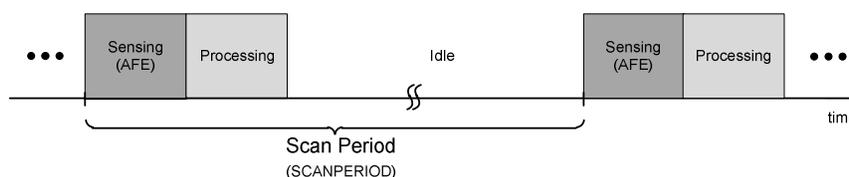


*Figure 6: Proximity Sensing Sequencing*

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The sensing and processing phase's durations vary with the number of sensors enabled, the sampling frequency, and the resolution programmed. During the Idle phase, the SX9300's analog circuits are turned off. Upon expiry of the idle timer, a new scan period cycle begins.

The scan period determines the minimum reaction time (actual/final reaction time also depends on debounce and filtering settings) and can be programmed from 30ms to 400ms.

## 3.3   Analog Front-End (AFE)

### 3.3.1   Capacitive Sensing Basics

Capacitive sensing is the art of measuring a small variation of capacitance in a noisy environment. As mentioned above, the chip's proximity sensing interface is based on capacitive sensing technology. In order to illustrate some of the user choices and compromises required when using this technology it is useful to understand its basic principles.

To illustrate the principle of capacitive sensing we will use the simplest implementation where the sensor is a copper plate on a PCB.

The figure below shows a cross-section and top view of a typical capacitive sensing implementation. The sensor connected to the chip is a simple copper area on top layer of the PCB. It is usually surrounded (shielded) by ground for noise immunity (shield function) but also indirectly couples via the grounds areas of the rest of the system (PCB ground traces/planes, housing, etc). For obvious reasons (design, isolation, robustness …) the sensor is stacked behind an overlay which is usually integrated in the housing of the complete system.
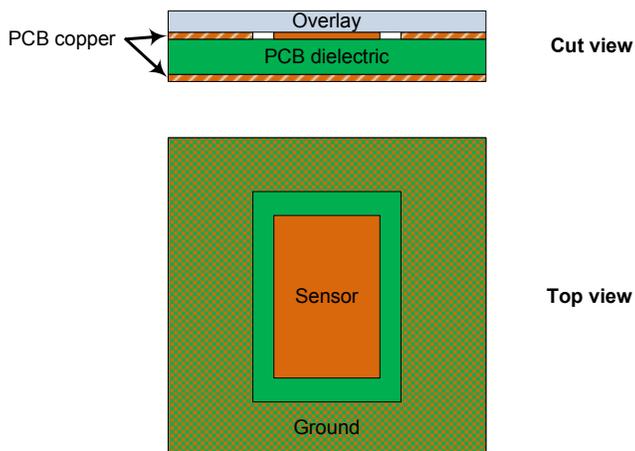


*Figure 7: Typical Capacitive Sensing Implementation*

When the conductive object to be detected (finger/palm/face, etc) is not present, the sensor only sees an inherent capacitance value $C_{Env}$ created by its electrical field's interaction with the environment, in particular with ground areas.

When the conductive object (finger/palm/face, etc) approaches, the electrical field around the sensor will be modified and the total capacitance seen by the sensor increased by the user capacitance $C_{User}$. This phenomenon is illustrated in the figure below.
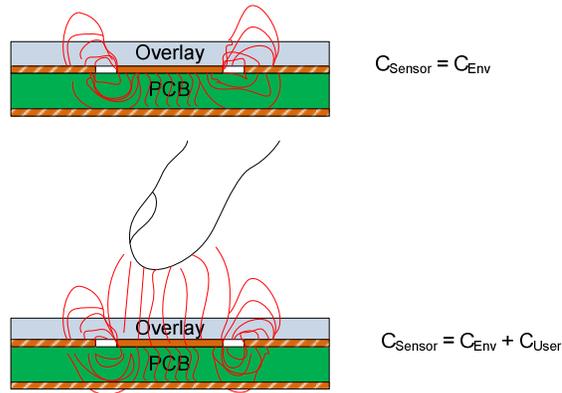
**Figure 8: Proximity Effect on Electrical Field and Sensor Capacitance**

The challenge of capacitive sensing is to detect this relatively small variation of $C_{Sensor}$ ($C_{User}$ usually contributes for a few percent only) and differentiate it from environmental noise ($C_{Env}$ also slowly varies together with the environment characteristics like temperature, etc). For this purpose, the chip integrates an auto offset compensation mechanism which dynamically monitors and removes the $C_{Env}$ component to extract and process $C_{User}$ only. See §3.3.5 for more details.

In first order, $C_{User}$ can be estimated by the formula below:

$$C_{User} = \frac{\varepsilon_o \cdot \varepsilon_r \cdot A}{d}$$

$A$ is the common area between the two electrodes hence the common area between the user's finger/palm/face and the sensor.

$d$ is the distance between the two electrodes hence the proximity distance between the user and the system.

$\varepsilon_o$ is the free space permittivity and is equal to 8.85 10e-12 F/m (constant)

$\varepsilon_r$ is the dielectric relative permittivity.

Typical permittivity of some common materials is given in the table below.

| Material | Typical $\varepsilon_r$ |
|---|---|
| Glass | 8 |
| FR4 | 5 |
| Acrylic Glass | 3 |
| Wood | 2 |
| **Air** | **1** |

**Table 7: Typical Permittivity of Some Common Materials**

From the discussions above we can conclude that the most robust and efficient design will be the one that minimizes $C_{Env}$ value and variations while improving $C_{User}$.

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### 3.3.2 AFE Block Diagram
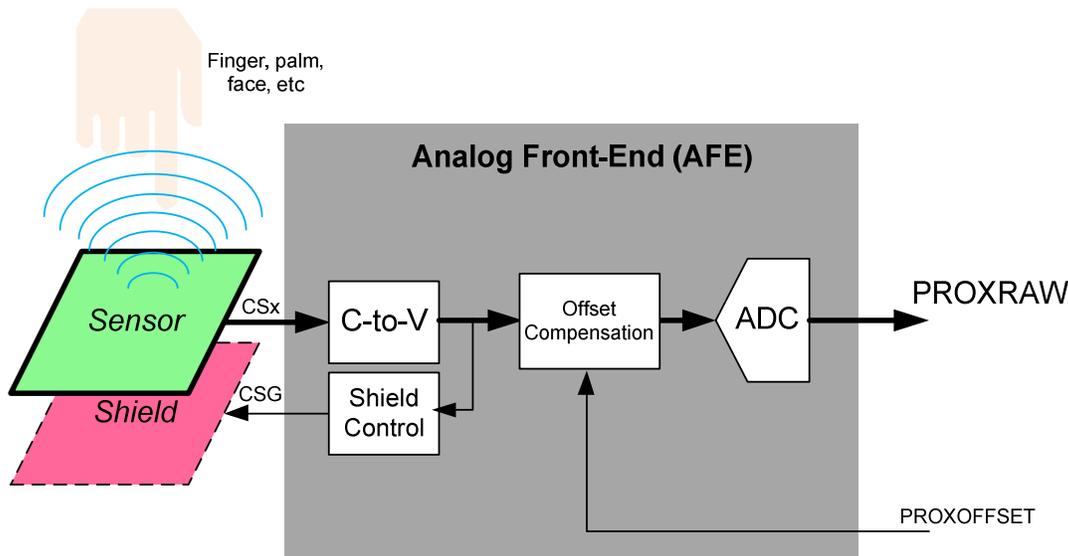


*Figure 9: Analog Front-End Block Diagram*

### 3.3.3 Capacitance-to-Voltage Conversion (C-to-V)

The sensitivity of the interface is defined by RANGE and GAIN parameters.

PROXFREQ defines the operating frequency of the interface and should be set as high as possible for power consumption reasons.

### 3.3.4 Shield Control

SHIELDEN allows enabling or disabling the shield function.

### 3.3.5 Offset Compensation

Offset compensation consists in performing a one-time measurement of $C_{Env}$ and subtracting it to the total capacitance $C_{Sensor}$ in order to feed the ADC with the closest contribution of $C_{User}$ only.
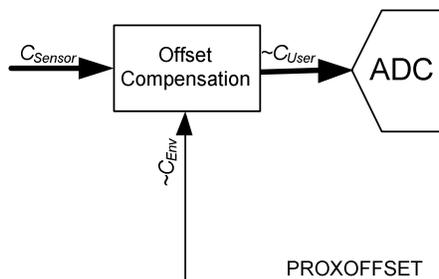


*Figure 10: Offset Compensation Block Diagram*

The ADC input $C_{User}$ is the total capacitance $C_{Sensor}$ to which $C_{Env}$ is subtracted.

There are five possible compensation sources which are illustrated in the figure below. When set to 1 by any of these sources, COMPSTAT will only be reset once the compensation is completed.
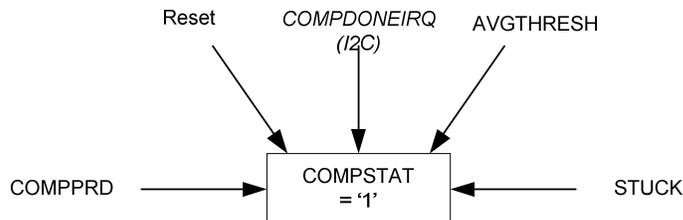


*Figure 11: Compensation Request Sources*

- **Reset:** a compensation for all sensors is automatically requested when a reset is performed (power-up, NRST pin, RegReset)

- **COMPDONEIRQ (I2C):** a compensation for all sensors can be manually requested anytime by the host through I2C interface by writing a 1 into COMPDONEIRQ.

- **AVGTHRESH:** a compensation for all sensors or only the affected one (depending on COMPMETHOD) can be automatically requested if it is detected that $C_{Env}$ has drifted beyond a predefined range programmed by the host.

- **COMPPRD:** a compensation can be automatically requested at a predefined rate programmed by the host.

- **STUCK:** a compensation can be automatically requested if it is detected that the proximity "Close" state lasts longer than a predefined duration programmed by the host.

Please note that the compensation request flag can be set anytime but the compensation itself is always done at the beginning of a scan period to keep all parameters coherent.
Also, when compensation occurs, all PROXSTAT flags turn OFF (ie no proximity detected) independently from the user's potential actual presence.

### 3.3.6 Analog-to-Digital Conversion (ADC)
An ADC is used to convert the analog capacitance information into a digital word PROXRAW.

## 3.4 Digital Processing

### 3.4.1 Overview
The main purpose of the digital processing block is to convert the raw capacitance information coming from the AFE (PROXRAW) into a robust and reliable digital flag (PROXSTAT) indicating if something is close to the proximity sensor.

The offset compensation performed in the AFE is a one-time measurement. However, the environment capacitance $C_{Env}$ may vary with time (temperature, nearby objects, etc). Hence, in order to get the best estimation of $C_{User}$ (PROXDIFF) it is needed to dynamically track and subtract $C_{Env}$ variations. This is performed by filtering PROXUSEFUL to extract its slow variations (PROXAVG).

PROXDIFF is then compared to user programmable threshold (PROXTHRESH) to extract PROXSTAT flag.

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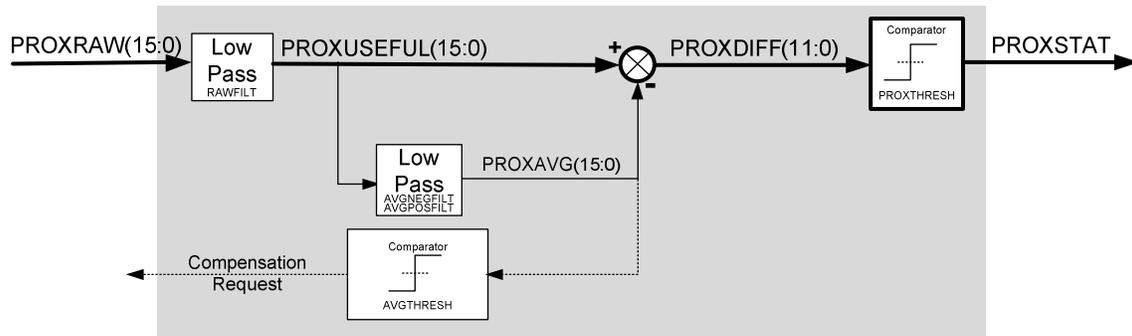


*Figure 12: Digital Processing Block Diagram*

Digital processing sequencing is illustrated in figure below. At every scan period wake-up, the block updates sequentially PROXRAW, PROXUSEFUL, PROXAVG, PROXDIFF and PROXSTAT before going back to Idle mode.
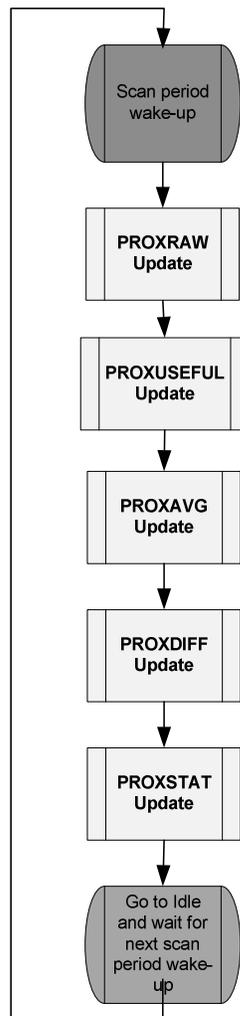


*Figure 13: Digital Processing Sequencing*

Digital processing block also updates COMPSTAT (set when compensation is currently pending execution or completion)

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### 3.4.2    PROXRAW Update

PROXRAW update consists mainly in starting the AFE and waiting for the new PROXRAW values (one for each CSx/sensor pin) to be ready. If compensation was pending it is performed first.
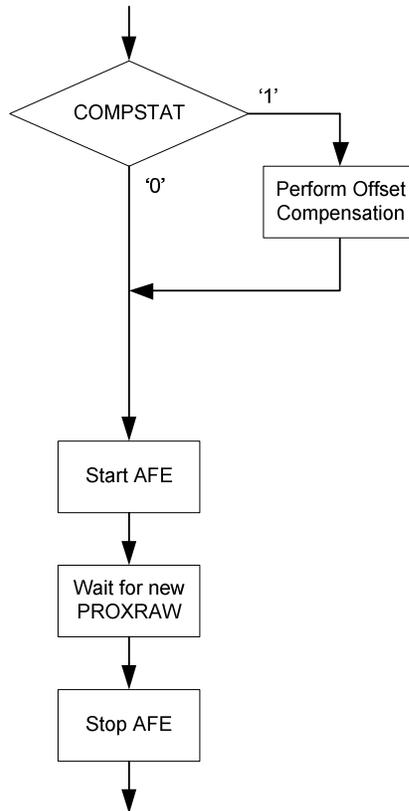


*Figure 14: ProxRaw Update*

Note that PROXRAW is not available in the "Sensor Data Readback" section of the registers. If needed it can be observed by setting RAWFILT=00 and reading PROXUSEFUL.

### 3.4.3    PROXUSEFUL Update

PROXUSEFUL update consists in filtering PROXRAW upfront to remove its potential high frequencies components(system noise, interferer, etc) and extract only user activity (few Hz max) and slow environment changes.
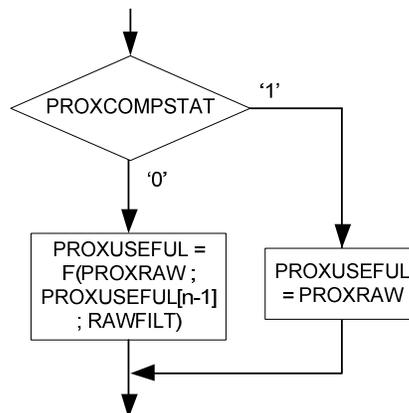


*Figure 15: PROXUSEFUL Update*

### 3.4.4    PROXAVG Update

PROXAVG update consists in averaging PROXUSEFUL to ignore its "fast" variations (i.e. user finger/palm/hand) and extract only the very slow variations of environment capacitance $C_{Env}$.

One can program a debounced threshold (AVGTHRESH/AVGDEB) to define a range within which PROXAVG can vary without triggering compensation (i.e. small acceptable environment drift).

Large positive values of PROXUSEFUL are considered as normal (user finger/hand/head) but large negative values are considered abnormal and should be compensated quickly. For this purpose, the averaging filter coefficient can be set independently for positive and negative variations via AVGPOSFILT and AVGNEGFILT. Typically we have AVGPOSFILT > AVGNEGFILT to filter out (abnormal) negative events faster.

To prevent PROXAVG to be "corrupted" by user activity (should only reflect environmental changes) it is frozen when proximity is detected.
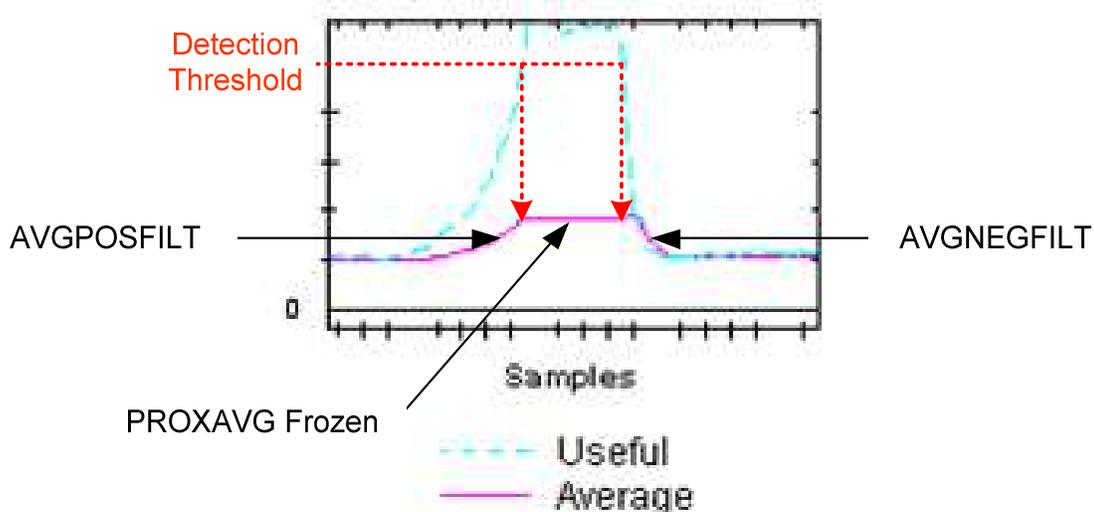


*Figure 16: ProxAvg vs Proximity Event*
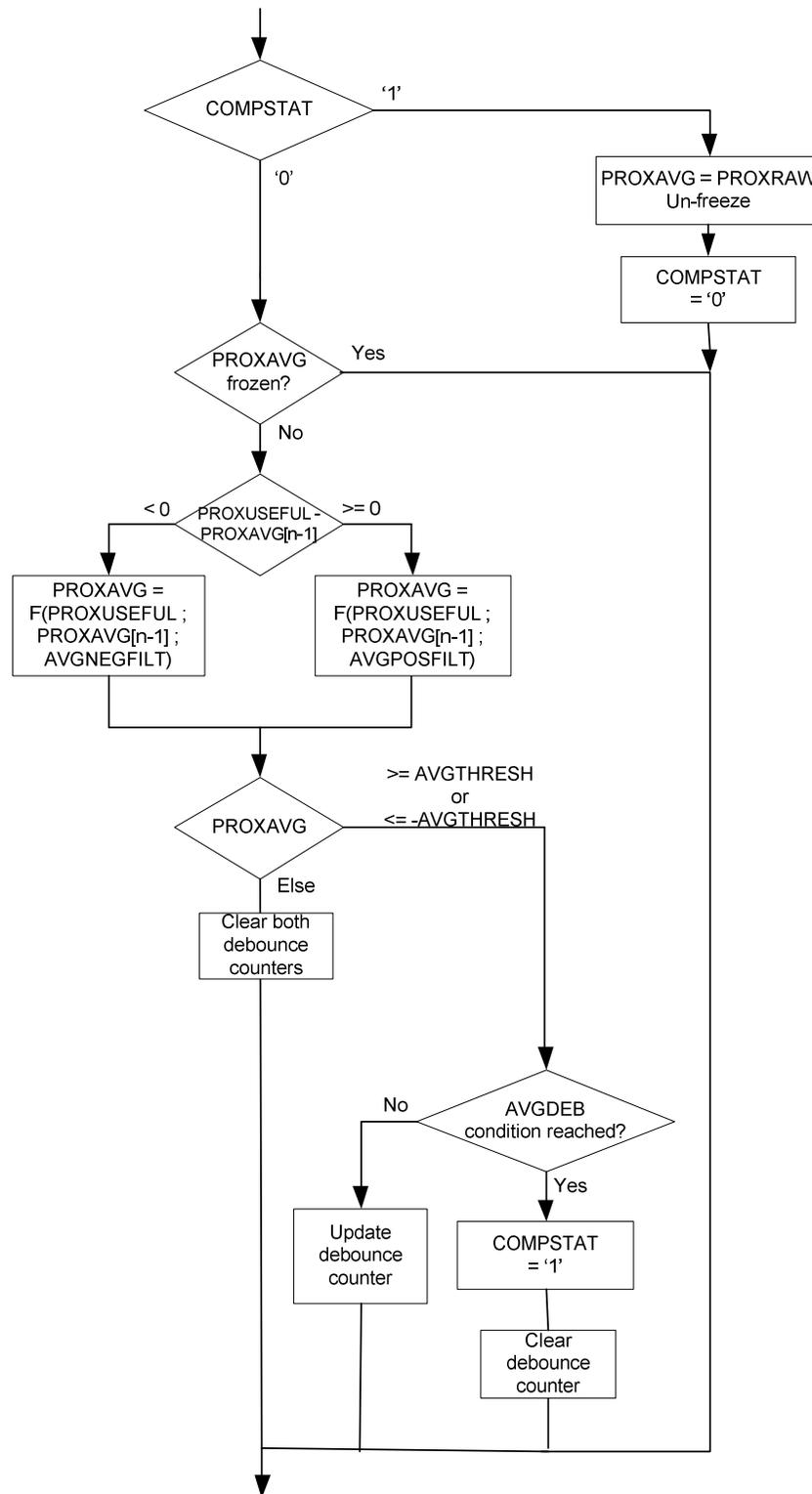
*Figure 17: ProxAvg Update*

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3.4.5 **PROXDIFF Update**

PROXDIFF update consists in the complementary operation i.e. subtracting PROXAVG to PROXUSEFUL to ignore slow capacitances variations ($C_{Env}$) and extract only the user related variations i.e. $C_{User}$.

$$PROXDIFF = [PROXUSEFUL - PROXAVG] >> 4$$
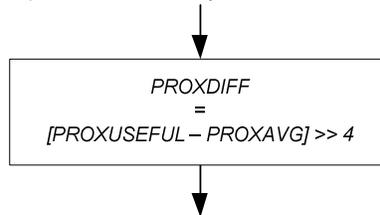
*Figure 18: ProxDiff Update*

Note that only the 12 upper bits of [PROXUSEFUL – PROXAVG] are kept for PROXDIFF.

3.4.6 **PROXSTAT Update**

PROXSTAT update consists in taking PROXDIFF information ($C_{User}$), comparing it with a user programmable threshold PROXTHRESH and finally updating PROXSTAT accordingly. When PROXSTAT=1, PROXAVG is frozen to prevent the user proximity signal averaging and hence absorbed into $C_{Env}$.
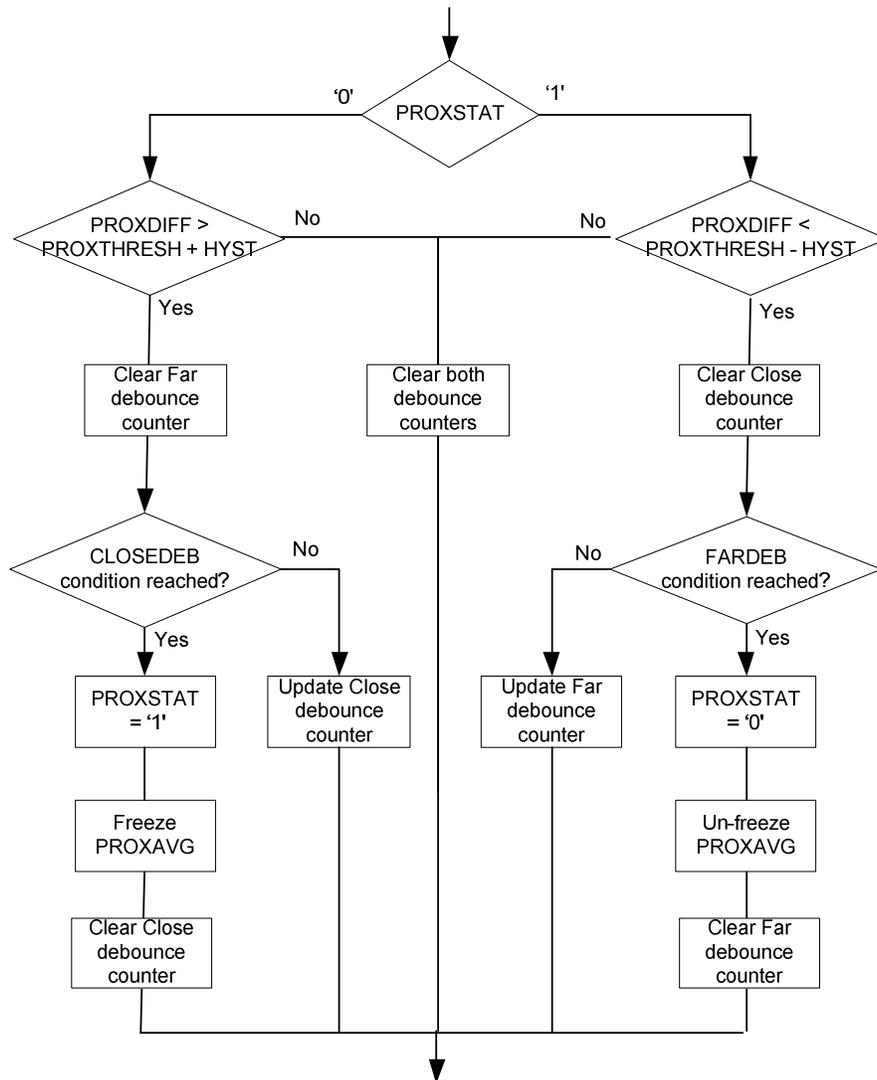


*Figure 19: PROXSTAT Update*

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## 3.5 Host Operation

An interrupt can be triggered when the user is detected to be close (in range), detected to be far (out of range), or both (CLOSEIRQEN, FARIRQEN).
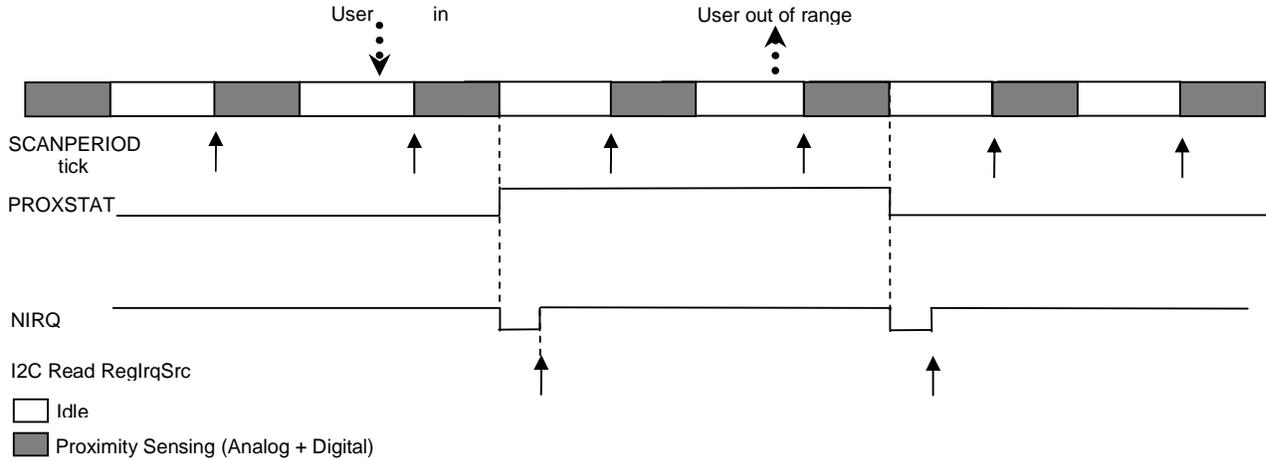


*Figure 20: Proximity Sensing Host Operation (RegIrqMsk[6:3] = 1100)*

An interrupt can also be triggered at the end of each proximity sensing operation, indicating to the host when the proximity sensing block is running (CONVDONEIRQEN). This may be used by the host to synchronize noisy system operations or to read sensor data (PROXUSEFUL, PROXAVG, PROXDIFF) synchronously for monitoring purposes.
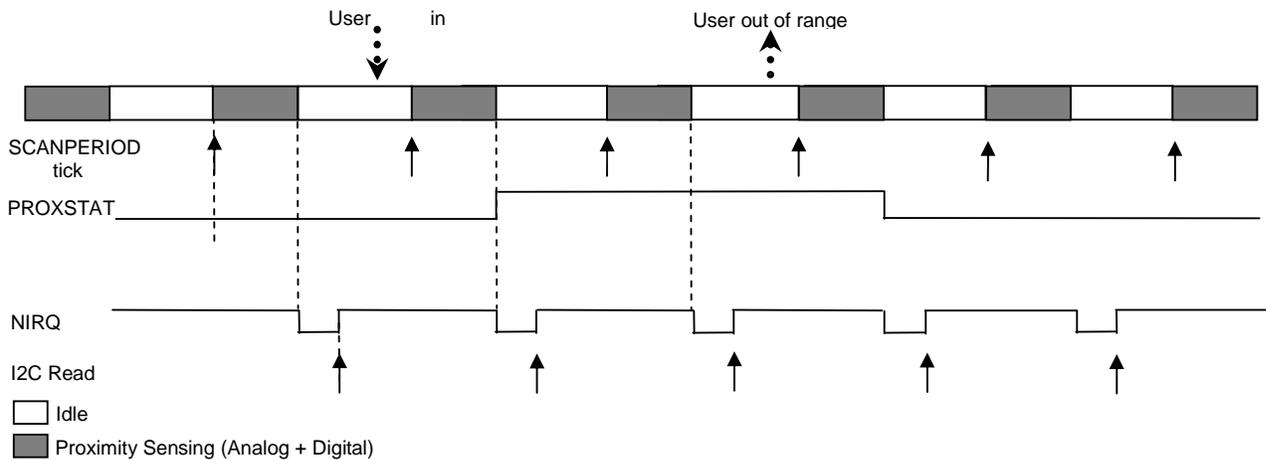


*Figure 21: Proximity Sensing Host Operation (RegIrqMsk[6:3] = 0001)*

In both cases above, an interrupt can also be triggered at the end of compensation (COMPDONEIRQEN).

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## 3.6 Operational Modes

### 3.6.1 Active

Active mode has the shortest scan periods, typically 30ms. In this mode, all enabled sensors are scanned and information data is processed within this interval. The Active scan period is user configurable (SCANPERIOD) and can be extended up to 400ms.

### 3.6.2 Doze

In some applications, the reaction/sensing time needs to be fast when the user is present (proximity detected), but can be slow when not detection has been done for some time.

The Doze mode, when enabled (DOZEEN), allows the chip to automatically switch between a fast scan period (SCANPERIOD) during proximity detection and a slow scan period (DOZEPERIOD) when no proximity is being detected (up to 6.4s). This allows reaching low average power consumption values at the expense obviously of longer reaction times.

As soon as proximity is detected on any sensor, the chip will automatically switch to Active mode while when it has not detected an object for DOZEPERIOD, it will automatically switch to Doze mode.

### 3.6.3 Sleep

Sleep mode can be entered by disabling all sensors (SENSOREN=0000). It places the SX9300 in its lowest power mode, with sensor scanning completely disabled and idle period set to continuous. In this mode, only the I2C serial bus is active. Enabling any sensor will make the chip leave Sleep mode (for Doze if enabled, else Active mode)

### 3.6.4 TXEN Pin

The TXEN input enables proximity sensing when HIGH, likewise when the TXEN input is LOW, the SX9300 is in Sleep mode. Specifically, on the rising edge of TXEN the SX9300 will begin measuring the sensors normally at the programmed rate (SCANPERIOD, DOZEPERIOD) as long as TXEN remains HIGH. When TXEN goes LOW the current measurement sequence will complete and then measurement will cease until the next rising edge of TXEN.

This feature can be used to synchronize proximity sensing with noisy and/or RF activity for example.

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## 4   SMART SAR ENGINE

### 4.1   Introduction

In addition to the proximity sensing interface, the SX9300 also embeds the world's first smart SAR engine which is able to discriminate between proximity generated by low permittivity (table) and high permittivity objects (body). This is typically useful for Specific Absorption Rate (SAR) applications in portable devices (tablets, cellphones, etc) where international regulations (FCC, ETSI, etc) impose to reduce RF power in the presence of human body for safety reasons.

Typical capacitive sensing solutions are not able to discriminate between proximity detection generated when a tablet for example is sitting on a table (no need to reduce RF power) vs when it is sitting the user's lap (need to reduce RF power) resulting in RF power and hence user's experience reduced significantly even when it is not needed.

The SX9300's unique smart SAR engine allows reducing RF power only in the presence of body (high permittivity material) and hence offering significantly better user experience while still conforming to safety regulations.

### 4.2   Sensor Design

In order to use SX9300's smart SAR engine, the sensors design must follow a few rules which are described in this section.

Each smart SAR sensor is physically made of two sensors (outer and inner) connected respectively to pins CSxA and CSxB. In the drawing below, the dark areas represent copper (conductor) and the light areas represents a non-conductor (spacing between the two copper areas).
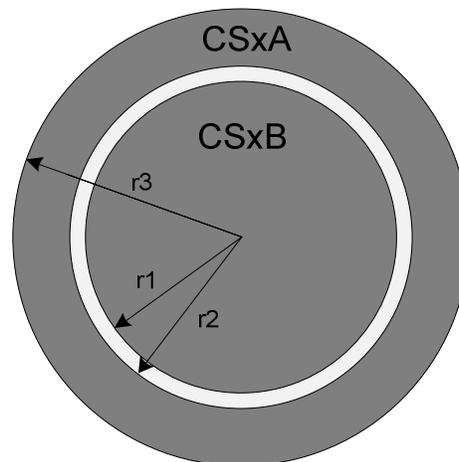


*Figure 22: Typical Smart SAR Capacitive Sensor*

**IMPORTANT:  The "A" and "B" sensors cannot be swapped.** The outer copper area is always the "A" sensor, and the inner copper area is always the "B" sensor else the smart SAR engine will not operate properly.

For each pair, the copper areas of CSxB and CSxA pads must be designed to be equal (as equal as the FPC/PCB technology tolerance allows).

Figure above illustrates an example of circular shape but smart SAR sensors can of course be designed in a variety of shapes (square, rectangular) depending on the physical/mechanical constraints of the system.

One SX9300 can support up to two pairs of sensors i.e. two smart SAR sensors.

### 4.3 Processing

The smart SAR engine is active for a pair of sensors when its CSxPROXSTAT is set i.e. both CSxA and CSxB's internal PROXSTAT values are set (i.e. both sensors of a the same pair have detected proximity).

When active, the smart SAR engine computes two real time values called delta and ratio (SARDELTA, SARRATIO), compares them to their respective user-defined debounced thresholds (SARDELTATHRESH, SARRATIOTHRESH, SARDEB) and updates CSxBODYSTAT accordingly (set to 1 when both delta and ratio exceed their respective thresholds).

Note that an hysteresis derivated from HYST is automatically applied to delta and ratio thresholds as defined below:

| HYST | Delta Threshold Hysteresis | Ratio Threshold Hysteresis |
|------|---------------------------|---------------------------|
| 00   | 2                         | 2                         |
| 01   | 4                         | 4                         |
| 10   | 8                         | 6                         |
| 11   | 16                        | 8                         |

*Table 8: Delta/Ratio Thresholds Hysteresis*

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## 5 I2C INTERFACE

### 5.1 Introduction

The I2C implemented on the SX9300 and used by the host to interact with it is compliant with:

- Standard (100kb/s) and fast mode (400kb/s)

- Slave mode

- 7-bit address (default is 0x28 assuming A1=A0=0)

The SX9300 has two I/O pins (A0 and A1) that provides four possible, user selectable I2C addresses:

| A1 | A0 | Address |
|----|----|---------|
| 0 | 0 | 0x28 |
| 0 | 1 | 0x29 |
| 1 | 0 | 0x2A |
| 1 | 1 | 0x2B |

*Table 9: I2C Sub-Address Selection*

The host can use the I2C to read and write data at any time, and these changes are effective immediately. Therefore the user should ideally disable the sensor before changing settings, or discard the results while changing.

### 5.2 I2C Write

The format of the I2C write is given in Figure 12. After the start condition [S], the slave address (SA) is sent, followed by an eighth bit ('0') indicating a Write. The SX9300 then Acknowledges [A] that it is being addressed, and the Master sends an 8 bit Data Byte consisting of the SX9300 Register Address (RA). The Slave Acknowledges [A] and the master sends the appropriate 8 bit Data Byte (WD0). Again the Slave Acknowledges [A]. In case the master needs to write more data, a succeeding 8 bit Data Byte will follow (WD1), acknowledged by the slave [A]. This sequence will be repeated until the master terminates the transfer with the Stop condition [P].

| S | SA | 0 | A | RA | A | WD0 | A | WD1 | A | • • • | WDn | A | P |

optional          optional

S:   Start condition
SA:  Slave Address
A:   Acknowledge
RA:  Register Address
WDn: Write Data byte (0…n)
P:   Stop condition

☐ from master to slave
☐ from slave to master
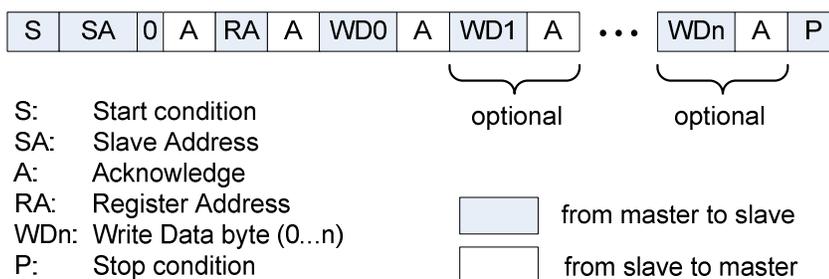
*Figure 23: I2C Write*

The register address is incremented automatically when successive register data (WD1...WDn) is supplied by the master.

### 5.3 I2C Read

The format of the I2C read is given in Figure 13. After the start condition [S], the slave address (SA) is sent, followed by an eighth bit ('0') indicating a Write. The SX9300 then Acknowledges [A] that it is being addressed, and the Master responds with an 8-bit Data consisting of the Register Address (RA). The Slave Acknowledges [A] and the master sends the Repeated Start Condition [Sr]. Once again, the slave address (SA) is sent, followed by an eighth bit ('1') indicating a Read. The SX9300 responds with an Acknowledge [A] and the read

Data byte (RD0). If the master needs to read more data it will acknowledge [A] and the SX9300 will send the next read byte (RD1). This sequence can be repeated until the master terminates with a NACK [N] followed by a stop [P].

| S | SA | 0 | A | RA | A | Sr | SA | 1 | A | RD0 | A | RD1 | ... | A | RDn | N | P |

optional            optional

S:      Start condition
SA:     Slave Address
Sr:     Repeated Start condition
A:      Acknowledge
N:      Not Acknowledge (terminating read stream)
RA:     Register Address
RDn:    Read Data byte (0...n)
P:      Stop condition

from master to slave

from slave to master
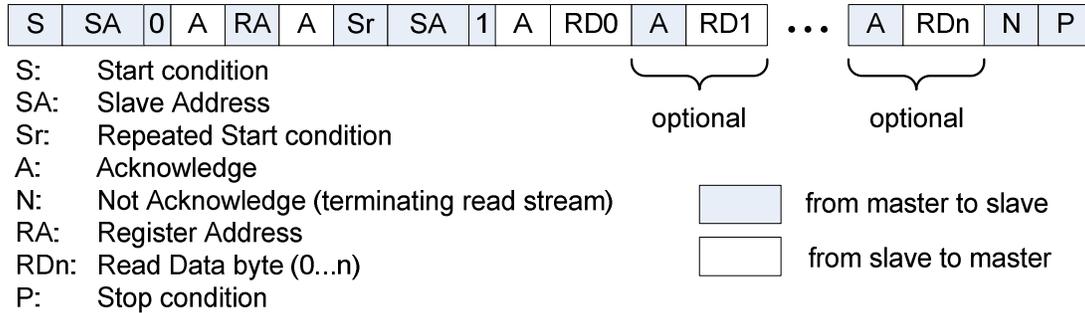
***Figure 24: I2C Read***

The register address is incremented automatically when successive register data (RD1...RDn) is retrieved by the master.

## 6   RESET

### 6.1   Power-up

During a power-up condition, the NIRQ output is HIGH until $V_{DD}$ has met the minimum input voltage requirements and a $T_{POR}$ time has expired upon which, NIRQ asserts to a LOW condition indicating the SX9300 is initialized. The host must perform an I2C read of RegIrqSrc to clear this NIRQ status.  The SX9300 is then ready for normal I2C communication and is operational.
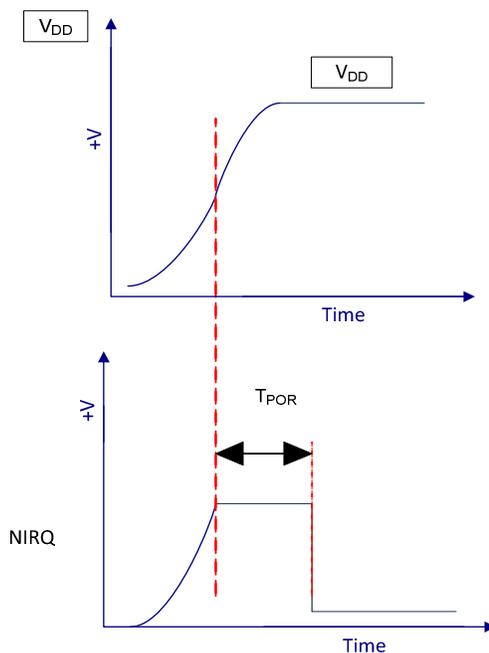
**Figure 25: Power-up vs. NIRQ**

### 6.2   NRST Pin

When the host asserts NRST LOW (for min. $T_{RESETPW}$) and then HIGH, the SX9300 will reset its internal registers and will become active after $T_{POR}$.  When not used, this pin must be pulled high to $SV_{DD}$.
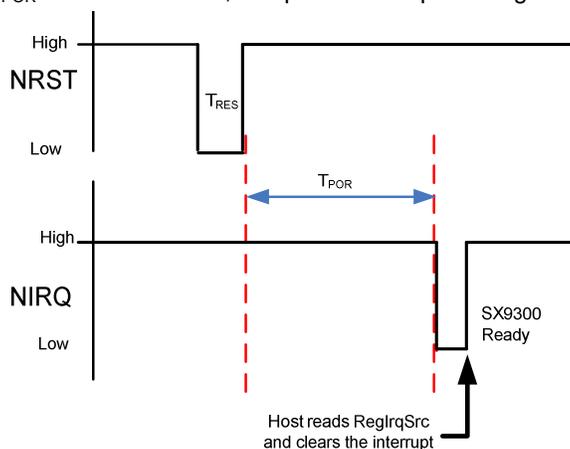
**Figure 26: Hardware Reset**

## 6.3 Software Reset

The host can also perform a reset anytime by writing 0xDE into RegReset. The NIRQ output will be asserted LOW and the Host is required to perform an I2C read to clear this NIRQ status.
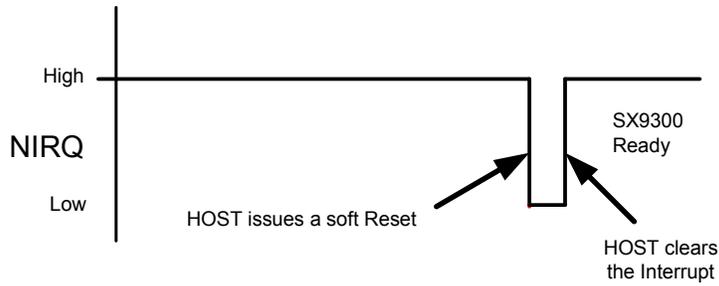


*Figure 27: Software Reset*

**WIRELESS & SENSING**

## 7 INTERRUPT

Except RESETIRQ, all interrupt sources are disabled by default upon power-up and resets, and thus must be enabled by the host. Any or all of the following interrupts can be enabled by writing a "1" into the appropriate locations within the RegIrqMsk register:

- Close (proximity detected)

- Far (proximity un-detected)

- Compensation completed

- Conversion completed

The interrupt status can be read from RegIrqSrc for each of these interrupt sources.

### 7.1 Power-up

During initial power-up, the NIRQ output is HIGH. Once the SX9300 internal power-up sequence has completed, NIRQ is asserted LOW, signaling that the SX9300 is ready. The host must perform a read to RegIrqSrc to acknowledge and the SX9300 will clear the interrupt and release the NIRQ line.

### 7.2 Assertion and Clearing

The NIRQ can be asserted in either the Active or Doze mode during a scan period. The NIRQ will be automatically cleared after the host performs a read of RegIrqSrc (which content will be cleared as well).

## 8  PINS DESCRIPTION

### 8.1  $V_{DD}$ and $SV_{DD}$

These are the device supply voltages.  VDD is the supply voltage for the internal core.  SVDD is the supply voltage for the host interface.  NOTE: SVDD MUST be equal or lower than $V_{DD}$ at all times.

### 8.2  TXEN

This signal can be used in many applications if a conversion trigger/enable is needed.  This input pin synchronizes the Capacitance Sensing inputs in systems that need to (for example) transmit RF signals.  When this signal is active, SX9300 performs capacitive measurements.  If this input becomes inactive during the middle of a measurement, the SX9300 will complete all remaining measurements and will enter sleep mode until TXEN goes active again.

### 8.3  Capacitive Sensing Interface (CS0A, CS0B, CS1A, CS1B, CSG)

The Capacitance Sensing input pins CS0A, CS0B, CS1A and CS1B are connected directly to the Capacitance Sensing Interface circuitry which converts the sensed capacitance into digital values.  The Capacitive Sensor Guard (CSG) output provides a guard reference to minimize the parasitic sensor pin capacitances to ground.  Capacitance sensor pins which are not used must not be connected.  Additionally, CSx pins must be connected directly to the capacitive sensors using a minimum length circuit trace to minimize external "noise" pick-up.

The capacitance sensor and capacitive sensor guard pins are protected from ESD events to VDD and GROUND.

### 8.4  Host Interface

The Host Interface consists of: NIRQ, NRST, SCL, SDA, and TXEN.  These signals are discussed below.

#### 8.4.1  NIRQ

The NIRQ pin is an open drain output that requires an external pull-up resistor (1...10 kOhm).  The NIRQ pin is protected from ESD events to VDD and GROUND.
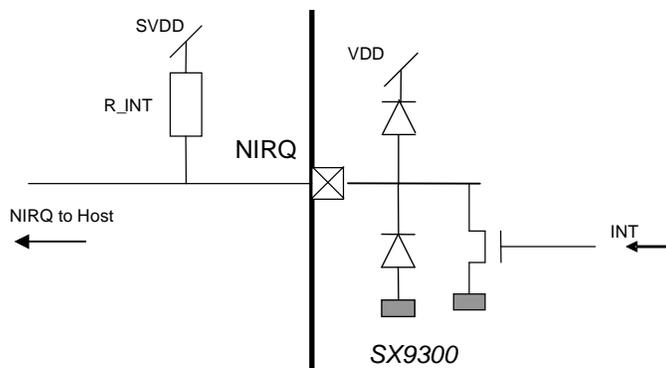


*Figure 28: NIRQ Output Simplified Diagram*

#### 8.4.2    SCL, NRST and TXEN

The SCL, NRST and TXEN pins are high impedance input pins that require an external pull-up resistor (1..10 kOhm).  NRST and TXEN can be connected without the requirement for a pull-up resistor if driven from a push-pull host output.  These pins are protected from ESD events to VDD and GROUND.
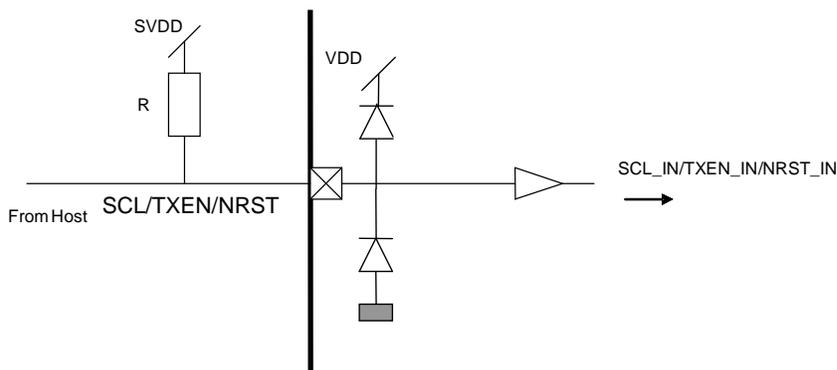


*Figure 29: SCL/TXEN/NRST*

#### 8.4.3    SDA

SDA is an I/O pin that requires an external pull-up resistor (1…10 kOhm).  The SDA I/O pin is protected to VDD and GROUND.
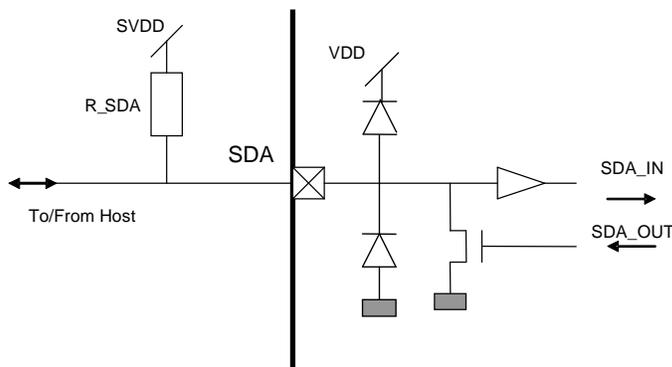


*Figure 30: SDA Simplified Diagram*

## 9  REGISTERS

### 9.1  Overview

The SX9300 allows the user full parameter customization for sensor sensitivity, hysteresis, detection thresholds, etc.  Custom parameters are controlled thru the volatile registers below and must be uploaded by the host thru I2C after power-up or after a reset.

| Address | Name | Default | Description |
|---------|------|---------|-------------|
| 0x00 | RegIrqSrc | 0x80 | Interrupt & Status |
| 0x01 | RegStat | 0x0F | |
| 0x03 | RegIrqMsk | 0x00 | |
| 0x06 | RegProxCtrl0 | 0x0F | Proximity Sensing Control |
| 0x07 | RegProxCtrl1 | 0x40 | |
| 0x08 | RegProxCtrl2 | 0x08 | |
| 0x09 | RegProxCtrl3 | 0x40 | |
| 0x0A | RegProxCtrl4 | 0x00 | |
| 0x0B | RegProxCtrl5 | 0x00 | |
| 0x0C | RegProxCtrl6 | 0x00 | |
| 0x0D | RegProxCtrl7 | 0x00 | |
| 0x0E | RegProxCtrl8 | 0x00 | |
| 0x0F | RegSarCtrl0 | 0x00 | Smart SAR Engine Control |
| 0x10 | RegSarCtrl1 | 0x00 | |
| 0x20 | RegSensorSel | 0x00 | Sensor Data Readback |
| 0x21 | RegUseMsb | 0x00 | |
| 0x22 | RegUseLsb | 0x00 | |
| 0x23 | RegAvgMsb | 0x00 | |
| 0x24 | RegAvgLsb | 0x00 | |
| 0x25 | RegDiffMsb | 0x00 | |
| 0x26 | RegDiffLsb | 0x00 | |
| 0x27 | RegOffsetMsb | 0x00 | |
| 0x28 | RegOffsetLsb | 0x00 | |
| 0x29 | RegSarDelta | 0x00 | |
| 0x2A | RegSarRatio | 0x00 | |
| 0x7F | RegReset | 0x00 | Software Reset |

*Table 10: Registers Overview*

NOTES:

1)  Addresses not listed above are reserved and should not be written.
2)  Reserved bits should be left to their default value unless otherwise specified.

## 9.2   Detailed Description

| Addr. | Name | R/W | Bits | Variable | Default | Function |
|-------|------|-----|------|----------|---------|----------|
| **Interrupt & Status** |||||||
| 0x00 | RegIrqSrc | R | 7 | RESETIRQ | 1 | Reset interrupt source status. (i.e. reset occurred) |
| | | | 6 | CLOSEIRQ | 0 | Close interrupt source status. (i.e. CSxPROXSTAT rising edge) |
| | | | 5 | FARIRQ | 0 | Far interrupt source status. (i.e. CSxPROXSTAT falling edge) |
| | | R/W | 4 | COMPDONEIRQ | 0 | Compensation interrupt source status. (i.e. compensation occurred) When set to 1, triggers compensation |
| | | R | 3 | CONVDONEIRQ | 0 | Conversion interrupt source status. (i.e. new set of sensor data available) |
| | | | 2:1 | Reserved | 00 | |
| | | | 0 | TXENSTAT | 0 | Indicates current TXEN pin status. |
| 0x01 | RegStat | R | 7 | CS1PROXSTAT | 0 | Indicates if proximity is being detected for the pair CS1A/CS1B (i.e. both A and B sensor's PROXDIFF values are above detection threshold) |
| | | | 6 | CS1BODYSTAT | 0 | When CS1PROXSTAT=1, indicates if the object detected is a human body. (i.e. delta and ratio values of this pair are above their respective threshold) |
| | | | 5 | CS0PROXSTAT | 0 | Indicates if proximity is being detected for the pair CS0A/CS0B. (i.e. both A and B sensor's PROXDIFF values are above detection threshold) |
| | | | 4 | CS0BODYSTAT | 0 | When CS0PROXSTAT=1, indicates if the object detected is a human body. (i.e. delta and ratio values of this pair are above their respective threshold) |
| | | | 3:0 | COMPSTAT | 1111 | Indicates which capacitive sensor(s) has a compensation pending. [3:0] = [CS1B, CS1A, CS0B, CS0A] |
| 0x03 | RegIrqMsk | R | 7 | Reserved | 0 | |
| | | R/W | 6 | CLOSEIRQEN | 0 | Enables the close interrupt. |
| | | | 5 | FARIRQEN | 0 | Enables the far interrupt. |
| | | | 4 | COMPDONEIRQEN | 0 | Enables the compensation interrupt. |
| | | | 3 | CONVDONEIRQEN | 0 | Enables the conversion interrupt. |
| | | R | 2:0 | Reserved | 000 | |
| **Proximity Sensing Control** |||||||
| 0x06 | RegProxCtrl0 | R/W | 7 | Reserved | 0 | |
| | | | 6:4 | SCANPERIOD | 000 | Defines the Active scan period : 000:  30 ms (Typ.) 001:  60 ms 010:  90 ms 011:  120 ms 100:  150 ms 101:  200 ms 110:  300 ms 111:  400 ms  Low values will allow fast reaction time while high values will provide low power consumption. |
| | | | 3:0 | SENSOREN | 1111 | Enables sensor pins. |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | | [3:0] = [CS1B, CS1A, CS0B, CS0A]<br><br>Sensors must always be enabled and disabled by pair (CS0A/B; CS1A/B). |
| 0x07 | RegProxCtrl1 | R/W | 7:6 | SHIELDEN | 01 | | Enables shield function on CSG pin:<br>00: Off, high impedance.<br>01: On (Typ.)<br>1x: Reserved |
| | | R/W | 5:2 | Reserved | 0000 | | |
| | | R/W | 1:0 | RANGE | 00 | | Defines the input capacitance range:<br>00: Large          (typ. +/-7.3pF FS)<br>01: Medium Large (typ. +/-3.7pF FS)<br>10: Medium Small (typ. +/-3pF FS)<br>11: Small          (typ. +/-2.5pF FS)<br><br>This parameter can be seen as an analog gain (small range = high gain) Full scale (FS) values assume no digital gain. |
| 0x08 | RegProxCtrl2 | R/W | 7 | Reserved | 0 | | |
| | | | 6:5 | GAIN | 00 | | Defines the digital gain factor:<br>00: Off (x1)<br>01: x2<br>10: x4<br>11: x8 (Typ.)<br><br>This is a pure digital gain (value shift) applied at the ADC output. |
| | | | 4:3 | FREQ | 01 | | Defines the sampling frequency:<br>00: 83 kHz<br>01: 125 kHz<br>10: 167 kHz (Typ.)<br>11: Reserved |
| | | | 2:0 | RESOLUTION | 000 | | Defines the capacitance measurement resolution/precision:<br>000: Coarsest<br>….<br>100: Medium<br>….<br>111: Finest (Typ.) |
| 0x09 | RegProxCtrl3 | R/W | 7 | Reserved | 0 | | |
| | | | 6 | DOZEEN | 1 | | Enables Doze mode. |
| | | | 5:4 | DOZEPERIOD | 00 | | When DOZEN=1, defines the Doze scan period:<br>00: 2x SCANPERIOD<br>01: 4x SCANPERIOD<br>10: 8x SCANPERIOD<br>11: 16x SCANPERIOD |
| | | | 3:2 | Reserved | 00 | | |
| | | | 1:0 | RAWFILT | 00 | | Defines PROXRAW filter strength :<br>00: Off - No filtering<br>01: Low (Typ.)<br>10: Medium<br>11: High - Max filtering |
| 0x0A | RegProxCtrl4 | R/W | 7:0 | AVGTHRESH | 0x00 | | Defines the positive and negative average thresholds which will trigger compensation:<br>Thresholds = +/- 128x AVGTHRESH<br><br>Typically set between +/-16384 and +/-24576 (i.e. ½ to ¾ of the system |

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| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | dynamic range). Should not be set below 0x40. |
| 0x0B | RegProxCtrl5 | R/W | 7:6 | AVGDEB | 00 | Defines the average debouncer applied to AVGTHRESH: 00: Off 01: 2 samples 10: 4 samples 11: 8 samples |
| | | | 5:3 | AVGNEGFILT | 000 | Defines the average negative filter strength: 000: Off - No filtering 001: Lowest (Typ.) …. 111: Highest - Max filtering |
| | | | 2:0 | AVGPOSFILT | 000 | Defines the average positive filter strength: 000: Off - No filtering 001: Lowest …. 111: Highest - Max filtering (Typ.) |
| 0x0C | RegProxCtrl6 | R/W | 7:5 | Reserved | 000 | |
| | | | 4:0 | PROXTHRESH | 00000 | Defines the proximity detection threshold (for all sensors). 00000: 0 00001: 20 00010: 40 00011: 60 00100: 80 00101: 100 00110: 120 00111: 140 01000: 160 01001: 180 01010: 200 01011: 220 01100: 240 01101: 260 01110: 280 01111: 300 10000: 350 10001: 400 10010: 450 10011: 500 10100: 600 10101: 700 10110: 800 10111: 900 11000: 1000 11001: 1100 11010: 1200 11011: 1300 11100: 1400 11101: 1500 11110: 1600 11111: 1700  Low values allow good sensitivity/distance while higher values allow better noise immunity. |
| 0x0D | RegProxCtrl7 | R/W | 7 | AVGCOMPDIS | 0 | Disables the automatic compensation triggered by AVGTHRESH. |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | 6 | COMPMETHOD | 0 | Defines the compensation method:<br>0: Compensate each CSx pin independently (Typ.)<br>1: Compensate all CSx pins together. |
| | | | 5:4 | HYST | 00 | Defines the proximity detection hysteresis applied to PROXTHRESH:<br>00: 32<br>01: 64<br>10: 128<br>11: 256 |
| | | | 3:2 | CLOSEDEB | 00 | Defines the Close debouncer applied to PROXTHRESH:<br>00: Off<br>01: 2 samples<br>10: 4 samples<br>11: 8 samples |
| | | | 1:0 | FARDEB | 00 | Defines the Far debouncer applied to PROXTHRESH:<br>00: Off<br>01: 2 samples<br>10: 4 samples<br>11: 8 samples |
| 0x0E | RegProxCtrl8 | R/W | 7:4 | STUCK | 0000 | Defines the proximity "stuck" timeout:<br>0000 : Off (Typ.)<br>00XX: STUCK x 64 samples<br>01XX: STUCK x 128 samples<br>1XXX: STUCK x 256 samples |
| | | | 3:0 | COMPPRD | 0000 | Defines the periodic compensation interval:<br>0000: Off (Typ.)<br>Else: COMPPRD x 128 samples |
| **Smart SAR Engine Control** | | | | | | |
| 0x0F | RegSarCtrl0 | R/W | 7:6 | Reserved | 00 | |
| | | | 5:4 | SARDEB | 00 | Defines the SAR engine debouncer applied to human body reporting (CSxBODYSTAT):<br>00: Off<br>01: 2 samples<br>10: 4 samples<br>11: 8 samples |
| | | | 3:0 | SARDELTATHRESH | 0000 | Defines the SAR delta threshold (for both sensor pairs):<br><br>0000: Off<br>0001: 1<br>0010: 3<br>0011: 5<br>0100: 10<br>0101: 15<br>0110: 20<br>0111: 25<br>1000: 30<br>1001: 35<br>1010: 40<br>1011: 45<br>1100: 50<br>1101: 55<br>1110: 60<br>1111: 70<br><br>A hysteresis derivated from HYST is |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | automatically applied, Cf. §4.<br><br>Off when set to 0000, i.e. delta value not used for body detection.<br>At least one of Delta or Ratio Threshold must be enabled. |
| 0x10 | RegSarCtrl1 | R/W | 7:0 | SARRATIOTHRESH | 0x00 | Defines the SAR ratio threshold (for both sensor pairs)<br><br>A hysteresis derivated from HYST is automatically applied, Cf. §4.<br><br>Off when set to 0x00, i.e. ratio value not used for body detection.<br>At least one of Delta or Ratio Threshold must be enabled. |
| **Sensor Data Readback** | | | | | | |
| 0x20 | RegSensorSel | R | 7:2 | Reserved | 000000 | |
| | | RW | 1:0 | SENSORSEL | 00 | Defines which sensor's data will be available in registers RegUseMsb to RegSarRatio (addr. 0x21 to 0x2A):<br>00: CS0A<br>01: CS0B<br>10: CS1A<br>11: CS1B |
| 0x21 | RegUseMsb | R | 7:0 | PROXUSEFUL | 0x00 | Useful current value. |
| 0x22 | RegUseLsb | R | 7:0 | | 0x00 | Signed, 2's complement format. |
| 0x23 | RegAvgMsb | R | 7:0 | PROXAVG | 0x00 | Average current value. |
| 0x24 | RegAvgLsb | R | 7:0 | | 0x00 | Signed, 2's complement format. |
| 0x25 | RegDiffMsb | R | 7:0 | PROXDIFF | 0x00 | Diff current value. |
| 0x26 | RegDiffLsb | R | 7:0 | | 0x00 | Signed, 2's complement format. |
| 0x27 | RegOffsetMsb | R/W | 7:0 | PROXOFFSET | 0x00 | Compensation offset current value. |
| 0x28 | RegOffsetLsb | R/W | 7:0 | | 0x00 | Unsigned.<br>To force a value, MSB and LSB registers must be written in sequence and change is effective after LSB. |
| 0x29 | RegSarDelta | R | 7 | Reserved | 0 | |
| | | | 6:0 | SARDELTA | 0000000 | SAR Delta current value of the pair.<br>Signed, 2's complement format |
| 0x2A | RegSarRatio | R | 7:0 | SARRATIO | 0x00 | SAR Ratio current value of the pair.<br>Unsigned. |
| **Software Reset** | | | | | | |
| 0x7F | RegReset | W | 7:0 | SOFTRESET | 0x00 | Writing 0xDE resets the chip. |

*Table 11: Registers Detailed Description*

## 10 APPLICATION INFORMATION

### 10.1 Typical Application Circuit
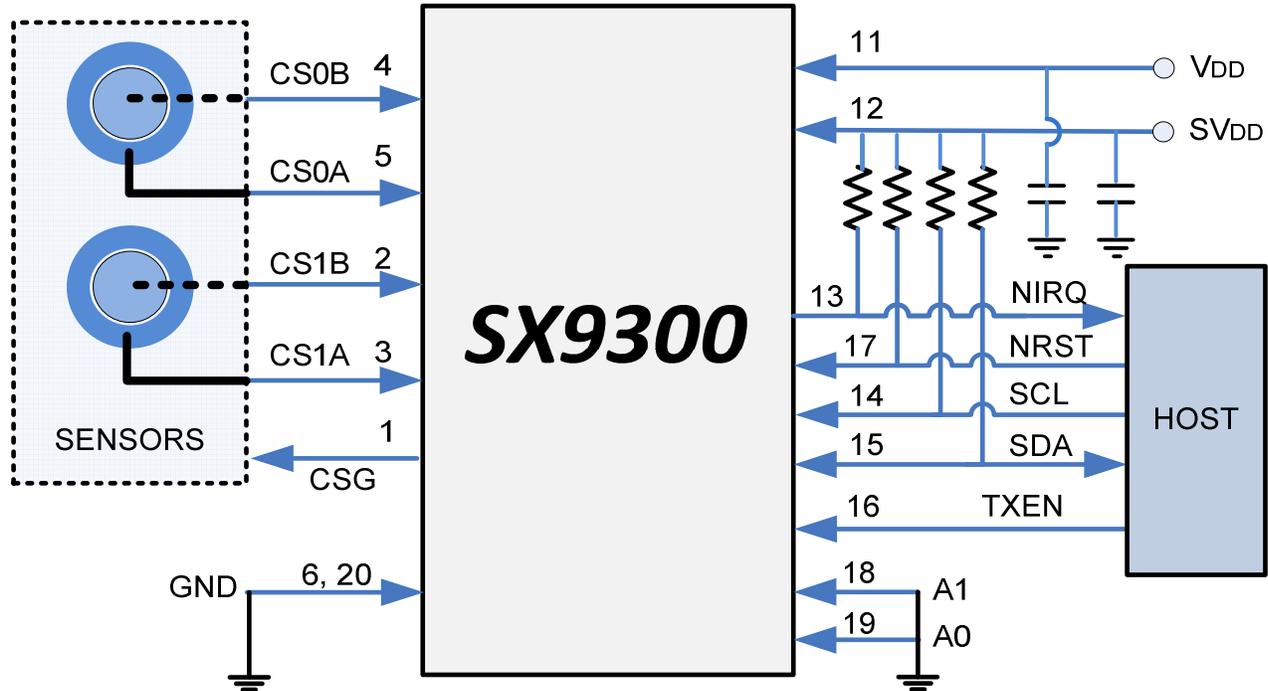


*Figure 31: Typical Application Circuit*

### 10.2 External Components Recommended Values

| Symbol | Description | Note | Min | Typ. | Max | Unit |
|---|---|---|---|---|---|---|
| CVDD | Core supply decoupling capacitor | | - | 100 | - | nF |
| CSVDD | Host interface supply decoupling capacitor | | - | 100 | - | nF |
| RPULL | Host interface pull-ups | +/- 50% | - | 10 | - | kΩ |

*Table 12: External Components Recommended Values*

## 11 PACKAGING INFORMATION

### 11.1 Outline Drawing



| DIM | INCHES | | | MILLIMETERS | | |
|-----|-----|-----|-----|-----|-----|-----|
| | MIN | NOM | MAX | MIN | NOM | MAX |
| A | .020 | - | .024 | 0.50 | - | 0.60 |
| A1 | .000 | - | .002 | 0.00 | - | 0.05 |
| A2 | | (.006) | | | (0.152) | |
| b | .006 | .008 | .010 | 0.15 | 0.20 | 0.25 |
| D | .114 | .118 | .122 | 2.90 | 3.00 | 3.10 |
| D1 | .061 | .067 | .071 | 1.55 | 1.70 | 1.80 |
| E | .114 | .118 | .122 | 2.90 | 3.00 | 3.10 |
| E1 | .061 | .067 | .071 | 1.55 | 1.70 | 1.80 |
| e | | .016 BSC | | | 0.40 BSC | |
| L | .012 | .016 | .020 | 0.30 | 0.40 | 0.50 |
| N | | 20 | | | 20 | |
| aaa | | .003 | | | 0.08 | |
| bbb | | .004 | | | 0.10 | |
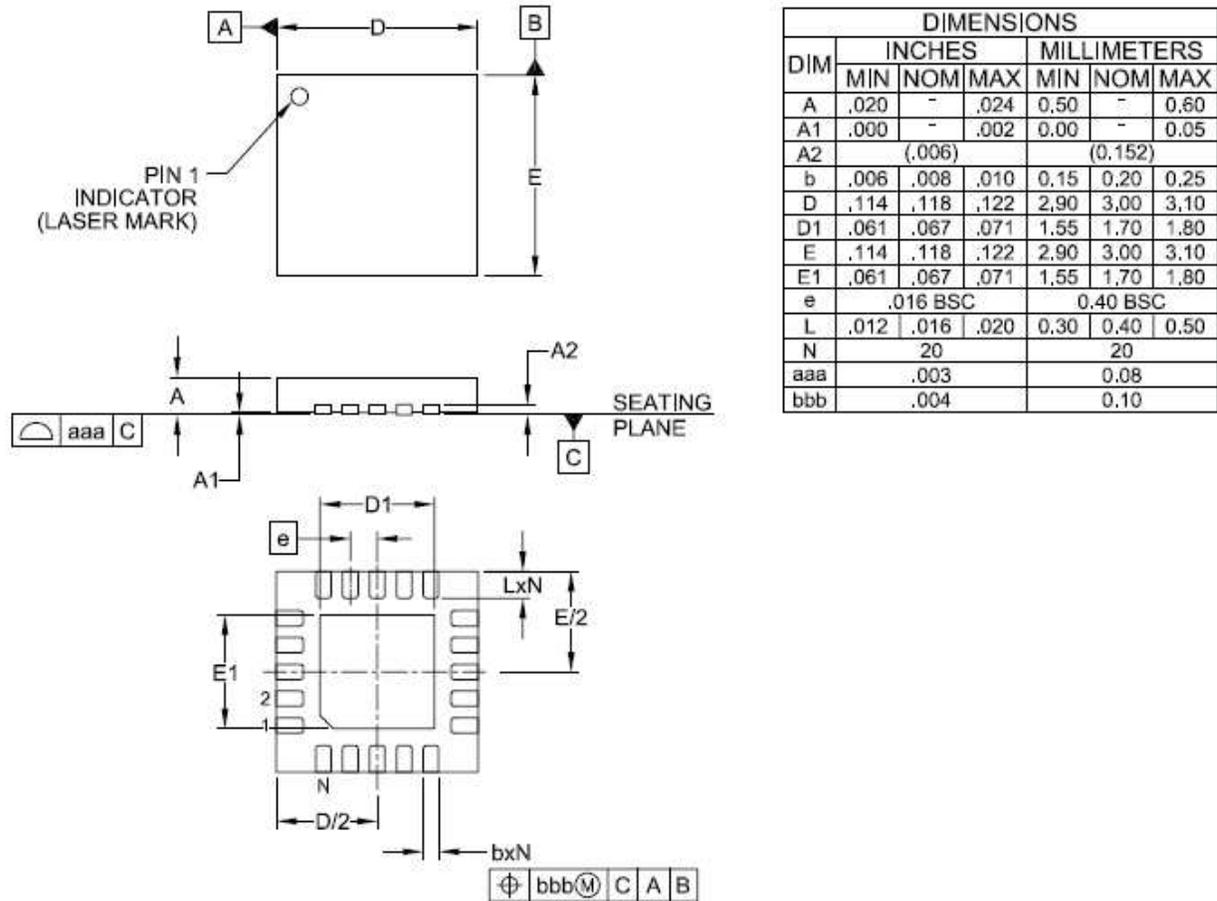
NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).

2. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

3. DAP IS 1.90 x 1.90mm.

*Figure 32: Outline Drawing*

**WIRELESS & SENSING**

## 11.2 Land Pattern
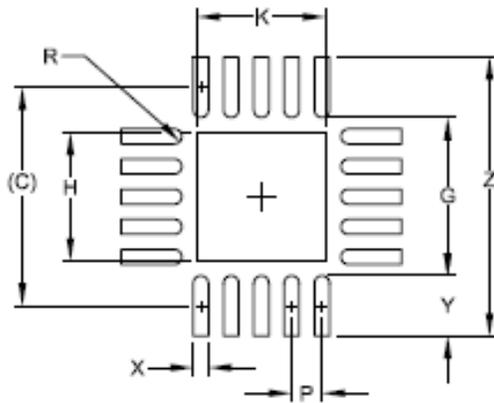


| DIM | DIMENSIONS | |
|-----|------------|--------------|
| | INCHES | MILLIMETERS |
| C | (.114) | (2.90) |
| G | .083 | 2.10 |
| H | .067 | 1.70 |
| K | .067 | 1.70 |
| P | .016 | 0.40 |
| R | .004 | 0.10 |
| X | .008 | 0.20 |
| Y | .031 | 0.80 |
| Z | .146 | 3.70 |

NOTES:

1. CONTROLLING DIMENSIONS ARE IN MILLIMETERS (ANGLES IN DEGREES).

2. THIS LAND PATTERN IS FOR REFERENCE PURPOSES ONLY. CONSULT YOUR MANUFACTURING GROUP TO ENSURE YOUR COMPANY'S MANUFACTURING GUIDELINES ARE MET.

3. THERMAL VIAS IN THE LAND PATTERN OF THE EXPOSED PAD SHALL BE CONNECTED TO A SYSTEM GROUND PLANE. FAILURE TO DO SO MAY COMPROMISE THE THERMAL AND/OR FUNCTIONAL PERFORMANCE OF THE DEVICE.

***Figure 33: Land Pattern***

**Contact Information**

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