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GENERAL DESCRIPTION

The SX9510 and SX9511 are 8–button capacitive touch sensor controllers that include 8-channels of LED drivers, a buzzer, an IR detector and analog outputs designed ideally for TV applications. The SX9510 offers proximity sensing.

The SX9510 and SX9511 operate autonomously using a set of programmable button sensitivities & thresholds, plus LED intensities & breathing functions with no external I2C communication required.

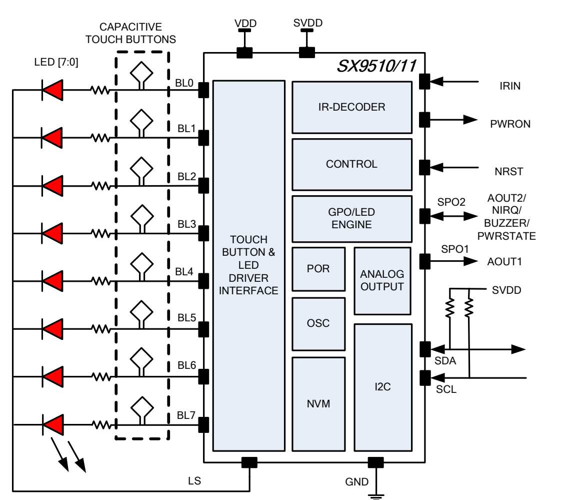
All devices feature three individual LED driver engines for advanced LED lighting control. On the SX9510, a proximity detection illuminates all LEDs to a pre-programmed intensity. Touching a button will enable the corresponding LED to a pre-programmed mode such as intensity, blinking or breathing.

Whenever the capacitive value changes from either a proximity detection or finger touch/release, the controller informs the host processor through the analog output(s) or an open drain interrupt and an I2C register read.

The SX9510 and SX9511 do not require additional external dynamic programming support or setting of parameters and will adapt to humidity and temperature changes to guarantee correct touch/no touch information.

The SX9510 and SX9511 are offered in 20-ld QFN and 24-ld TSSOP packages and operate over an ambient temperature range of -40°C to +85°C.

TYPICAL APPLICATION CIRCUIT



KEY PRODUCT FEATURES

- ♦ Separate Core and I/O Supplies
  - o 2.7V – 5.5V Core Supply Voltage
  - o 1.65V – 5.5V I/O Supply Voltage
- ♦ 8 - Button Capacitance Controller
  - o Capacitance Offset Compensation to 40pF
  - o Adaptive Measurements For Reliable Proximity And Button Detection
- ♦ Proximity Sensing (SX9510)
  - o High Sensitivity
  - o LEDs Activated During Proximity Sense
- ♦ 8-channel LED Controller & Driver
  - o Blink And Breathing Control
  - o High Current, 15 mA LED Outputs
- ♦ 2-Channel Analog Output, 6-bit DAC Programmable Control
- ♦ Support Metal Overlay UI Design (SX9510)
- ♦ Infra Red Detector for Power-On signaling and LED feedback
  - o programmable address with eight commands
  - o compatible with NEC, RC5, RC6, Toshiba, RCA, etc
- ♦ Simple (400kHz) I^2C Serial Interface
  - o Interrupt Driven Communication via NIRQ Output
- ♦ Power-On Reset, NRST Pin and Soft Reset
- ♦ Low Power
  - o Sleep, Proximity Sensing: 330uA
  - o Operating: 600uA
- ♦ -40°C to +85°C Operation
- ♦ 4.0 mm x 4.0 mm, 20-lead QFN package
- ♦ 4.4 mm x 7.8 mm, 24-lead TSSOP package
- ♦ Pb & Halogen free, RoHS/WEEE compliant

APPLICATIONS

- ♦ LCD TVs, Monitors
- ♦ White Goods
- ♦ Consumer Products, Instrumentation, Automotive
- ♦ Mechanical Button Replacement

ORDERING INFORMATION

Part Number	Package	Marking
SX9511EWLTRT[1]	QFN-20	ZK72
SX9511ETSTRT[2]	TSSOP-24	AC72T
SX9510EWLTRT[1]	QFN-20	ZL73
SX9510ETSTRT[2]	TSSOP-24	AC73X
SX9510EVK	Evaluation Kit	-

[1] 3000 Units/Reel
[2] 2500 Units/Reel

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Table of Figures

1 General Description

1.1 Pin Diagram SX9510/11

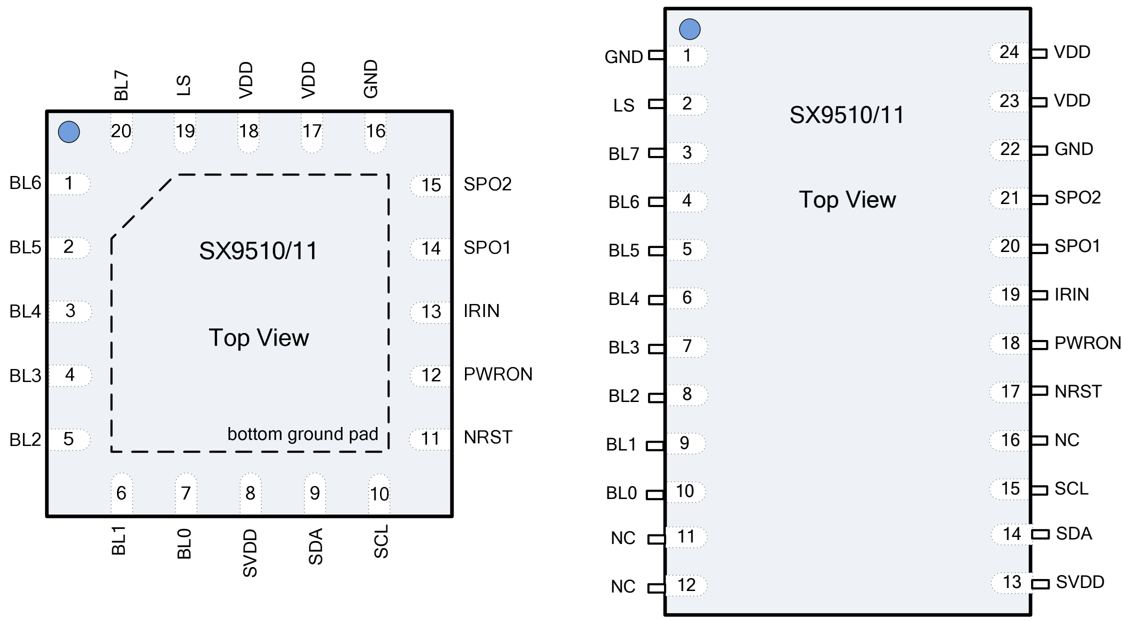


Figure 1 Pinout Diagram SX9510/11 (QFN, TSSOP)

1.2 Marking information SX9511

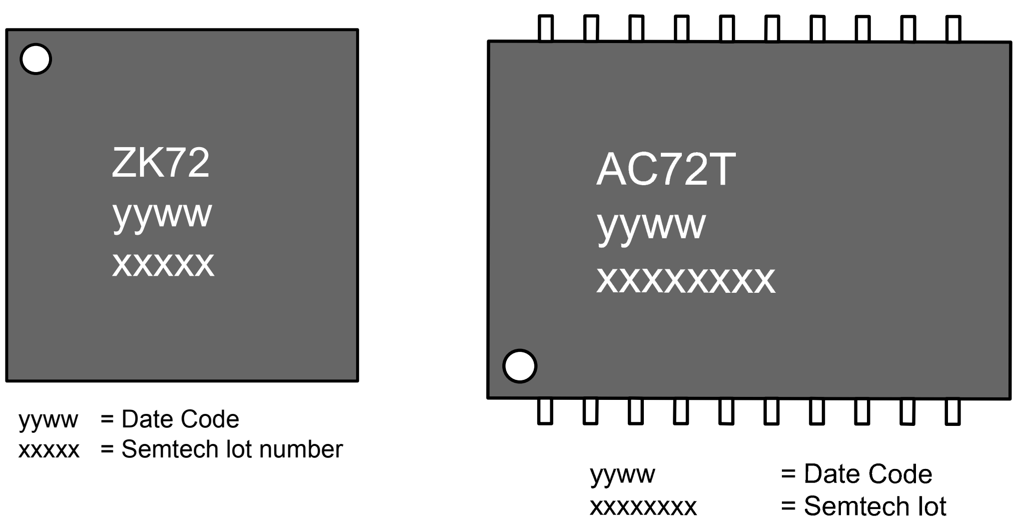


Figure 2 Marking Information SX9511 (QFN, TSSOP)

1.3 Marking information SX9510

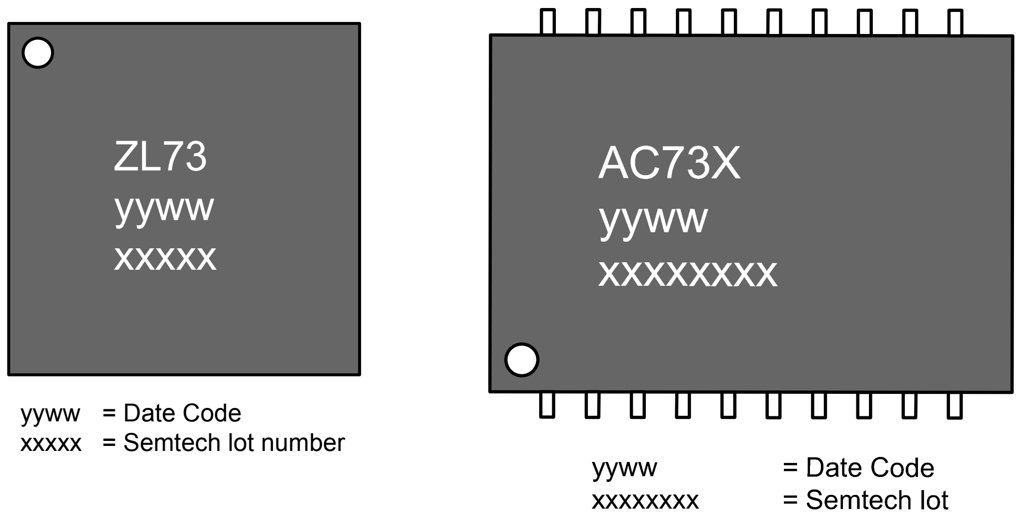


Figure 3 Marking Information SX9510 (QFN, TSSOP)

1.4 Pin Description

Pin QFN	Pin TSSOP	Name	Type	Description
1	4	BL6	Analog	Button Sensor and Led Driver 6
2	5	BL5	Analog	Button Sensor and Led Driver 5
3	6	BL4	Analog	Button Sensor and Led Driver 4
4	7	BL3	Analog	Button Sensor and Led Driver 3
5	8	BL2	Analog	Button Sensor and Led Driver 2
6	9	BL1	Analog	Button Sensor and Led Driver 1
7	10	BL0	Analog	Button Sensor and Led Driver 0
8	13	SVDD	Power	IO Power Supply, SVDD must be ≤ VDD
9	14	SDA	Digital Input/Output	I2C Data, requires pull up resistor to SVDD (in host or external)
10	15	SCL	Digital Input	I2C Clock, requires pull up resistor to SVDD(in host or external)
11	17	NRST	Digital Input	Active Low Reset. Connect to SVDD if not used.
12	18	PWRON	Digital Output	Power On Signal (positive edge triggered, push pull)
13	19	IRIN	Digital Input	Input Signal from IR receiver.
14	20	SPO1	Analog	Special Purpose Output 1: - AOUT1: Analog Voltage indicating touched buttons (filtered digital)
15	21	SPO2	Analog/Digital	Special Purpose Output 2: - AOUT2: Analog Voltage indicating touched buttons (filtered digital) - BUZZER: Driver (digital push-pull output) - NIRQ: Interrupt Output, active low (digital open drain output) - PWRSTATE: Signal indicating system power state (digital input)
16	22	GND	Ground	Ground
17	23	VDD	Power	Power Supply
18	24	VDD	Power	Power Supply
19	2	LS	Analog	Led Sink/Shield
20	3	BL7	Analog	Button Sensor and Led Driver 7
bottom plate	1	GND	Ground	Connect to ground
	11, 12, 16	NC	No Connect	Leave Floating

Table 1 Pin description

1.5 Simplified Block Diagram

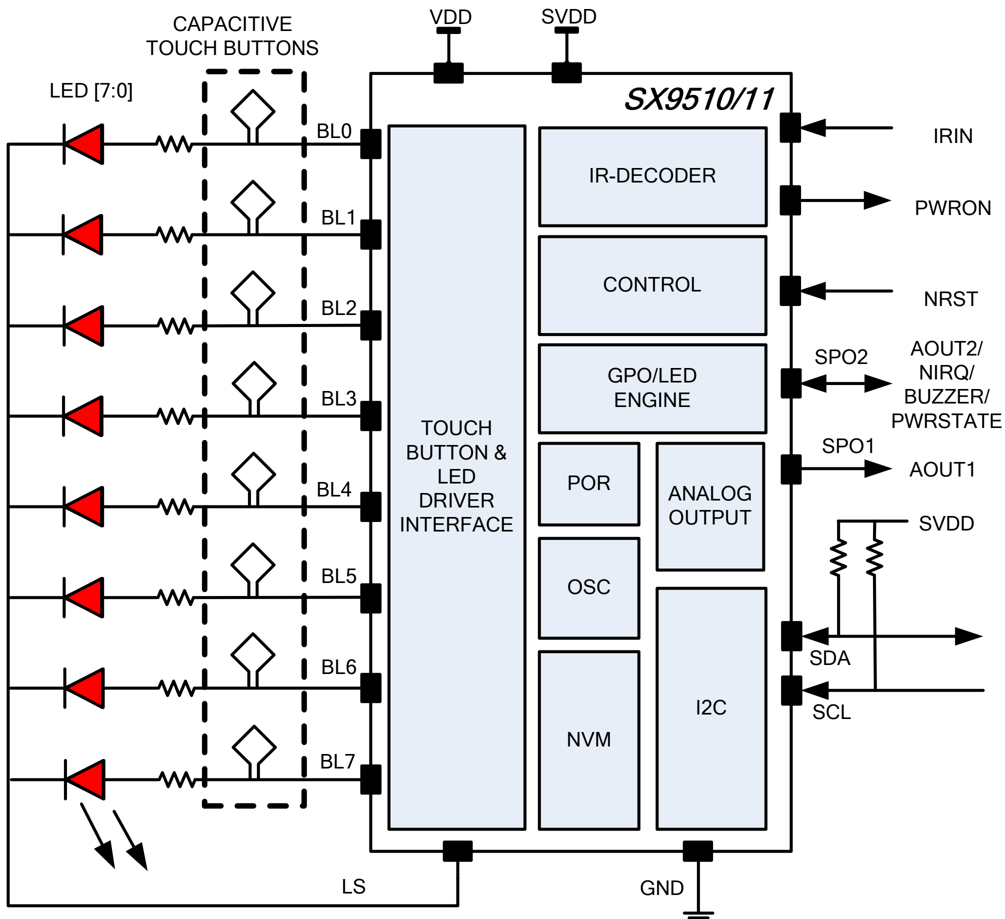


Figure 4 Simplified Block diagram of the SX9510/11

1.6 Acronyms

AOI	Analog Output Interface
ASI	Analog Sensor Interface
NVM	Non Volatile Memory
PWM	Pulse Width Modulation
SPO	Special Purpose Output

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 “Recommended Operating Conditions”, is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

Parameter	Symbol	Min.	Max.	Unit
Supply Voltage	VDD, SVDD	-0.5	6.0	V
Input voltage (non-supply pins)	V_{IN}	-0.5	VDD + 0.3	V
Input current (non-supply pins)	I_{IN}	-10	10	mA
Operating Junction Temperature	T_{JCT}	-40	150	°C
Reflow temperature	T_{RE}		260	°C
Storage temperature	T_{STOR}	-50	150	°C
ESD HBM (Human Body model)(i)	ESD_{HBM}	3		kV
Latchup(ii)	I_{LU}	± 100		mA

Table 2 Absolute Maximum Ratings

(i) Tested to JEDEC standard JESD22-A114

(ii) Tested to JEDEC standard JESD78

2.2 Recommended Operating Conditions

Parameter	Symbol	Min.	Max.	Unit
Supply Voltage	VDD	2.7	5.5	V
Supply Voltage (SVDD must be ≤ VDD)	SVDD	1.65	5.5	V
Ambient Temperature Range	T_A	-40	85	°C

Table 3 Recommended Operating Conditions

2.3 Thermal Characteristics

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Thermal Resistance - Junction to Ambient (vi)	$\theta_{JA,QFN}$			25		°C/W
Thermal Resistance - Junction to Ambient (vi)	$\theta_{JA,SSOP}$			78		°C/W

Table 4 Thermal Characteristics

(vi) ThetaJA is calculated from a package in still air, mounted to 3" x 4.5", 4 layer FR4 PCB with thermal vias under exposed pad (if applicable) per JESD51 standards.

2.4 Electrical Specifications

All values are valid within the operating conditions unless otherwise specified.

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Current consumption						
Sleep	I_{sleep}	All buttons are scanned at a 200ms rate. (40ms scan with skip 4 frames)		330	350	uA
Operating	$I_{operating}$	All buttons are scanned at a 40 ms rate, excluding LED forward current.		600	650	uA
Input Levels NRST, IRIN, SCL, SDA, SPO2 (in PWRSTATE mode)						
Input logic high	V_{IH}		0.7*SVDD		SVDD + 0.3	V
Input logic low	V_{IL}	GND applied to GND pins	GND - 0.3		0.3*SVDD	V
Input leakage current	L_I	CMOS input			±1	uA
Output PWRON, SPO1, SPO2, SDA						
Output logic high (PWRON, SP01, & SP02 Only)	V_{OH}	I_{OH}<3mA	SVDD-0.4			V
Output logic low	V_{OL}	$I_{OL,}$<6mA			0.6	V
CapSense Interface						
Offset Compensation Range	C_{off}			40		pF
Power up time	t_{por}				10	ms
Reset						
Power on reset voltage	V_{por}			1.1		V
Reset time after power on	t_{por}			1		ms
Reset pulse width on NRST	t_{res}			20		ns
Recommended External components						
capacitor between SVDD, GND	C_{vreg}	tolerance +/-20%		0.1		uF
capacitor between VDD, GND	C_{vdd}	tolerance +/-20%		0.1		uF

Table 5 Electrical Specifications

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
I2C Timing Specifications (i)						
SCL clock frequency	f_{SCL}				400	KHz
SCL low period	t_{LOW}		1.3			us
SCL high period	t_{HIGH}		0.6			us
Data setup time	$t_{SU;DAT}$		100			ns
Data hold time	$t_{HD;DAT}$		0			ns
Data valid time	$t_{VD;DAT}$				0.9	us
Repeated start setup time	$t_{SU;STA}$		0.6			us
Start condition hold time	$t_{HD;STA}$		0.6			us
Stop condition setup time	$t_{SU;STO}$		0.6			us
Bus free time between stop and start	t_{BUF}		1.3			us
Input glitch suppression	t_{SP}	Up to 0.3xVDD from GND, down to 0.7xVDD from VDD			50	ns

Table 6 I2C Timing Specification

Notes:

(i) All timing specifications, Figure 5 and Figure 6, refer to voltage levels (V_{IL}, V_{IH}, V_{OL}) defined in Table 5.

(ii) $t_{VD;DAT}$ = Minimum time for SDA data out to be valid following SCL LOW.

The interface complies with slave F/S mode as described by NXP: "I2C-bus specification, Rev. 03 - 19 June 2007"

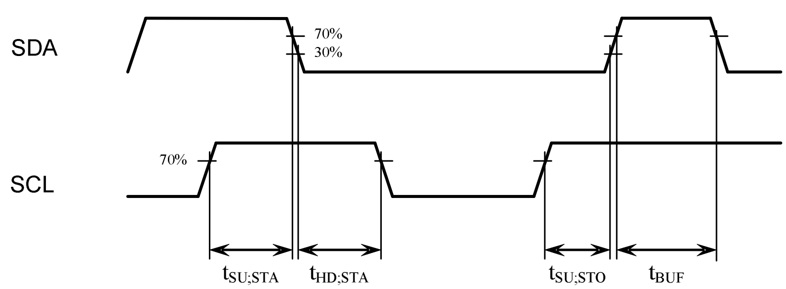


Figure 5 I2C Start and Stop timing

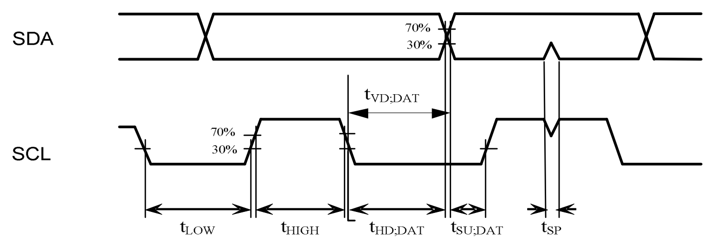


Figure 6 I2C Data timing

3 FUNCTIONAL DESCRIPTION

3.1 Introduction

3.1.1 General

The SX9510/11 is intended to be used in applications which require capacitive sensors covered by isolating overlay material and which may need to detect the proximity of a finger/hand though the air. The SX9510/11 measures the change of charge and converts that into digital values. The larger the charge on the sensors, the larger the number of digital value will be. The charge to digital value conversion is done by the SX9510/11 Analog Sensor Interface (ASI).
The digital values are further processed by the SX9510/11 and converted in a high level, easy to use information for the user's host.
The information between SX9510/11 and the user's host is passed through the I2C interface with an additional interrupt signal indicating that the SX9510/11 has new information. For buttons this information is simply touched or released. The SX9510/11 can operate without the I2C and interrupt by using the analog output interface (SPO1, SPO2) with a changing voltage level to indicate the button touched.

3.1.2 Feedback

Visual feedback to the user is done by the button and LED pins BL[7...0]. The LED drivers will fade-in when a finger touches a button or proximity is detected and fade-out when the button is released or finger goes out of proximity. Fading intensity variations can be logarithmic or linear. Interval speed and initial and final light intensity can be selected by the user.

Audible feedback can be obtained through the Special Purpose Output (SPO2) pin connected to a buzzer.

3.1.3 Analog Output Interface SPO1 and SPO2

The Analog Output Interface (AOI) is a Digital signal driven from GND to SVDD and controlled by a PWM. When the digital signal on the SPO line is filtered with an RC low pass filter you produce a DC voltage, the level of which depends on the buttons that has been touched. A host controller can then measure the voltage delivered by the SPO output and determine which button is touched at any given time.
The AOI feature allows the SX9510/11 device to directly replace legacy mechanical button controllers in a quick and effortless manner. The SX9510/11 supports up to two Analog Output Interfaces, on SPO1 and SPO2 respectively. The SX9510/11 allows buttons to be mapped on either SPO1 or SPO2. The button mapping as well as the mean voltage level that each button produces on an SPO output can be configured by the user through a set of parameters described in later chapters.

3.1.4 Buzzer

The SX9510/11 can drive a buzzer (on SPO2) to provide audible feedback on button touches. The buzzer provides two phases, each of which can vary from 5ms to 30ms in length and can drive 1KHz, 2KHz, 4KHz or 8KHz tones.

3.1.5 Configuration

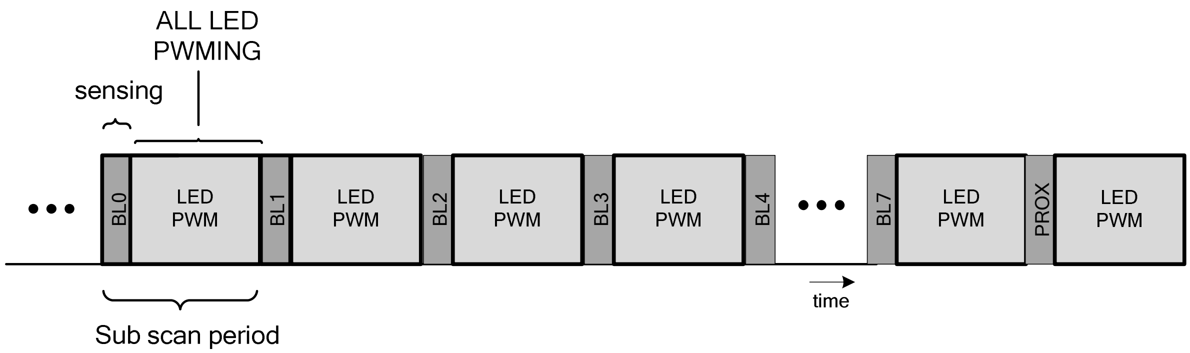
The control and configuration registers can be read from and written to an infinite number of times. During the development phase the parameters can be determined and fine tuned by the users and updated over the I2C.

Once the parameter set has been determined, the settings can be downloaded over the I2C by the host each time the SX9510/11 boots up or they can be stored in the Multiple Time Programmable (MTP) Non Volatile Memory (NVM) on the SX9510/11. This allows the flexibility of dynamically setting the parameters at the expense of I2C traffic or autonomous operation without host intervention.

After the parameters are written to the NVM, the registers can still be dynamically overwritten in whole or in part by the host when desired.

3.2 Scan Period

The SX9510/11 interleaves the sensing of the touch buttons with the driving of the LEDs. To keep the LED intensities constant and flicker free the BL sensing is done in a round robin fashion with an LED drive period between each of the BL sensing periods.



Nine (9) scan periods (1 frame) are required to scan all 8 buttons & Perform Combined Channel Proximity Sensing

Figure 7 CapSense Scan Frame SX9510/11

To keep timing consistency the scan frame always cycles through all channels (BL0 to BL7) and Combined Channel proximity even if a channel is disabled or a device does not have the proximity feature. This means that the frame time is always the sum of nine CapSense measurement times and nine LED PWM times.

The SX9510/11 can reduce it's average power consumption by inserting fames that skip the CapSense measurements but maintain the LED PWM timing.

The Scan period of the SX9510/11 is the time between the measurement of a particular channel and its next measurement. This period is the time for one CapSense frame plus the time for any skip frames and is the key factor in determining system touch response timing.

Figure 8 shows the different SX9510/11 periods over time.

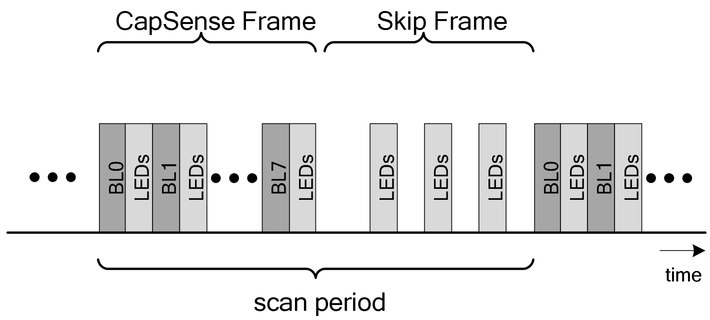


Figure 8 Scan Period SX9510/11

3.3 Operation modes

The SX9510/11 has 2 operation modes, Active and Sleep. The main difference between the 2 modes is found in the reaction time (corresponding to the scan period) and power consumption.

Active mode offers fast scan periods. The typical reaction time is 40ms. All enabled sensors are scanned and information data is processed within this interval.

Sleep mode increases the scan period time which increases the reaction time to 200ms typical and at the same time reduces the operating current.

The user can specify other scan periods for the Active and Sleep mode and decide for other compromises between reaction time and power consumption.

In most applications the reaction time needs to be fast when fingers are present, but can be slow when no person uses the application. In case the SX9510/11 is not used during a scan frame it will go from Active mode into Sleep mode and power will be saved. (when sleep mode is enabled)

To leave Sleep mode and enter Active mode this can be done by a touch on any button or the detection of proximity.

The host can decide to force the operating mode by issuing commands over the I2C (using register 0x3A[3]) and take fully control of the SX9510/11. The diagram in Figure 9 shows the available operation modes and the possible transitions.

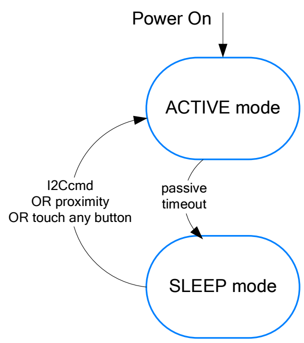


Figure 9 Operation modes

3.4 Sensors on the PCB

The capacitive sensors are relatively simple copper areas on the PCB connected to the eight SX9510/11 capacitive sensor input pins (BL0…BL7). The sensors are covered by isolating overlay material (typically 1mm...3mm). The area of a sensor is typically one square centimeter which corresponds to about the area of a finger touching the overlay material. The area of a proximity sensor is usually significantly larger than the smaller touch sensors.

The SX9510 and the SX9511 capacitive sensors can be setup as ON/OFF buttons for control applications (see example Figure 10).

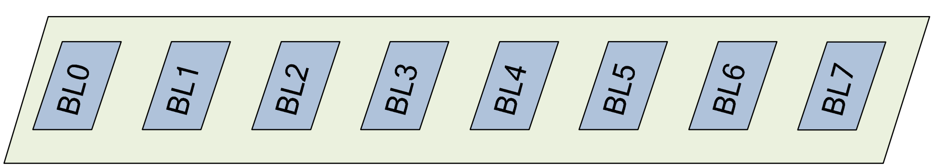


Figure 10 PCB top layer of touch buttons sensors surrounded by the shield, SX9510/11

The SX9510 offers 2 options for proximity detection. Depending on the PCB area, the proximity detection distance can be optimized.

1) Individual Sensor Proximity

Single sensor proximity is done by replacing the shield area shown in Figure 10 with a connection to BL0 as shown in Figure 24.

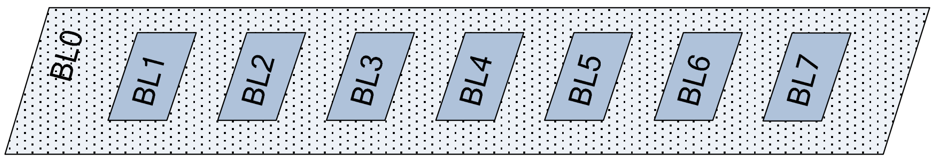


Figure 11 PCB top layer for proximity and touch buttons, SX9510

2) Combined Channel Proximity

In Combined Channel Proximity the SX9510 will put some or all of the sensors in parallel and execute one sensing cycle on this combined large sensor.

3.5 Button Information

The touch buttons have two simple states (see Figure 12): ON (touched by finger) and OFF (released and no finger press).

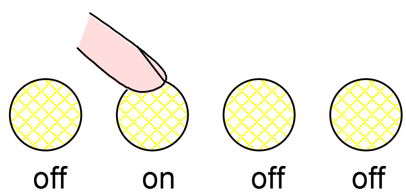


Figure 12 Buttons

A finger is detected as soon as the digital values from the ASI reach a user-defined threshold plus a hysteresis.

A release is detected if the digital values from the ASI go below the threshold minus a hysteresis. The hysteresis around the threshold avoids rapid touch and release signaling during transients.

Buttons can also be used to do proximity sensing. The principle of proximity sensing operation is exactly the same as for touch buttons except that proximity sensing is done several centimeters above the overlay through the air. ON state means that finger/hand is detected by the sensor and OFF state means the finger/hand is far from the sensor and not detected.

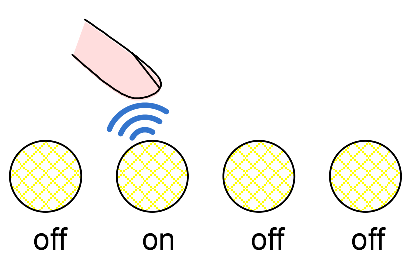


Figure 13 Proximity

3.6 Buzzer

The SX9510/11 has the ability to drive a buzzer (on SPO2) to provide an audible indication that a button has been touched. The buzzer is driven by a square wave signal for approximately 10ms (default). During both the first phase (5ms) and the second phase (5ms) the signal's frequency is default 1KHz.
The buzzer is activated only once during any button touch and is not repeated for long touches. The user can choose to enable or disable the buzzer by configuration and define the idle level, frequencies and phase durations (see §4.6).

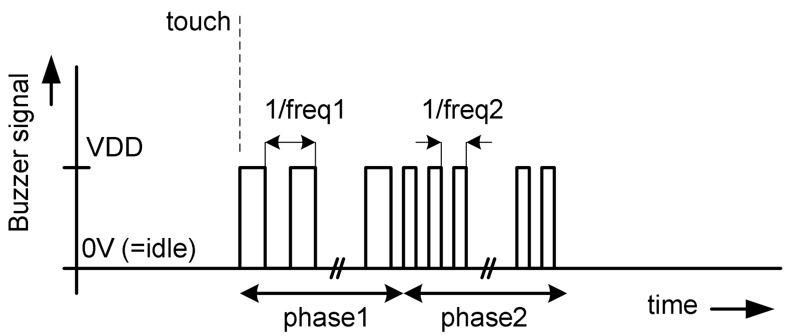


Figure 14 Buzzer behavior

3.7 Analog Output Interface

The Analog Output Interface outputs a PWM signal with a varying duty cycle depending on which button is touched. By filtering (with a simple RC filter) the PWM signal results in a DC voltage that is different for each button touch. The host controller measures the DC voltage level and determines which buttons has been touched.

In the case of single button touches, each button produces its own voltage level as configured by the user.

Figure 15 show how the AOI will behave when the user touches and releases different buttons.
The AOI will switch between the AOI idle level and the level for each button.

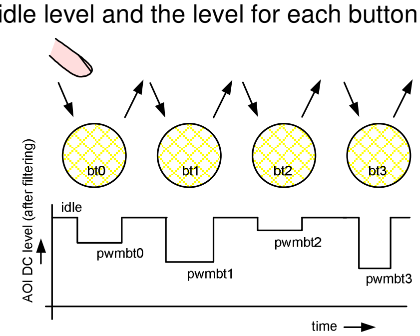


Figure 15 AOI behavior

The PWM Blocks used in AOI modes are 6-bits based and are typically clocked at 2MHz.

Figure 16 shows the PWM definition of the AOI.

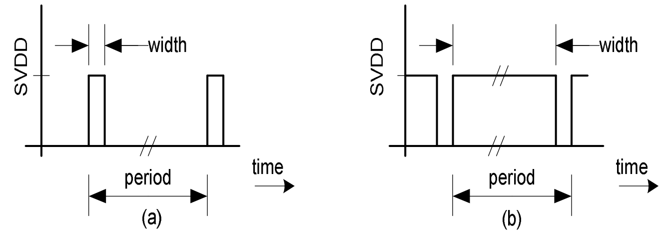


Figure 16 PWM definition, (a) small pulse width, (b) large pulse width

The AOI always reports one button per output channel. The AOI can be split over SPO1 and SPO2 (AOI-A, AOI-B. The user can map any button to either AOI-A or AOI-B or both.

In most applications only one AOI pin will be selected. The two AOI pins allow the user to use a more coarse detection circuit at the host. Assuming a 3.3V supply and 8 buttons on one single AOI then the AOI levels could be separated by around 0.3…0.4V. In the case of using the two AOI pins, 4 buttons could be mapped on AOI-A separated by around 0.8V (similar for 4 buttons on AOI-B) which is about double that of the case of a single AOI.

In the case of a single touch the button reporting is straight forward (as in Figure 15). If more than one button is touched the reported depends on the selected button reporting mode parameter (see yyy). Three reporting modes exist for the SX9510/11 (All, Single and Strongest).
The All reporting mode is applicable only for the I2C reporting (AOI is not available). In All-mode all buttons that are touched are reported in the I2C buttons status bits and on the LEDs. In the Single-mode a single touched button will be reported on the AOI and the I2C. All touches that occur afterwards will not be reported as long as the first touch sustains. Only when the first reported button is released will the SX9510/11 report another touch.

Figure 17 shows the Single-mode reporting in case of 2 touches occurring over time.

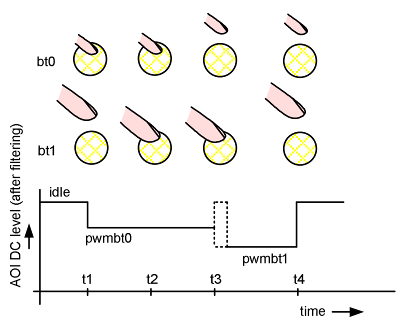


Figure 17 Single-mode reporting with 2 touches

At time t1 button0 is touched and reported on the AOI. At time t2 button1 is touched as well but not reported. At time t3 the button0 is released and button1 will be reported immediately (or after one scan period at idle level). At time t4 both buttons are released and the AOI reports the idle level.

The button with the lowest Cap pin index will be reported in case of a simultaneous touch (that means touches occurring within the same scan period).

In the Strongest-mode the strongest touched button will be reported on the AOI and the I2C. All touches that occur afterwards representing a weaker touch will not be reported. Only a touch which is stronger will be reported by the SX9510/11.
Figure 18 shows the Strongest-mode reporting in case of 2 touches (with bt1 the strongest touch).

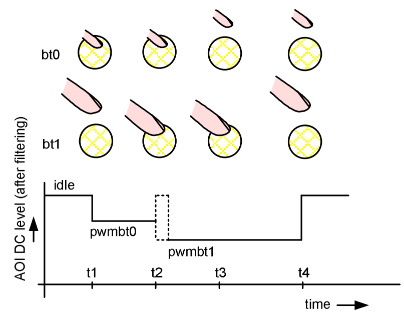


Figure 18 Strongest-mode reporting with 2 touches

At time t1 button0 is touched and reported on the AOI. At time t2 button1 is touched as well. As bt1 is the strongest touch it will be reported on the AOI immediately (or after one scan period at idle level). At time t3 the button0 is released while the AOI continues to report button1. At time t4 both buttons are released and the AOI reports the idle level.

3.8 Analog Sensing Interface

The Analog Sensing Interface (ASI) induces a charge on the sensors and then converts the charge into a digital value which is further digitally processed. The basic principle of the ASI will be explained in this section.

The ASI consists of a multiplexer selecting the sensor, analog switches, a reference voltage, a high-resolution ADC converter and an offset compensation DAC (see Figure 19).

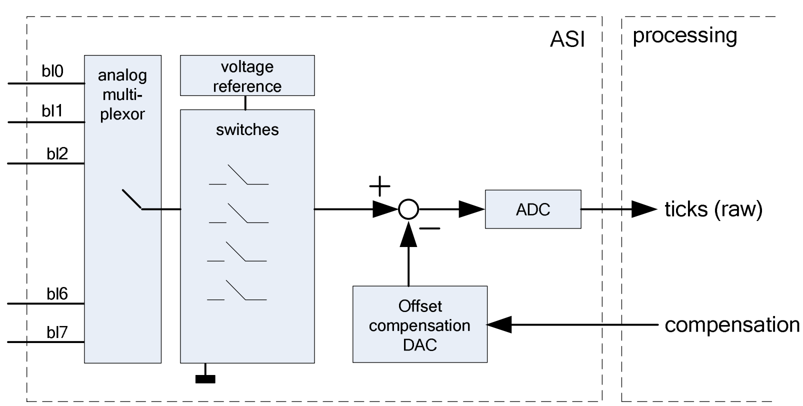


Figure 19 Analog Sensor Interface

The SX9510 offers the additional Combined Channel Proximity mode where all sensors are sensed in parallel.

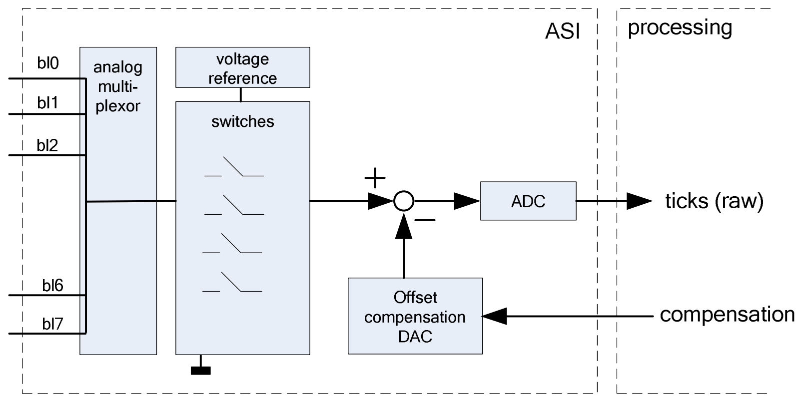


Figure 20 Analog Sensor Interface for SX9510, Combined Channel Prox Mode

To get the digital value representing the charge on a specific sensor the ASI will execute several steps. A voltage will be induced on the sensor developing a charge relative to the absolute capacitance of the sensor. The charge on a sensor cap (e.g BL0) will then be accumulated multiple times on the internal integration capacitor (Cint). This results in an increasing voltage on Cint proportional to the capacitance on BL0.

At this stage the offset compensation DAC is enabled. The compensation DAC generates a voltage proportional to an estimation of the external parasitic capacitance (the capacitance of the system without the calibration).

The difference between the DAC output and the charge on Cint is the desired signal. In the ideal case the difference of charge will be converted to a zero digital value if no finger is present and the digital value becomes high in case a finger is present.

The difference of charge on Cint and the DAC output will be transferred to the ADC.

After the charge transfer to the ADC the steps above will be repeated.

The SX9510/11 allows setting the sensitivity for each sensor individually for applications which have a variety of sensors sizes or different overlays or for fine-tuning performances. The optimal sensitivity depends heavily on the final application. If the sensitivity is too low the digital value will not pass the thresholds and touch/proximity detection will not be possible. In case the sensitivity is set too large, some power will be wasted and false touch/proximity information may be output (i.e. for touch buttons => finger not touching yet, for proximity sensors => finger/hand not close enough).

The digital values from the ASI will then be handled by the digital processing.

The ASI will shut down and wait until new sensing period will start.

3.8.1 Processing

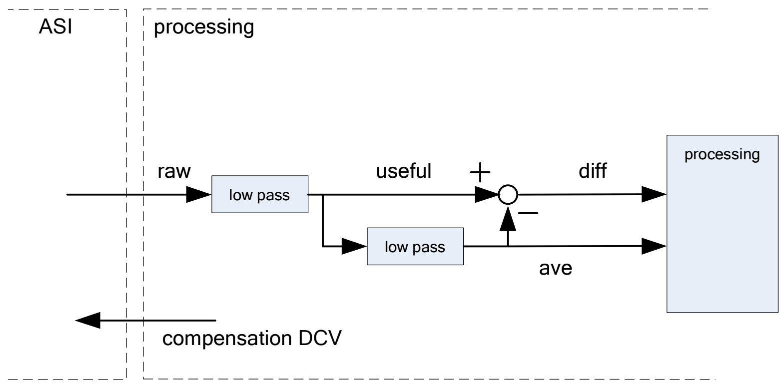


Figure 21 Processing

The raw data is processed through a programmable low pass filter to create useful data (data with fast environmental noise suppressed). The useful data is processed through a second programmable low pass filter (with a longer time constant) to create average data. The average data tracks along with the slow environmental changes and is subtracted from the useful data to create the diff data. The diff data represents any fast capacitance changes such as a touch or proximity event.

3.8.2 Offset Compensation

The parasitic capacitance at the BL pins is defined as the intrinsic capacitance of the integrated circuit, the PCB traces, ground coupling and the sensor planes. This parasitic capacitance is relatively large (tens of pF) and will also vary slowly over time due to environmental changes.

A finger touch is in the order of one pF and its effect typically occurs much faster than the environmental changes.

The ASI has the difficult task of detecting a small, fast changing capacitance that is riding on a large, slow varying capacitance. This would require a very precise, high resolution ADC and complicated, power consuming, digital processing.

The SX9510/11 features a 16 bit DAC which compensates for the large, slow varying capacitance already in front of the ADC. In other words the ADC converts only the desired small signal. In the ideal world the ADC will put out a zero digital value even if the external capacitance is as high as 40pF.

At each power-up of the SX9510/11 the Compensation Values are estimated by the digital processing algorithms. The algorithm will adjust the compensation values such that a near-zero value will be generated by the ADC. Once the correct compensation values are found these will be stored and used to compensate each BL pin.

If the SX9510/11 is shut down the compensation values will be lost. At a next power-up the procedure starts all over again. This assures that the SX9510/11 will operate under any condition.
However if temperature changes this will influence the external capacitance. The ADC digital values will drift then slowly around zero values basically because of the mismatch of the compensation circuitry and the external capacitance.
In case the average value of the digital values become higher than the positive calibration threshold (configurable by user) or lower than the negative threshold (configurable by user) then the SX9510/11 will initiate a compensation procedure and find a new set of compensation values.

The host can initiate a compensation procedure by using the I2C interface. This is required after the host changes the sensitivity of sensors.

3.9 IR Interface

The IR interface for the SX9510/11 allows the user to save power by powering down their main processor. When a preprogrammed IR sequence is received the SX9510/11 generates a PWRON pulse to wake up the system.

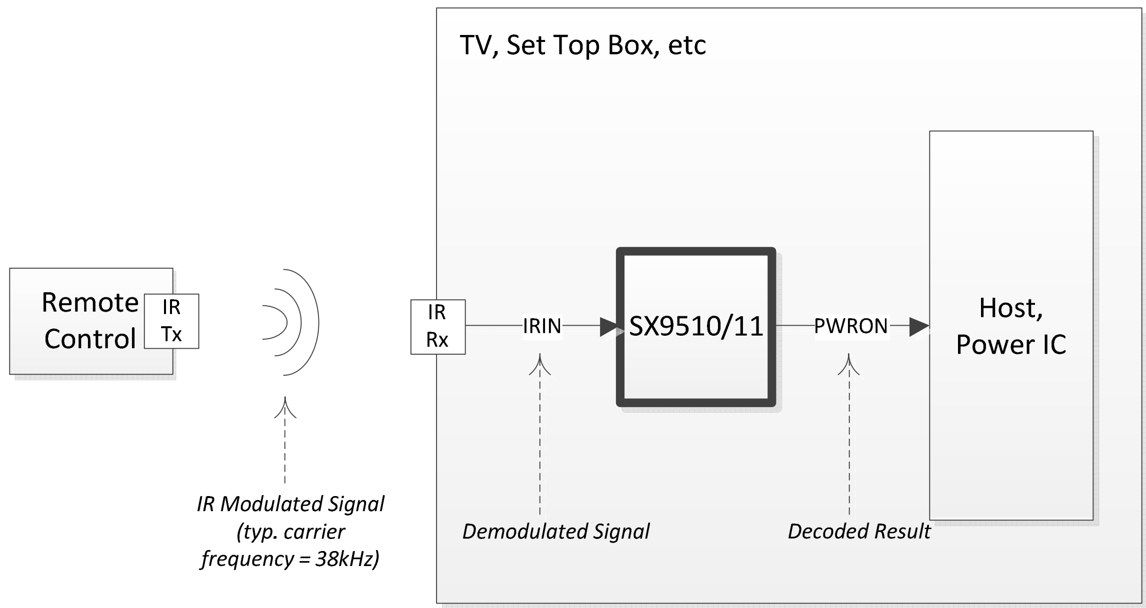


Figure 22 IR Interface Overview

The IR interface can be programmed to match one manufacturer code (address, 1 to 16 bits) and up to 8 button codes (commands, 1 to 8 bits each). The IR interface has been designed to be very flexible and can be programmed for phase coding (e.g. RC5/RC6) or space encoding (e.g. NEC, RCA, etc…), with or without header, etc, allowing it to be potentially usable with any type of IR remote control.

An added feature allows the user to blink the power LED (if power LED functions are enabled) when an IR sequence is received that matches either the specified manufacturer code (address) or match both the manufacturer code and one of the 8 button codes (commands). This gives a visual indication of incoming IR commands without main processor/host intervention.

3.9.1 Phase and Space Encoding

The IR signal sent over the IR is modulated and demodulated as follow:
- Mark = presence of carrier frequency
- Space = no presence of carrier frequency

In both encoding schemes, each logic bit is composed of a mark and a space.

Phase encoding (also called Manchester encoding) consists in having same duration/width for both space and mark and coding the logic level depending if mark or space comes first.
In other words, the edge of the transition defines the logical level. For example, with normal polarity, mark-to-space denotes logic 1 while space-to-mark denotes logic 0. For inverted polarity it is the opposite.

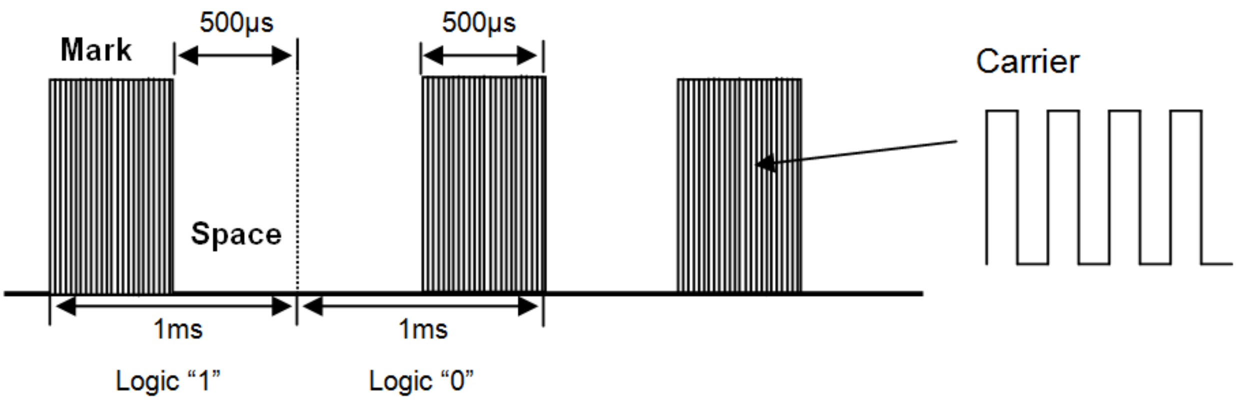


Figure 23 Phase Encoding Example (RC5) with Normal Polarity

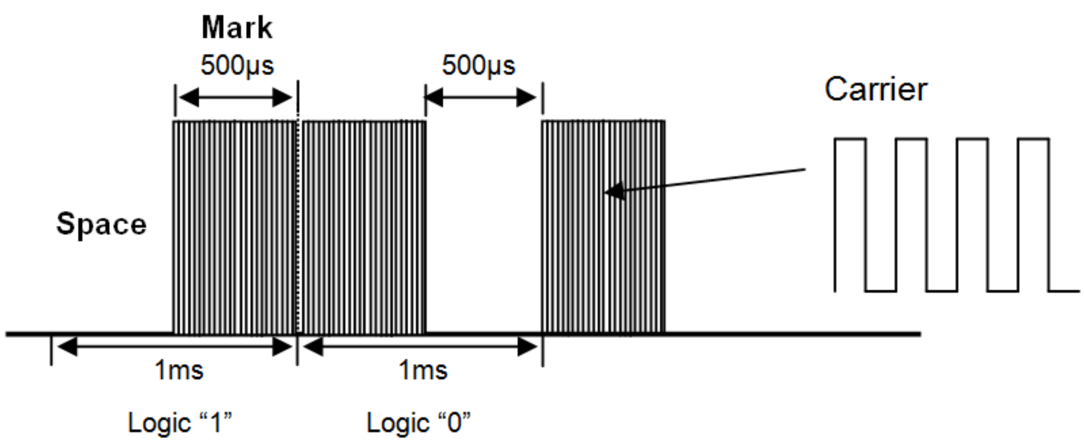


Figure 24 Phase Encoding Example (RC6) with Inverted Polarity

Space encoding consists in having same mark-space order and coding the logic level depending on the duration/width of the space.

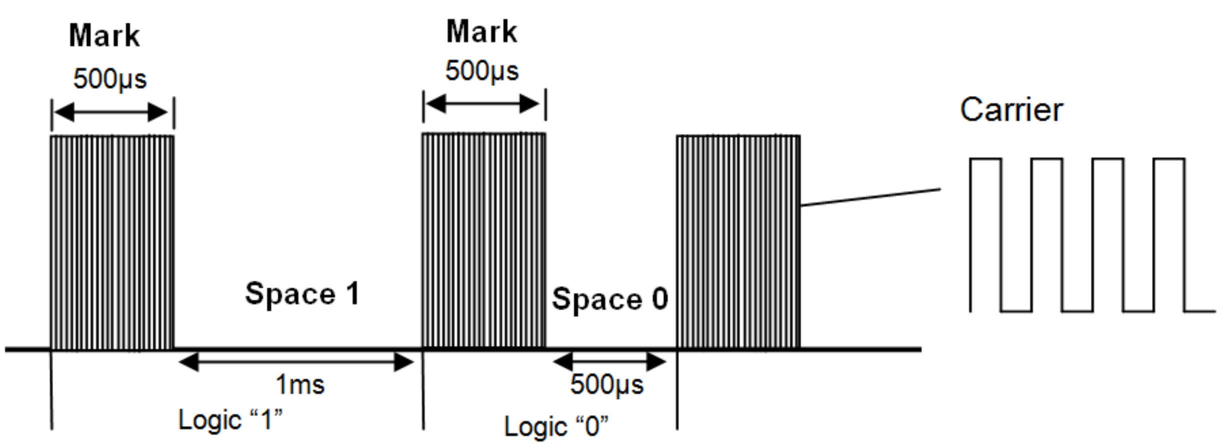


Figure 25 Space Encoding Example

3.9.2 Header

The header, when used in the protocol, is the very first part of an IR frame and always consists in a mark followed by a space but usually with specific durations/widths different from the following data composing the frame.
Usually the header mark is quite long (several ms), and is used by the receiver to adjust its gain control for the strength of the signal.

3.9.3 Data (Address and Command)

After the header, comes the data section of the IR frame which for us consists in two fields:
- Address: manufacturer code
- Command: button code corresponding to the button pressed on the remote control (Power, Ch+, Ch-, etc)

Depending on the protocol, address or command field comes first.

If an IR frame which matches all pre-programmed timings (+/- IR margin), address, and command is received; then a pulse is generated on PWRON pin to wake up the system.

3.10 Configuration

Figure 26 shows the building Blocks used for configuring the SX9510/11.

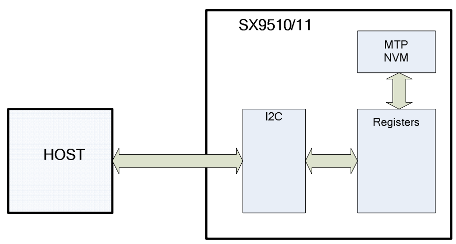


Figure 26 Configuration

During development of a touch system the register settings for the SX9510/11 are adjusted until the user is satisfied with the system operation. When the adjustments are finalized contents of the registers can be stored in the Multiple Time Programmable (MTP) Non Volatile Memory (NVM). The NVM contains all those parameters that are defined and stable for the application. Examples are the number of sensors enabled, sensitivity, active and Sleep scan period. The details of these parameters are described in the next chapters.

At power up or reset the SX9510/11 copies the settings from the NVM into the registers.

3.11 Clock Circuitry

The SX9510/11 has its own internal clock generation circuitry that does not require any external components. The clock circuitry is optimized for low power operation.

3.12 I2C interface

The host will interface with the SX9510/11 through the I2C bus and the analog output interface.
The I2C of the SX9510/11 consists of 95 registers. Some of these I2C registers are used to read the status and information of the buttons. Other I2C registers allow the host to take control of the SX9510/11.

The I2C slave implemented on the SX9510/11 is compliant with the standard (100kb/s) and fast mode (400kb/s)
The default SX9510/11 I2C address equals 0b010 1011.

3.13 Interrupt

The NIRQ mode of SPO2 has two main functions, the power up sequence and maskable interrupts (detailed below).

3.13.1 Power up

During power up the NIRQ is kept low (if SPO2 is configured for NIRQ in the NVM). Once the power up sequence is terminated the NIRQ is cleared autonomously. The SX9510/11 is then ready for operation. The AOI levels are updated at the latest one scan period after the rising edge of NIRQ.

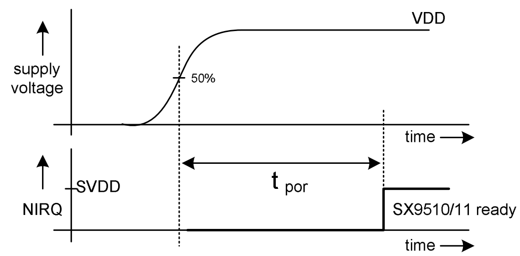


Figure 27 Power Up vs. NIRQ

During the power on period the SX9510/11 stabilizes the internal regulators, RC clocks and the firmware initializes all registers.

During the power up the SX9510/11 is not accessible and I2C communications are forbidden. The value of NIRQ before power up depends on the NIRQ pull up resistor to the SVDD supply voltage.

3.13.2 NIRQ Assertion

When the NIRQ function is enabled for SPO2 then NIRQ is updated in Active or Sleep mode once every scan period.

The NIRQ will be asserted at the following events:

- if a Button event occurred (touch or release if enabled)
- a proximity even occurred (prox or loss of prox (SX9510 only))
- once compensation procedure is completed either through automatic trigger or via host request
- during reset (power up, hardware NRST, software reset)

3.13.3 Clearing

The clearing of the NIRQ is done as soon as the host performs a read to any of the SX9510/11 I2C registers.

3.13.4 Example

A typical example of the assertion and clearing of the NIRQ and the I2C communication is shown in Figure 28.

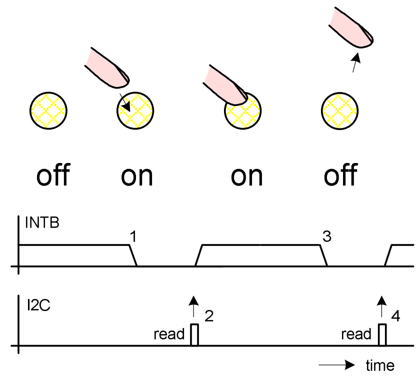


Figure 28 Interrupt and I2C

When a button is touched the SX9510/11 will assert the interrupt (1). The host will read the SX9510/11 status information over the I2C (2) and this clears the interrupt.

If the finger releases the button the interrupt will be asserted (3), the host reads the status (4) which clears the interrupt.

In case the host will not react to an interrupt then this will result in a missing touch.

3.14 Reset

The reset can be performed by 3 sources:

- power up,
- NRST pin,
- software reset.

3.14.1 Power up

During power up the NIRQ is kept low (if SPO2 is configured for NIRQ in the NVM). Once the power up sequence is terminated the NIRQ is cleared autonomously. The SX9510/11 is then ready for operation. The AOI levels are updated at the latest one scan period after the rising edge of NIRQ.

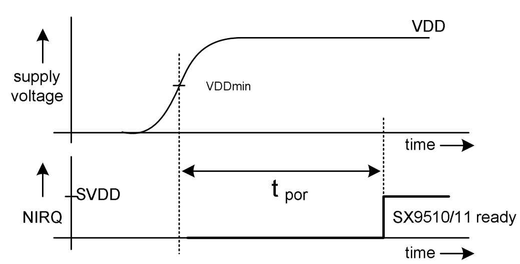


Figure 29 Power Up vs. NIRQ

During the power on period the SX9510/11 stabilizes the internal regulators, RC clocks and the firmware initializes all registers.

During the power up the SX9510/11 is not accessible and I2C communications are forbidden.
As soon as the NIRQ rises the SX9510/11 will be ready for I2C communication.

3.14.2 NRST

When NRST is driven low the SX9510/11 will reset and start the power up sequence as soon as NRST is driven high or pulled high.

In case the user does not require a hardware reset control pin then the NRST pin can be connected to SVDD.

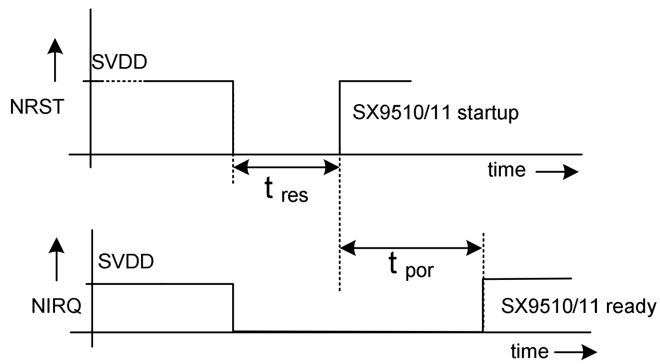


Figure 30 Hardware Reset

3.14.3 Software Reset

To perform a software reset the host needs to write 0xDE followed by 0x00 at the SoftReset register at address 0xFF.

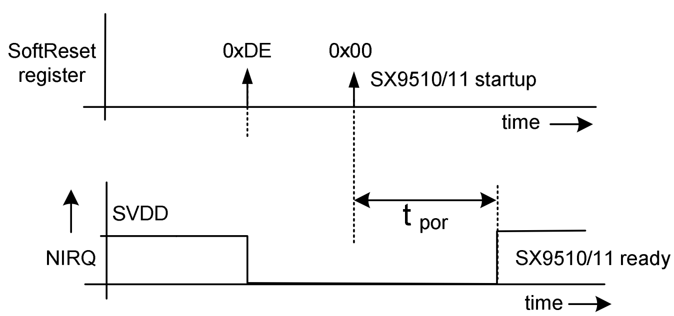


Figure 31 Software Reset