

## 3-Channel Capacitive Touch and Proximity Controller

### Features

- 3-channel capacitive sensing
  - Self/Mutual capacitive sensing techniques
  - Capacitance resolution down to 1aF
  - Auto-Offset-Tuning (AOT)
  - Adaptive Temperature Compensation
  - Effective waterproof
  - Independent configurations per channel
- Built-in gesture/event recognition:
  - Click/Wear detection
  - Linear slide detection
  - Capacitive force detection
- 400kHz I<sup>2</sup>C interface
  - 1.2/1.8V IO logic supported
  - Default address: 0x12
- External interrupt pin INTN, open-drain output
- Built-in brown-out reset(BOR)
- Low power consumption
  - Active mode: 15.5μA
  - Doze mode: 6.5μA
  - Sleep mode: 5.0μA
  - Deep Sleep mode: 2.5μA
- 2.7V~3.6V power supply
- WLCSP 1.75mm×1.19mm×0.57mm-8B package

### Applications

Mobile phones, Tablets, Laptops

Wearable devices, TWS

Desk lamp, Smart door locks

### General Description

AW93203CSR is a 3-channel capacitive proximity and touch controller mainly used for wear detection, touch key, linear slider, wheel slider, etc. The chip can realize accurate position detection for lamp dimming, volume adjustment, etc.

AW93203CSR can recognize various gestures, such as single/double/triple click, short/long press and linear slide with the high-resolution capacitive sensing. The chip integrates mutual capacitive technology and dedicated algorithm, which greatly improves the waterproof performance for touch key.

The built-in ultra-low-power MCU and 16KB flash realize AFE sampling control, signal filtering, RF noise suppression, adaptive temperature compensation, baseline tracking, touch/wearing status determination, etc. The chip can flexibly customize the program and support online upgrade function.

## Typical Application Circuit

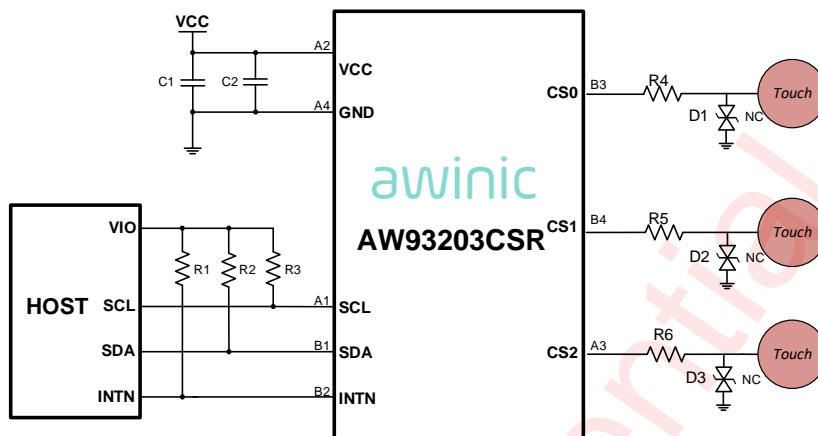
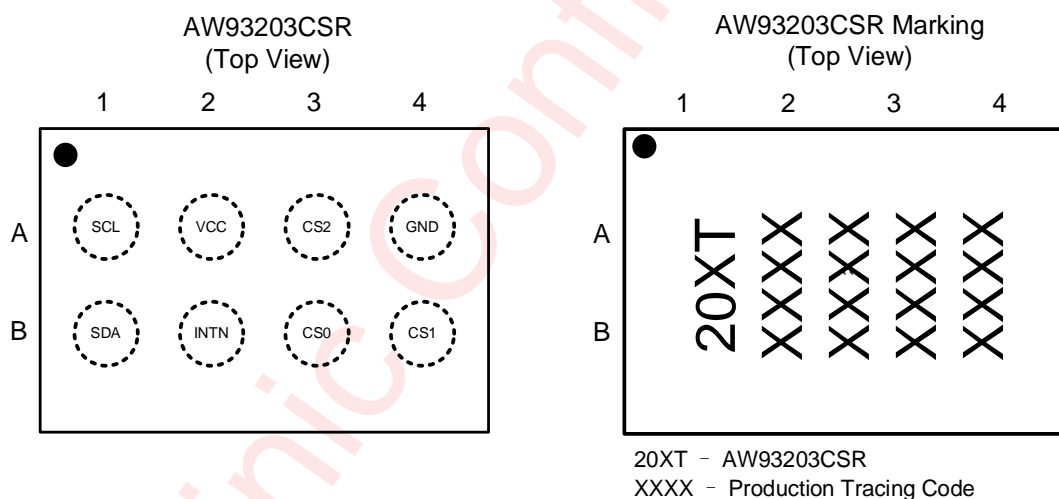


Figure 1 AW93203CSR Typical Application Circuit

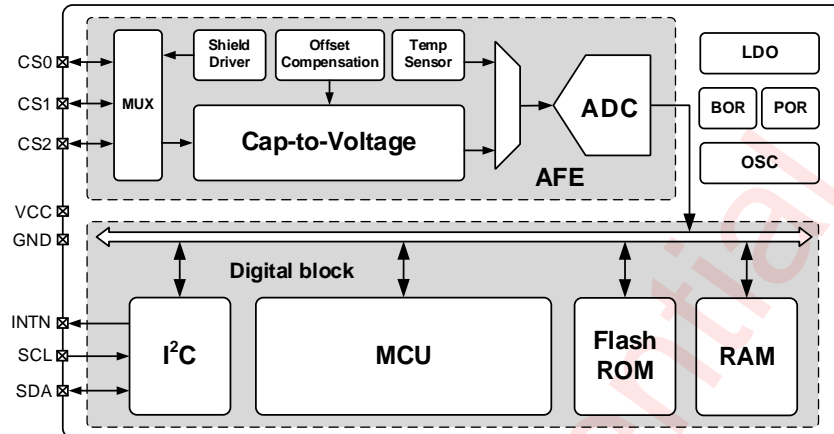
## Pin Configuration and Top Mark



## Pin Definition

No.	NAME	DESCRIPTION
A1	SCL	I <sup>2</sup> C clock, requires pull-up resistor
A2	VCC	Power supply (2.7V~3.6V), requires decoupling capacitor
A3	CS2	Capacitive sensor input/shield/digital I/O
A4	GND	Ground
B1	SDA	I <sup>2</sup> C data, requires pull-up resistor
B2	INTN	Interrupt output, requires pull-up resistor
B3	CS0	Capacitive sensor input/shield/digital I/O
B4	CS1	Capacitive sensor input/shield/digital I/O

## Functional Block Diagram



**Notes:** AFE means Analog Front-End.

**Figure 2 Functional Block Diagram**

## Ordering Information

Part Number	Temperature	Package	Marking	Moisture Sensitivity Level	Environmental Information	Delivery Form
AW93203CSR	-40°C ~ 85°C	WLCSP 1.75mmx1.19mm x0.57mm-8B	20XT	MSL1	ROHS+HF	4500 units/ Tape and Reel

## Absolute Maximum Ratings<sup>(NOTE1)</sup>

PARAMETERS		RANGE
Supply voltage range VCC		-0.5V to 3.6V
Input voltage range	CSx, SCL, SDA, INTN	-0.5V to 3.6V
Output voltage range	CSx, SCL, SDA, INTN	-0.5V to 3.6V
Operating free-air temperature range		-40°C to 85°C
Maximum operating junction temperature T <sub>JMAX</sub>		150°C
Storage temperature T <sub>STG</sub>		-65°C to 150°C
Lead temperature (soldering 10 seconds)		260°C
ESD(Including HBM CDM) <sup>(NOTE 2)</sup>		
HBM		±8kV
CDM		±1.5kV
Latch-Up		
Test condition: according to JESD78E		+IT: 350mA -IT: -350mA

NOTE1: Conditions out of those ranges listed in "absolute maximum ratings" may cause permanent damages to the device. In spite of the limits above, functional operation conditions of the device should within the ranges listed in "recommended operating conditions". Exposure to absolute-maximum-rated conditions for prolonged periods may affect device reliability.

NOTE2: The HBM test method: ESDA/JEDEC JS-001-2017 ,the CDM test method: ESDA/JEDEC JS-002-2018.

## Recommended Operating Conditions

PARAMETERS	SYMBOL	MIN	MAX	UNIT
Supply voltage	VCC	2.7	3.6	V
Pull-up voltage	VIO	1.2	3.6	V
Ambient temperature	T <sub>A</sub>	-40	85	°C

## Electrical Characteristics

Note: Typical values are given for T<sub>A</sub> = +25°C, VCC=2.8V unless otherwise specified.

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
<b>CHIP CURRENTS</b>						
I <sub>DEEPSLEEP</sub>	Deep Sleep Mode Current	LDO on, OSC off I <sup>2</sup> C listening		2.5		μA
I <sub>SLEEP</sub>	Sleep Mode Current	LDO on, OSC on I <sup>2</sup> C listening		5.0		μA
I <sub>DOZE</sub>	Doze Mode Current	SCANPERIOD = 400ms FREQ = 100kHz CDCRES = 6 CHEN = b000001 Digital filter features OFF I <sup>2</sup> C listening. No load		6.5		μA
I <sub>ACTIVE</sub>	Active Mode Current	SCANPERIOD = 30ms FREQ = 100kHz CDCRES = 6 CHEN = b000001 Digital filter features OFF I <sup>2</sup> C listening. No load		15.5		μA
<b>CAPACITANCE SENSING</b>						
C <sub>RANGE</sub>	Measurement Range		±0.55	±2.2	±9.9	pF
N <sub>BIT</sub>	Measurement Resolution			21		bits
C <sub>RES</sub>			1			aF
F <sub>OSC</sub>	Nominal OSC Frequency			4		MHz
F <sub>Trim</sub>	OSC Trim Accuracy	Around Nominal Value, Ta=25°C, VCC=2.8V	-4		4	%
F <sub>Temp</sub>	OSC Temp. Dependency	Around Nominal Value, Full Ta range, VCC=2.8V	-1		1	%
F <sub>VCC</sub>	OSC VCC Dependency	Around Nominal Value, Ta=25°C, Full VCC range	-0.6		0.6	%

PARAMETER		TEST CONDITION	MIN	TYP	MAX	UNIT
F <sub>S</sub>	Nominal Sampling Freq	Programmable with FREQ			250	kHz
C <sub>DCEXT</sub>	External DC Cap. to GND per Measurement Phase	One CSx as measured input			220	pF
R <sub>FILTIN</sub>	Input driving Res		0		30	kΩ
R <sub>INT</sub>	Compensation Res		125		1000	Ω
<b>TEMPERATURE SENSING</b>						
T <sub>INRANGE</sub>	Input Range	Ambient Temperature(T <sub>A</sub> )	-40		85	°C
T <sub>OUTRANGE</sub>	Output Range		0		32767	LSB
<b>I<sup>2</sup>C INTERFACE</b>						
I <sub>OL</sub> (SDA, INTN)	Output low current	V <sub>OL</sub> ≤ 0.4V	8			mA
V <sub>IH</sub>	Input high level	SCL, SDA	0.84		3.6	V
V <sub>IL</sub>	Input low level	SCL, SDA	-0.5		0.36	V
t <sub>DEG_SDA</sub>	SDA deglitch time	SDA		88		ns
t <sub>DEG_SCL</sub>	SCL deglitch time	SCL		77		ns

## I<sup>2</sup>C Interface Timing

PARAMETER		MIN	TYP	MAX	UNIT
F <sub>SCL</sub>	Interface Clock frequency			400	kHz
T <sub>HD:STA</sub>	(Repeat-start) Start condition hold time	0.6			μs
T <sub>LOW</sub>	Low level width of SCL	1.3			μs
T <sub>HIGH</sub>	High level width of SCL	0.6			μs
T <sub>SU:STA</sub>	(Repeat-start) Start condition setup time	0.6			μs
T <sub>HD:DAT</sub>	Data hold time	0			μs
T <sub>SU:DAT</sub>	Data setup time	0.1			μs
T <sub>R</sub>	Rising time of SDA and SCL			0.3	μs
T <sub>F</sub>	Falling time of SDA and SCL			0.3	μs
T <sub>SU:STO</sub>	Stop condition setup time	0.6			μs
T <sub>BUF</sub>	Time between start and stop condition	1.3			μs

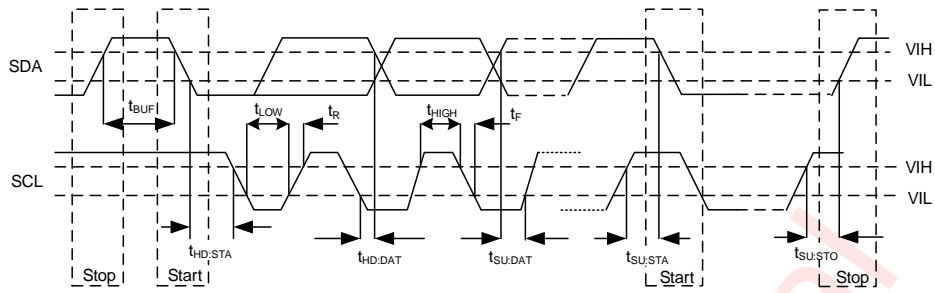


Figure 3 I<sup>2</sup>C Interface Timing

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## Capacitive Sensor Basics

When a conductive object, such as a finger, comes in contact or close proximity with the sensing electrode, the capacitance of one or more sensors changes. The figure below shows the basic structure and equivalent model of a capacitive sensor. The top layer is the front-panel, and the middle green area below is a copper sensor pad. The sensor is usually surrounded by ground, resulting in a parasitic capacitance ( $C_{PARA}$ ).

There are two main operational modes in the capacitance sensing circuits: self-capacitance sensing and mutual capacitance sensing. An electric field is created around the sensor when system is working. In the self-capacitance sensing mode, with target object approaching, some of the electric field lines couple to the target object and add a small amount of finger capacitance ( $C_{PROX}$ ) to the existing  $C_{PARA}$ . This feature can be used to detect proximity or touch action.

At least two electrodes are needed in the mutual capacitance sensing mode: one is a transmitter (Tx) and the other is a receiver (Rx). Tx and ground will form a capacitance ( $C_{PARAT}$ ); Rx and ground will form a capacitance ( $C_{PARAR}$ ); Tx and Rx will form a capacitance ( $C_M$ ). When target object approaches, Tx and Rx will form a capacitance ( $C_M'$ ) which is less than  $C_M$ .

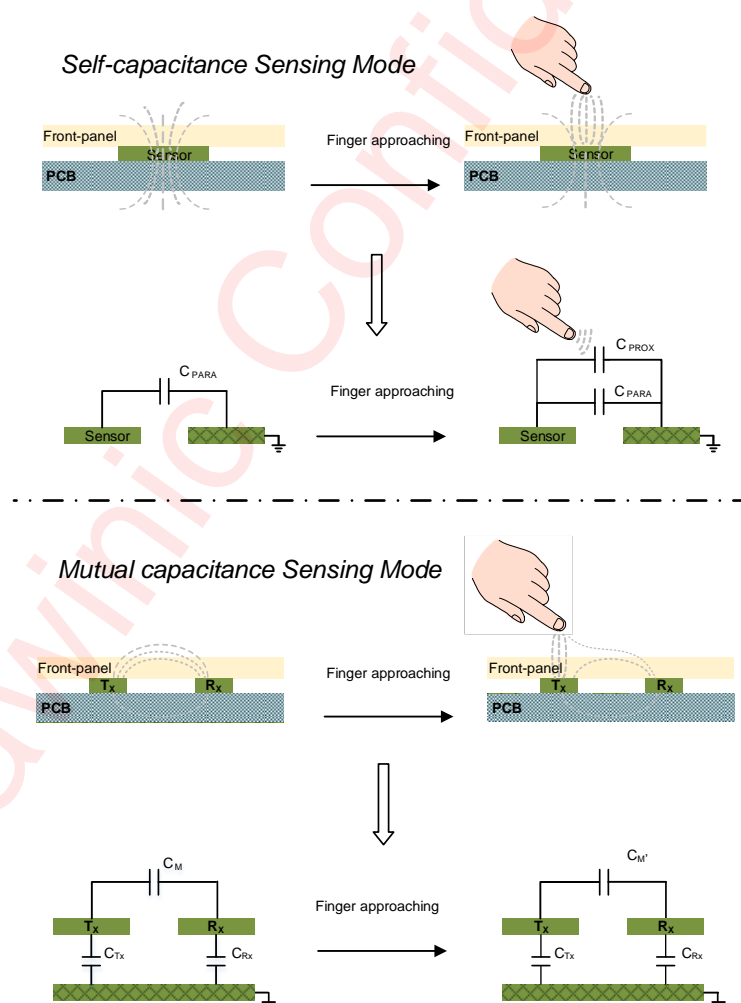


Figure 4 Capacitive Sensor Structure

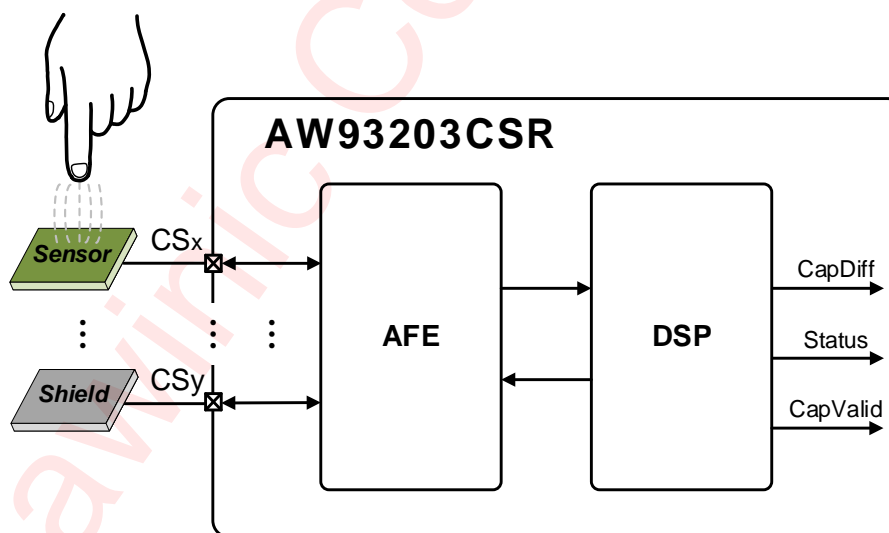
## Detailed Functional Description

### Overview

AW93203CSR is a capacitive in-ear detection and touch key controller with a built-in ultra-low-power MCU. Each sensor channel can be configured as mutual capacitance detection or self-capacitance detection. AW93203CSR is composed of AFE, MCU, FLASH, RAM, OSC, I<sup>2</sup>C, etc. AFE is mainly used to drive the sensor and shield electrodes, and convert the capacitance of sensor to digital data. MCU executes the algorithm program in the FLASH, and performs basic operations such as signal filtering, baseline calculation, automatic compensation for environmental drift, radio frequency(RF) noise suppression, proximity detection, etc. It is able to accurately identify single/double/triple click, short/long press, linear slide and wheel slide, etc.

### Capacitive Sensing Techniques

The proximity sensing system consists of three parts: capacitive sensor, AFE and DSP. Among them, the function of AFE is to drive the capacitive sensor and the shield electrode, and convert the sensor capacitance into digital data. The function of DSP is to process the data from AFE and transmit the sensor capacitance value (CapDiff, CapValid) together with proximity status (status) to the host. When the target object is approaching or moving away, the proximity sensing system will transmit key information to the host after dedicated processing.

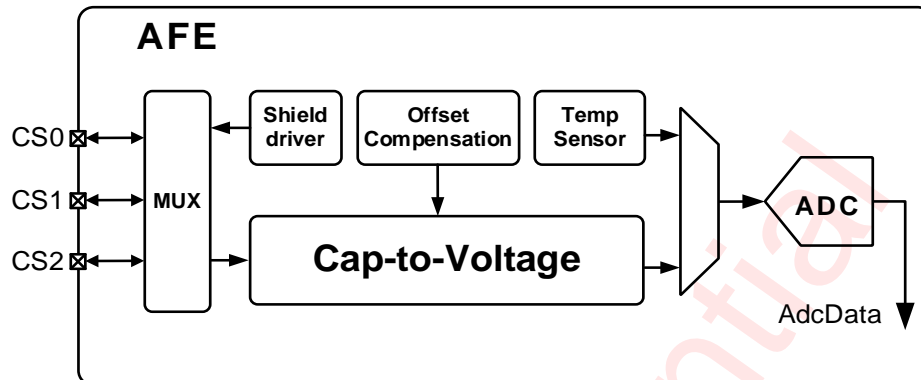


Notes:

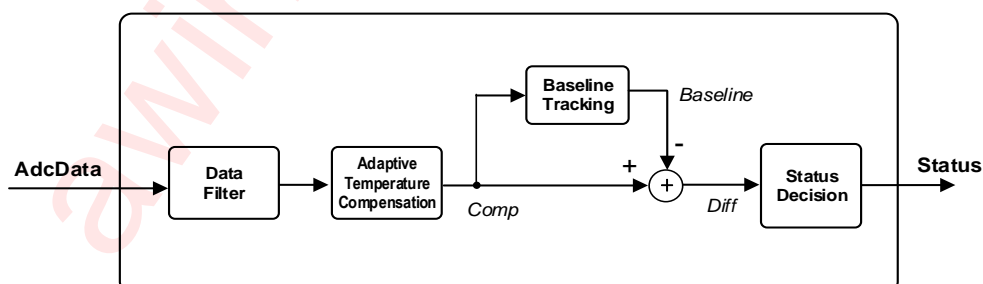
1. x ranges from 0 to 3
2. y ranges from 0 to 3

Figure 5 Proximity Sensor Operation Overview



**AFE Description****Figure 6 AFE Block Diagram**

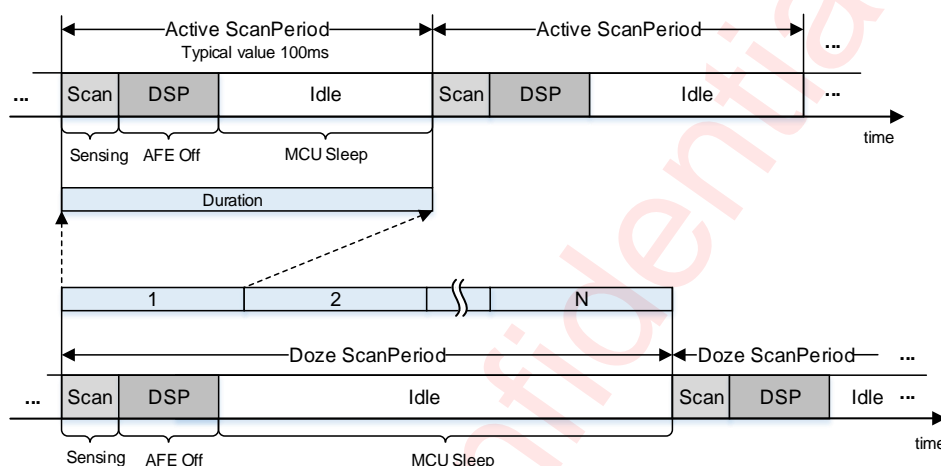
- ※ MUX selects CSx as capacitance measurement input or shield output
- ※ If CSx is used as shield electrode, it is excited by shield driver. The driven shield signal is a replica of the sensor signal. Shield electrode around can protect the sensor from environmental interference, and reduce the parasitic capacitance.
- ※ Cap-to-Voltage integrates a charge amplifier, it detects the sensor capacitance with a charge-transfer method. The capacitance is converted into a voltage signal, which is the input of ADC.
- ※ Offset Compensation measures parasitic capacitance( $C_{PARA}$ ), which is compensated during the process of charge transferring of Cap-to-Voltage. Thus, the input capacitance of Cap-to-Voltage is nearly  $C_{PROX}$  alone.
- ※ Temp Sensor measures the temperature of the chip, and the output is converted by ADC to digital data. The temperature data can be used as reference to correct the capacitance measurement result.
- ※ ADC converts voltage signals obtained by Cap-to-Voltage or Temp Sensor into AdcData.

**DSP Description****Figure 7 Digital Signal Processing Diagram**

- ※ DSP processes the AdcData from the AFE, and finally outputs a series of reliable proximity status.
- ※ Data Filter effectively filters the high-frequency noise and interference, which greatly improves the signal-to-noise ratio(SNR).
- ※ The adaptive temperature compensation module can automatically compensate for environmental drift in real time, especially temperature drift. Thereby it can be ensured that the final proximity status will not be misjudged due to temperature drift.

- ※ The role of the Baseline is to further track the slowly varying data caused by the residual temperature compensation or other gradual environmental drift.
- ※ Finally, the Status Decision module outputs a certain and reliable proximity status based on the Diff data and the proximity threshold etc.

### SCAN Period



**Figure 8 Active Mode and Doze Mode Scan Period**

Each scan period can be divided into three stages. In the first stage, the selected sensor channel is scanned and AdcData is generated. In the second stage, the AFE is closed and the AdcData obtained by the DSP module is processed. In the last stage, all data processing has been completed and the chip enters idle status, in order to reduce power consumption, neither AFE nor MCU will work.

The figure above shows the composition and meaning of the active mode and doze mode scan periods. The scan period of active mode and doze mode can be configured by register SCANCTRL1( Address: 0x1A04) and AFECFG3\_CHx (x=0,1,2). Generally, doze mode consumes much lower power than active mode.

### Clock

The AW93203CSR uses a built-in 4MHz OSC clock.

### Reset

#### Power On Reset (POR)

Reset operation is triggered during power up. When nRST released, the initialization process starts to perform and it will last for about 20ms. INTN will be set to low when the initialization process is completed, then I<sup>2</sup>C can communicate normally.

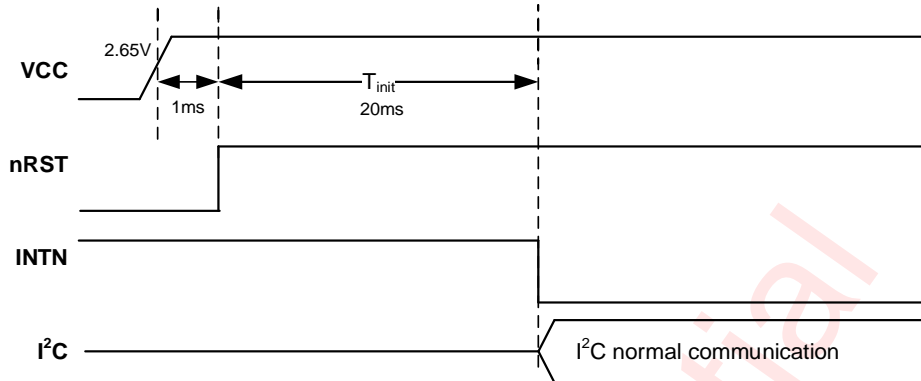


Figure 9 Power On Timing

**Brown Out Reset (BOR)**

Reset operation is triggered when VCC drop to the threshold of BOR. After the reset operation, all the registers will be reset to the default value. The chip returns to normal operation mode until the power supply rises to a normal value.

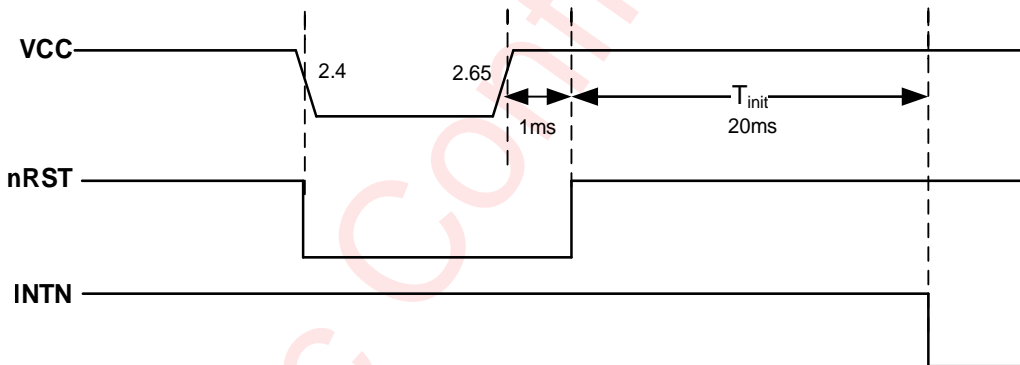


Figure 10 Brown Out Timing

**Soft Reset**

The soft reset operation can be triggered by writing “0x3C” to the soft reset register (Address: 0xFF18). After the reset operation is completed, all the registers will be reset to the default value.

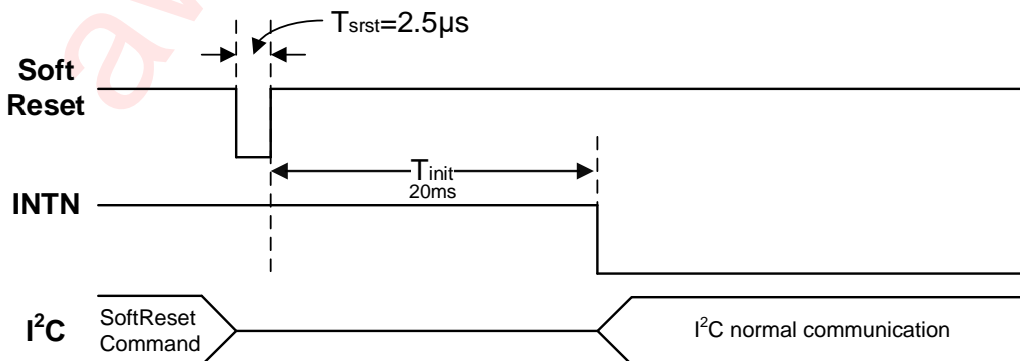


Figure 11 Soft Reset Timing

## Initialization

After power on, OSC runs normally, and MCU starts to execute the initialization program in Flash ROM. It performs the following operations.

- Read information from NVM
- Issue an interrupt after initialization and then enters into sleep mode.

## Operation Mode

There are four operation modes in the AW93203CSR: Deep Sleep, Sleep, Active and Doze.

### **Deepsleep**

The device power consumption is lowest in this mode. OSC and AFE are closed, CPU is sleeping, only I<sup>2</sup>C interface is active.

### **Sleep**

The device is in a low power state. OSC is on, AFE is off, and CPU is sleeping, waiting for interrupt to wake up.

### **Active**

The device works at full speed. All modules including AFE, MCU, OSC, etc., are running normally. When no touch or proximity has been detected for some time, it will automatically switch to Doze mode. In this mode the external HOST can send Sleep command to switch the device into sleep mode.

### **Doze**

The scan period is long, MCU and AFE work intermittently. During the large part of period, most modules are in idle state. So the average power consumption is lower.

Once a proximity is detected in doze mode, it will automatically return to active mode. The external HOST can also send Sleep command to switch the device to sleep mode.

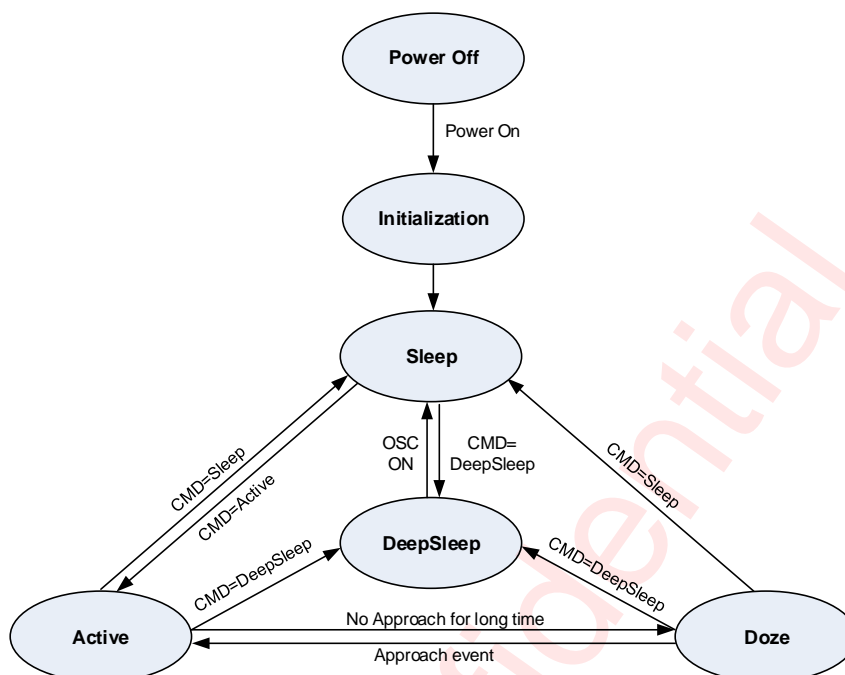


Figure 12 Operation Mode Switching

## Interrupt

The AW93203CSR reports the interrupt signal to the host through the INTN pin. Register IRQSRC (Address: 0x4410) stores interrupt information, including the completion of parasitic capacitance calibration, scan cycle completion, and so on. Register IRQSRC is cleared after host read. Each specified interrupt triggered or not can be configured by register IRQEN (Address: 0x4414).

## I<sup>2</sup>C Interface

AW93203CSR supports the I<sup>2</sup>C serial bus and data transmission protocol in fast mode at 400kHz. It operates as a slave on the I<sup>2</sup>C bus. Connections to the bus are made via the open-drain I/O pins SCL and SDA. The pull-up resistor can be selected in the range of 1k~10kΩ and the typical value is 4.7kΩ. AW93203CSR can support different high level of the I<sup>2</sup>C interface. Additionally, the I<sup>2</sup>C device supports continuous read and write operations. The I<sup>2</sup>C register address is 16-bit and register data is 32-bit, and the data transmission is in big-endian mode.

### I<sup>2</sup>C Start/Stop

I<sup>2</sup>C start: SDA changes from high level to low level when SCL is high level.

I<sup>2</sup>C stop: SDA changes from low level to high level when SCL is high level.

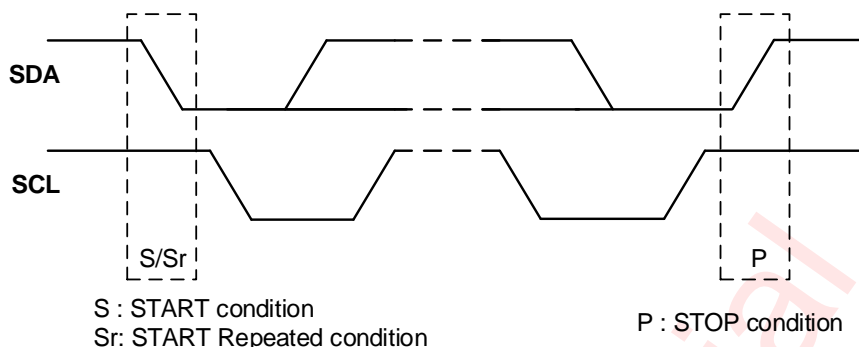


Figure 13 I<sup>2</sup>C Start/Stop Condition Timing

**Data Validation**

When SCL is high level, SDA level must be constant. SDA can be changed only when SCL is low level.

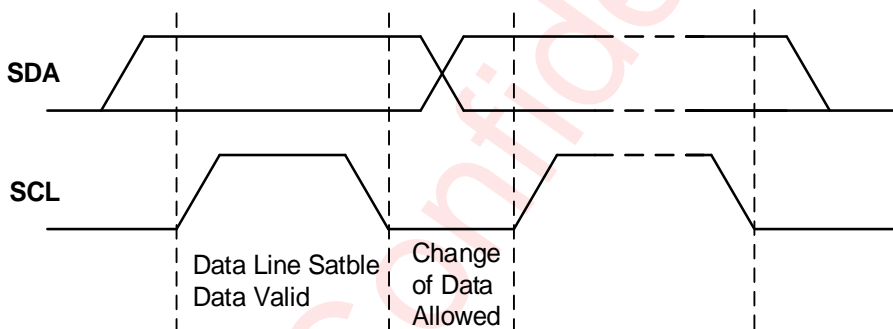


Figure 14 Data Validation Diagram

**ACK (Acknowledgement)**

ACK means the successful transfer of I<sup>2</sup>C bus data. After master sends an 8-bit data, SDA must be released; SDA is pulled down to GND by slave device when slave acknowledges.

When master reads, slave device sends 8-bit data, releases the SDA and waits for ACK from master. If ACK is sent and I<sup>2</sup>C stop is not sent by master, slave device sends the next data. If ACK is not sent by master, slave device stops to send data and waits for I<sup>2</sup>C stop.

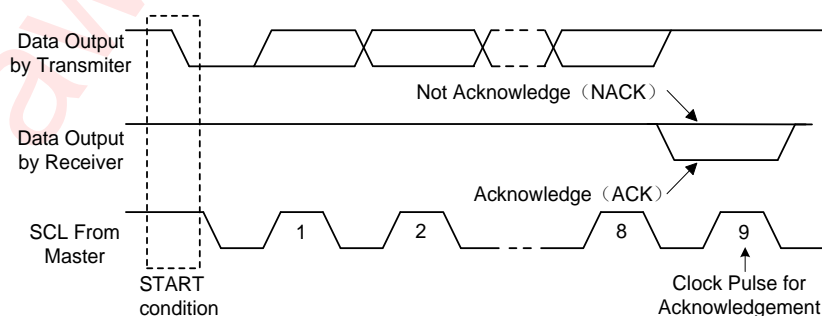


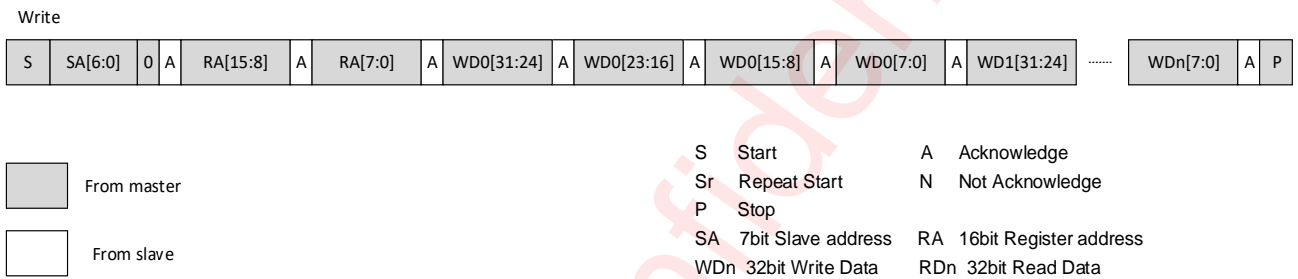
Figure 15 I<sup>2</sup>C ACK Timing

**Write Cycle**

One data bit is transferred during each clock pulse. Data is sampled during the high state of the serial clock (SCL). Consequently, throughout the clock’s high period, the data should remain stable. Any changes on the SDA line during the high state of the SCL and in the middle of a transaction, aborts the current transaction. New data should be sent during the low SCL state. This protocol allows a single data line to transfer both command/control information and data using the synchronous serial clock.

Each data transaction is composed of a start condition, a number of byte transfers (set by the software) and a stop condition to terminate the transaction. Every byte written to the SDA bus must be 8 bits long and is transferred with the most significant bit first. After each byte, an Acknowledge signal must follow.

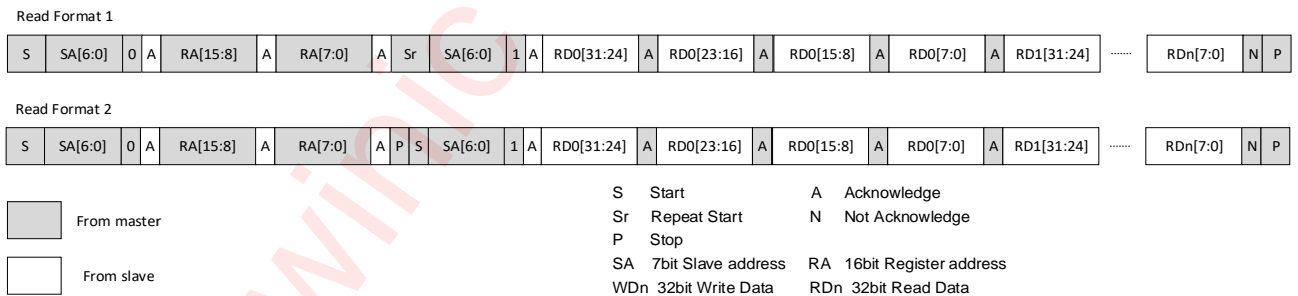
I<sup>2</sup>C Register address is 16-bit and register data is 32-bit. Note that I<sup>2</sup>C also support 8-bit data transfer. Writing process of I<sup>2</sup>C is showed as below picture.



**Figure 16 I<sup>2</sup>C Write Byte Cycle**

**Read Cycle**

I<sup>2</sup>C supports read operation data format with repeated start conditions, so there are two formats of I<sup>2</sup>C read operations. Read process of I<sup>2</sup>C is showed as below picture.



**Figure 17 I<sup>2</sup>C Read Byte Cycle**

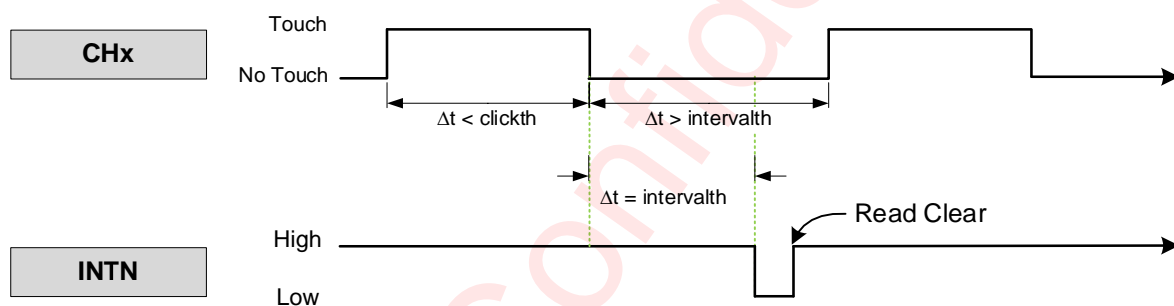
## Gestures

AW93203CSR can implement several gestures on the button and slider, including **single-click**, **double-click**, **triple-click**, **short-press**, **long-press** and **slide**.

### Single-click

**Single-click** refers to a quick tap event, when a touch is triggered and then released in the same location within a short period of time. The *clickth* and *intervalth* threshold can be adjusted according to practical application requirements. **Single-click** event is based on the following conditions:

- > 1<sup>st</sup> condition: The time of the touch state must be less than the *clickth*.
- > 2<sup>nd</sup> condition: The time between two touch states must be more than the *intervalth*.



Notes:

*Clickth*: the maximum touch time of a valid single-click event

*Intervalth*: the maximum interval between two valid single-click events

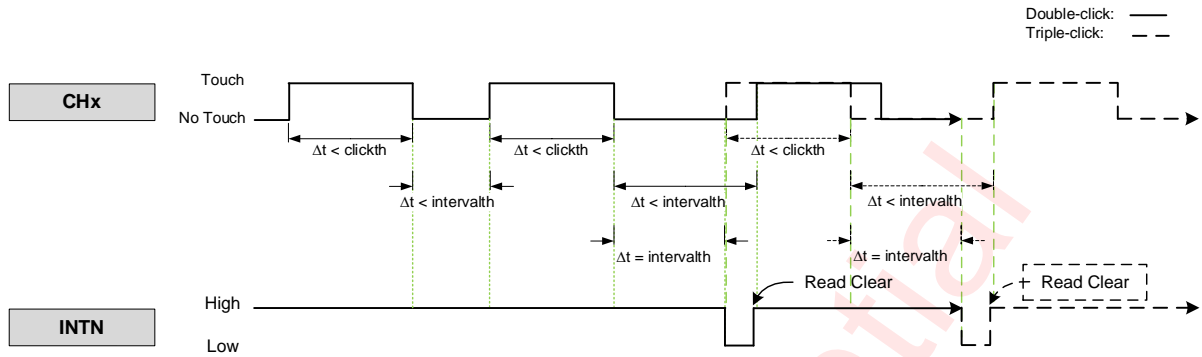
Figure 18 Single-click Sequence Diagram

### Double-click and Triple-click

**Double-click** refers to two quick tap events and **triple-click** refers to three quick tap events. The definition of **triple-click** and **double-click** are different in the number of taps. **Double-click** and **triple-click** events are based on the following conditions:

- > 1<sup>st</sup> condition: The time of the touch state must be less than the *clickth*.
- > 2<sup>nd</sup> condition: The time between two adjacent touch states must be less than the *intervalth*.





Notes:

Clickth: the maximum touch time of a valid single-click event

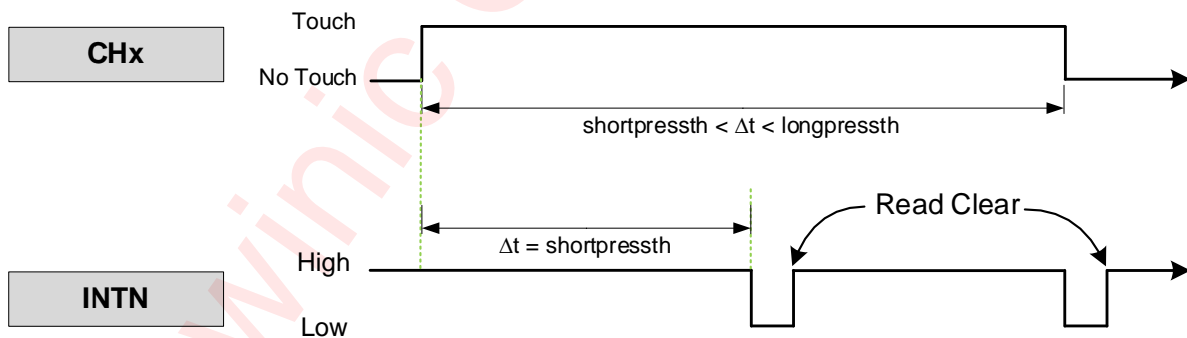
Intervalth: the maximum interval between two valid single-click events

Figure 19 Double-click and Triple-click Sequence Diagram

### Short-press

**Short-press** refers to a short time touch event, **Short-press** gesture is based on the following condition: The time during the touch state must be less than the *longpressth* and more than *shortpressth*.

**Short-press** will generate two interrupt messages. The first interrupt is reported when the touch time reaches the *shortpressth*. The second interrupt is reported when the touch state is released.



Notes:

Shortpressth: the minimum touch time of a short-press event

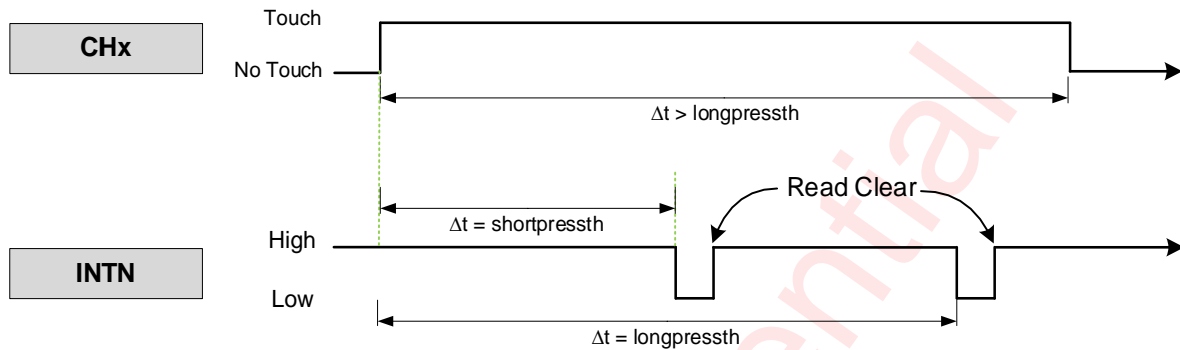
Longpressth: the minimum touch time of a long-press event

Figure 20 Short-press Sequence Diagram

### Long-press

**Long-press** refers to a long time touch event. **Long-press** is based on the following condition: The time during the touch state must be more than the *longpressth*.

**Long-press** will generate two interrupt messages. The first interrupt is reported when the touch time reaches the *shortpressth*. The second interrupt is reported when the touch time reaches the *longpressth* threshold.



Notes:  
*Shortpressth*: the minimum touch time of a short-press event  
*Longpressth*: the minimum touch time of a long-press event

Figure 21 Long-press Sequence Diagram

### Slide

**Slide** is based on the following condition: The coordinate change during the touch state must be more than the *slideth* (the minimum slip distance of a slide event).

A click (or press) is more difficultly recognized as a **slide** with a higher *slideth*. A **slide** is more difficultly recognized as a click (or press) with a lower *slideth*.

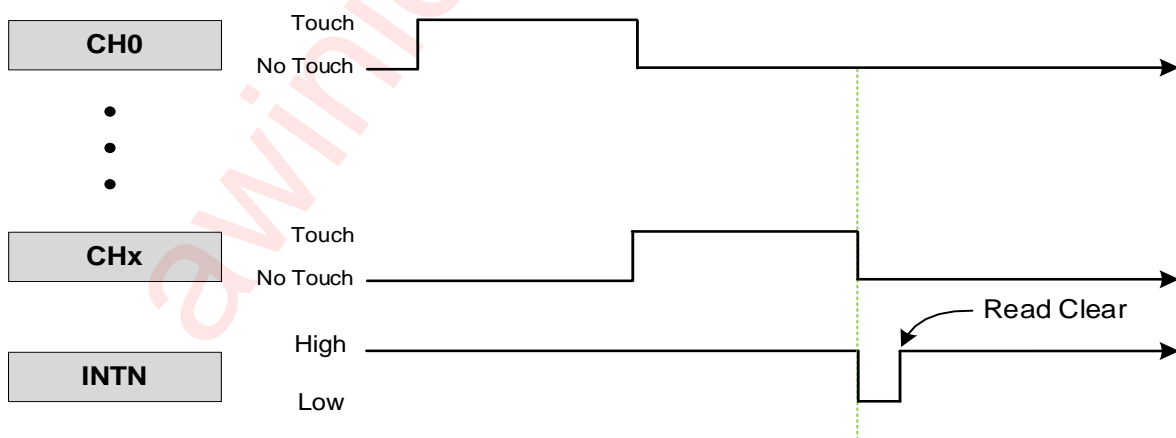


Figure 22 Slide Sequence Diagram

Single sliding definition: The finger touches the slide bar, slide for distance on the slide bar, and the sliding

event is reported after the finger leaves. There are two slide speed levels: fast sliding and slow sliding.

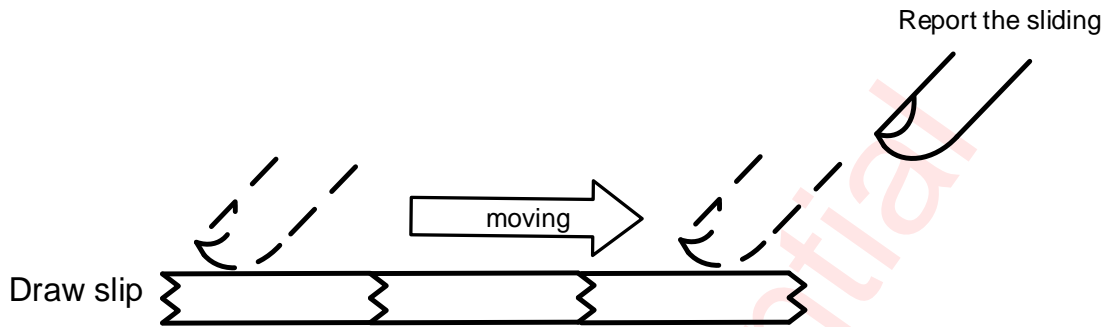


Figure 23 Single Sliding Diagram

## Application Information

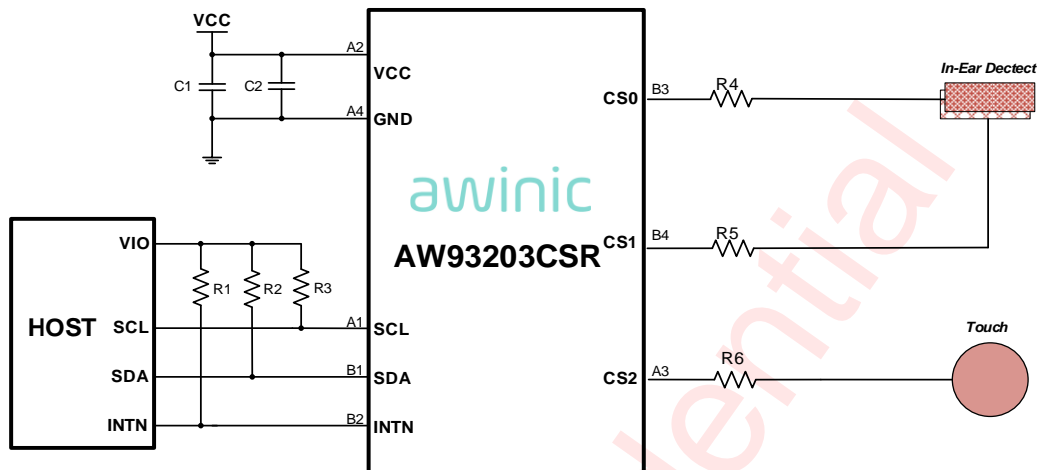


Figure 24 AW93203CSR Typical Application Circuit (an in-ear and a touch key)

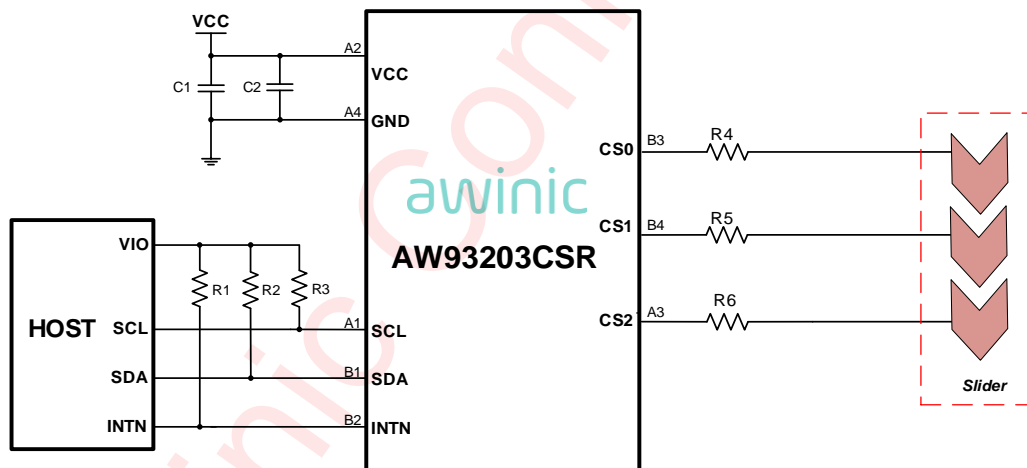


Figure 25 AW93203CSR Typical Application Circuit (a slider)

### Capacitors Selection

The recommended value of the capacitance C1 is 1 $\mu$ F and C2 is 0.1 $\mu$ F.

### Resistor Selection

The recommended values of the resistor R1~R3, which were applied in pins SCL, SDA and INTN, are 4.7k $\Omega$ . The recommended values of the resistor R4~R6, which were applied in pins CS0~2, are 390 $\Omega$ .

## Recommended Components List

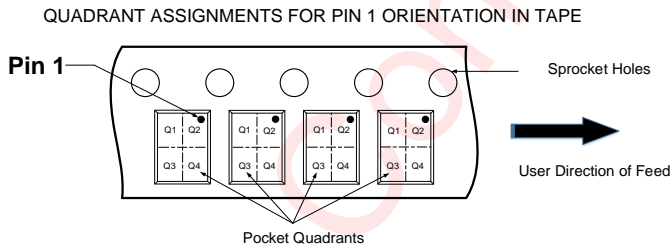
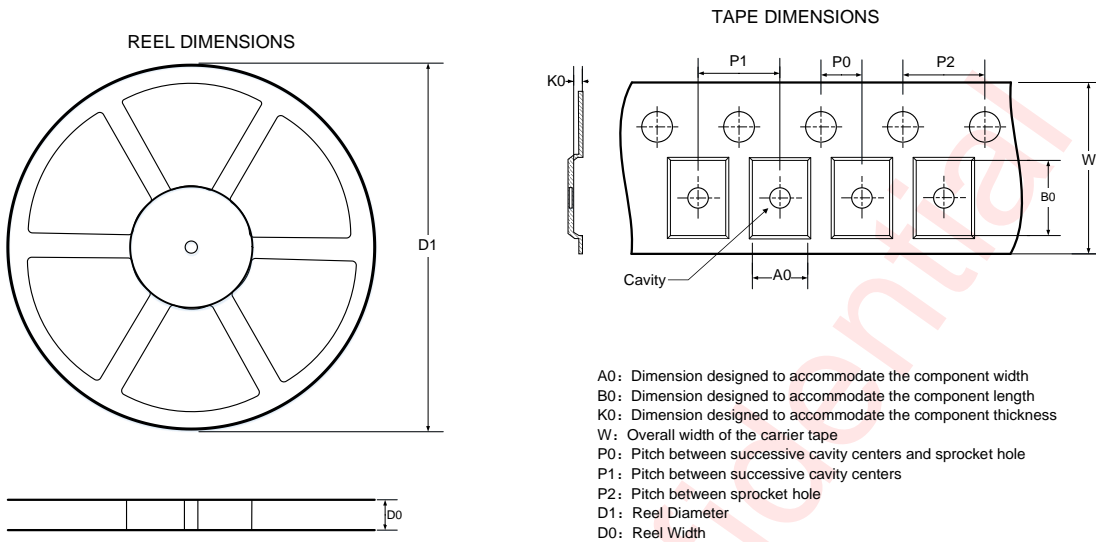
Component	Name	Description	TYP.	Unit
C	C1	-	1	$\mu\text{F}$
	C2	-	0.1	$\mu\text{F}$
R	R1,R2,R3	5% resolution	4.7	$\text{k}\Omega$
	R4,R5,R6	5% resolution	390	$\Omega$

## PCB Layout Consideration

AW93203CSR is a 3-channel capacitive touch and proximity controller, to obtain the optimal performance, PCB layout should be considered carefully. Here are some guidelines:

1. All peripheral components should be placed as close to the chip as possible. C1 and C2 should be close to VCC. Avoid connecting peripheral devices and chip pins with two different layers of copper, use the same layer of copper instead.
2. Place the chip close to capacitive sensor and make trace as short as possible.
3. Make sure the sensor and traces be away from mic, earphone line in case of disturbing audio line.
4. Place reference channel along with sensor channel to get better performance.
5. Use low noise power supply for SAR sensor.

## Tape And Reel Information

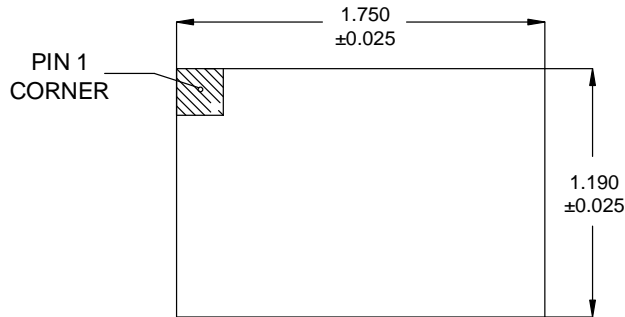


DIMENSIONS AND PIN 1 ORIENTATION

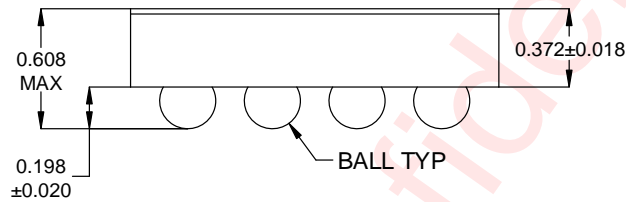
D1 (mm)	D0 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
179.00	9.00	1.31	1.87	0.71	2.00	4.00	4.00	8.00	Q2

All dimensions are nominal

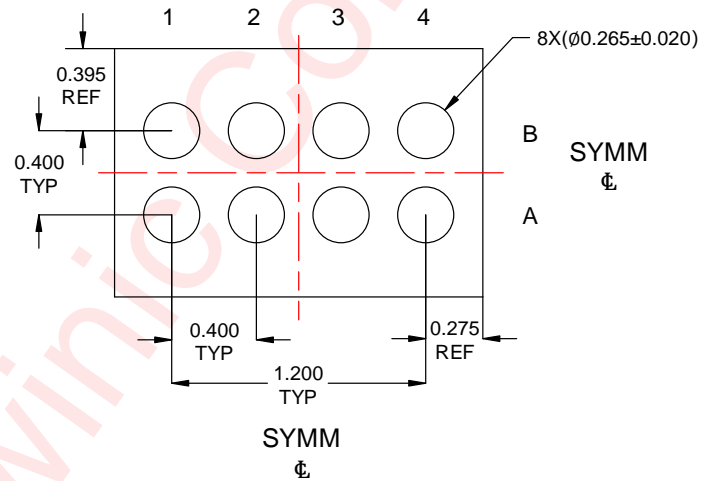
Package Description



Top View



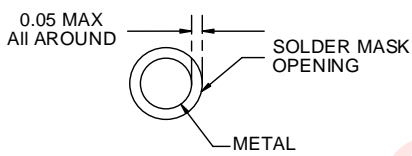
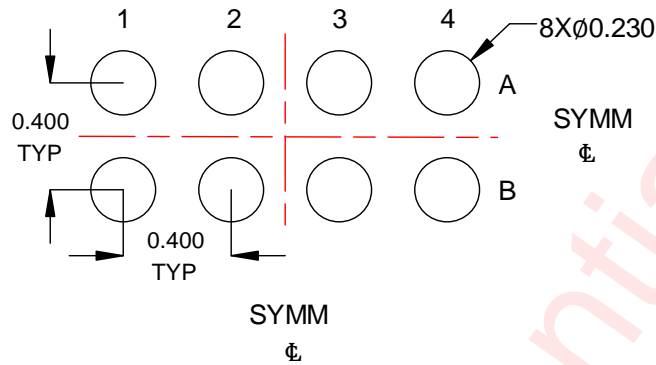
Side View



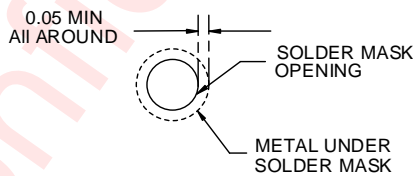
Bottom View

Unit:mm

Land Pattern Data



NON-SOLDER MASK DEFINED



SOLDER MASK DEFINED

Unit: mm



## Revision History

Version	Date	Change Record
V1.0	Jun.2021	Officially released
V1.1	Apr.2022	Modifying gesture Definitions.

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