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CAP1296

6-Channel Capacitive Touch Sensor with Proximity Detection & Signal Guard

General Description

The CAP1296 is a multiple channel capacitive touch sensor controller. It contains six (6) individual capacitive touch sensor inputs with programmable sensitivity for use in touch sensor applications. Each sensor input is calibrated to compensate for system parasitic capacitance and automatically recalibrated to compensate for gradual environmental changes.

In addition, the CAP1296 can be configured to detect proximity on one or more channels with an optional signal guard to reduce noise sensitivity and to isolate the proximity antenna from nearby conductive surfaces that would otherwise attenuate the e-field.

The CAP1296 includes Multiple Pattern Touch recognition that allows the user to select a specific set of buttons to be touched simultaneously. If this pattern is detected, a status bit is set and an interrupt is generated.

The CAP1296 has Active and Standby states, each with its own sensor input configuration controls. The Combo state allows a combination of sensor input controls to be used which enables one or more sensor inputs to operate as buttons while another sensor input is operating as a proximity detector. Power consumption in the Standby and Combo states is dependent on the number of sensor inputs enabled as well as averaging, sampling time, and cycle time. Deep Sleep is the lowest power state available, drawing 5µA (typical) of current. In this state, no sensor inputs are active, and communications will wake the device.

Applications

- Desktop and Notebook PCs
- LCD Monitors
- Consumer Electronics
- Appliances

Features

- Six (6) Capacitive Touch Sensor Inputs
  - Programmable sensitivity
  - Automatic recalibration
  - Calibrates for parasitic capacitance
  - Individual thresholds for each button
- Proximity Detection
- Signal Guard
  - Isolates the proximity antenna from attenuation
  - Reduces system noise sensitivity effects on inputs
- Multiple Button Pattern Detection
- Power Button Support
- Press and Hold Feature for Volume-like Applications
- 3.3V or 5V Supply
- Analog Filtering for System Noise Sources
- RF Detection and Avoidance Filters
- Digital EMI Blocker
- 8kV ESD Rating on All Pins (HBM)
- Low Power Operation
  - 5µA quiescent current in Deep Sleep
  - 50µA quiescent current in Standby (1 sensor input monitored)
  - Samples one or more channels in Standby
- SMBus / I^{2}C Compliant Communication Interface
- Available in a 10-pin 3mm x 3mm DFN RoHS compliant package

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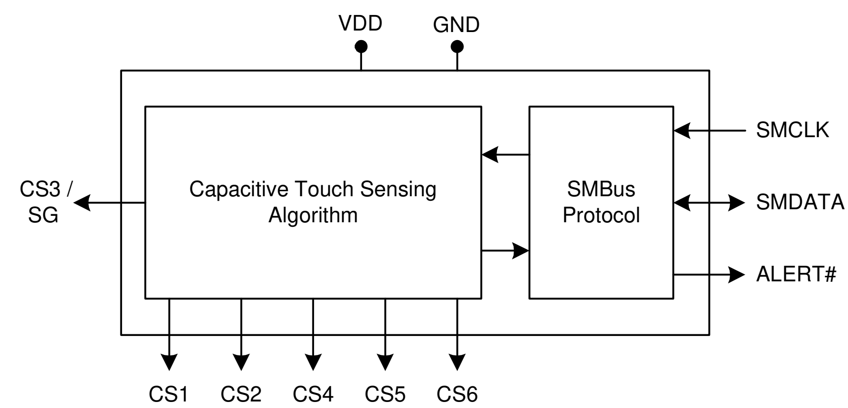
1.0 INTRODUCTION

1.1 Block Diagram

FIGURE 1-1: CAP1296 BLOCK DIAGRAM



1.2 Pin Diagrams

FIGURE 1-2: CAP1296 14-PIN SOIC

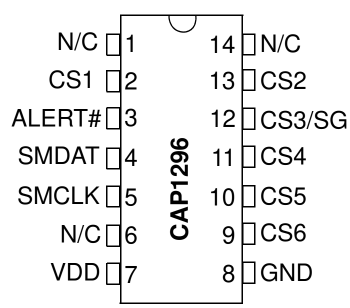


FIGURE 1-3: CAP1296 PIN DIAGRAM (10-PIN 3 X 3 MM DFN)

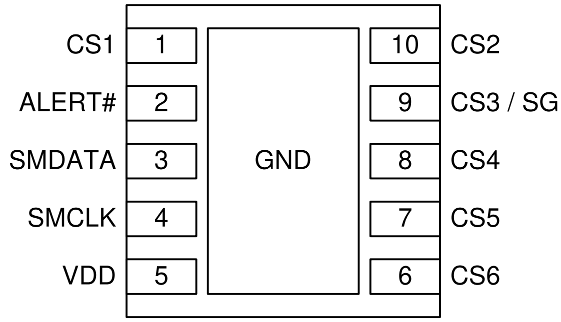


TABLE 1-1: PIN DESCRIPTION FOR CAP1296

QFN Pin #	SOIC Pin #	Pin Name	Pin Function	Pin Type	Unused Connection
1	2	CS1	Capacitive Touch Sensor Input 1	AIO	Connect to Ground
2	3	ALERT#	ALERT# - Active low alert / interrupt output for SMBus alert - requires pull-up resistor (default)	OD	Connect to Ground
3	4	SMDATA	SMDATA - Bi-directional, open-drain SMBus or I^2C data - requires pull-up resistor	DIOD	n/a
4	5	SMCLK	SMCLK - SMBus or I^2C clock input - requires pull-up resistor	DI	n/a
5	7	VDD	Positive Power supply	Power	n/a
6	9	CS6	Capacitive Touch Sensor Input 6	AIO	Connect to Ground
7	10	CS5	Capacitive Touch Sensor Input 5	AIO	Connect to Ground
8	11	CS4	Capacitive Touch Sensor Input 4	AIO	Connect to Ground
9	12	CS3 / SG	CS3 - Capacitive Touch Sensor Input 3	AIO	Connect to Ground
	12		SG - Signal guard output	AIO	Leave Open
10	13	CS2	Capacitive Touch Sensor Input 2	AIO	Connect to Ground
Bottom Pad	8	GND	Ground	Power	n/a

1.3 Pin Description

APPLICATION NOTE: All digital pins are 5V tolerant pins.

The pin types are described in Table 1-2, "Pin Types".

TABLE 1-2: PIN TYPES

Pin Type	Description
Power	This pin is used to supply power or ground to the device.
DI	Digital Input - This pin is used as a digital input. This pin is 5V tolerant.
AIO	Analog Input / Output - This pin is used as an I/O for analog signals.
DIOD	Digital Input / Open Drain Output - This pin is used as a digital I/O. When it is used as an output, it is open drain and requires a pull-up resistor. This pin is 5V tolerant.
OD	Open Drain Digital Output - This pin is used as a digital output. It is open drain and requires a pull-up resistor. This pin is 5V tolerant.

2.0 ELECTRICAL SPECIFICATIONS

TABLE 2-1: ABSOLUTE MAXIMUM RATINGS

Voltage on VDD pin	-0.3 to 6.5	V
Voltage on CS pins to GND	-0.3 to 4.0	V
Voltage on 5V tolerant pins (V_{5VT_PIN})	-0.3 to 5.5	V
Voltage on 5V tolerant pins ($\lvert V_{5VT\_PIN} - V_{DD}\rvert$) (see Note 2-2)	0 to 3.6	V
Input current to any pin except VDD	$\pm$10	mA
Output short circuit current	Continuous	N/A
Package Power Dissipation up to T_A = 85°C for 10-pin DFN (see Note 2-3)	0.5	W
Junction to Ambient (θ_{JA}) (see Note 2-4)	78	°C/W
Operating Ambient Temperature Range	-40 to 125	°C
Storage Temperature Range	-55 to 150	°C
ESD Rating, All Pins, HBM	8000	V

Note 2-1 Stresses above those listed could cause permanent damage to the device. This is a stress rating only and functional operation of the device at any other condition above those indicated in the operation sections of this specification is not implied.

Note 2-2 For the 5V tolerant pins that have a pull-up resistor, the voltage difference between V_{5VT_PIN} and V_{DD} must never exceed 3.6V.

Note 2-3 The Package Power Dissipation specification assumes a recommended thermal via design consisting of a 2x3 matrix of 0.3mm (12mil) vias at 0.9mm pitch connected to the ground plane with a 1.6 x 2.3mm thermal landing.

Note 2-4 Junction to Ambient (θ_{JA}) is dependent on the design of the thermal vias. Without thermal vias and a thermal landing, the θ_{JA} will be higher.

TABLE 2-2: ELECTRICAL SPECIFICATIONS

V_{DD} = 3V to 5.5V, T_A = 0°C to 85°C, all Typical values at T_A = 25°C unless otherwise noted.						
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
DC Power						
Supply Voltage	V_{DD}	3.0		5.5	V	
Supply Current	I_{STBY_DEF}		120	170	µA	Standby state active 1 sensor input monitored Default conditions (8 avg, 70ms cycle time)
	I_{STBY_LP}		50		µA	Standby state active 1 sensor input monitored 1 avg, 140ms cycle time
	I_{DSLEEP_3V}		5	TBD	µA	Deep Sleep state active No communications T_A < 40°C 3.135 < V_{DD} < 3.465V
	I_{DD}		500	750	µA	Capacitive Sensing Active signal guard disabled
Capacitive Touch Sensor Inputs						
Maximum Base Capacitance	C_{BASE}			50	pF	Pad untouched
Minimum Detectable Capacitive Shift	ΔC_{TOUCH}	20			fF	Pad touched - default conditions
Recommended Cap Shift	ΔC_{TOUCH}	0.1		2	pF	Pad touched - Not tested
Power Supply Rejection	PSR		±3	±10	counts / V	Untouched Current Counts Base Capacitance 5pF - 50pF Negative Delta Counts disabled Maximum sensitivity All other parameters default
Power-On and Brown-out Reset (see Section 4.2, "Reset")						
Power-On Reset Voltage	V_{POR}		1	1.3	V	Pin States Defined
Power-On Reset Release Voltage	V_{PORR}		2.85		V	Rising V_{DD} Ensured by design
Brown-Out Reset	V_{BOR}		2.8		V	Falling V_{DD}
VDD Rise Rate (ensures internal POR signal)	SV_{DD}	0.05			V/ms	0 to 3V in 60ms
Power-Up Timer Period	t_{PWRT}		10		ms	
Brown-Out Reset Voltage Delay	t_{BORDC}	1			µs	$V_{DD} = V_{BOR} - 1$

TABLE 2-2: ELECTRICAL SPECIFICATIONS (CONTINUED)

V_{DD} = 3V to 5.5V, T_A = 0°C to 85°C, all Typical values at T_A = 25°C unless otherwise noted.						
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
Timing						
Time to Communications Ready	t_{COMM_DLY}			15	ms	
Time to First Conversion Ready	t_{CONV_DLY}		170	200	ms	
I/O Pins						
Output Low Voltage	V_{OL}			0.4	V	I_{SINK_IO} = 8mA
Output High Voltage	V_{OH}	V_{DD} - 0.4			V	I_{SOURCE_IO} = 8mA
Input High Voltage	V_{IH}	2.0			V	
Input Low Voltage	V_{IL}			0.8	V	
Leakage Current	I_{LEAK}			±5	µA	powered or unpowered T_A < 85°C pull-up voltage ≤ 3.6V if unpowered
SG Pin						
Capacitive Drive Capability	C_{BASE_SG}	20		200	pF	capacitance to ground
SMBus Timing						
Input Capacitance	C_{IN}		5		pF	
Clock Frequency	f_{SMB}	10		400	kHz	
Spike Suppression	t_{SP}			50	ns	
Bus Free Time Stop to Start	t_{BUF}	1.3			µs	
Start Setup Time	$t_{SU:STA}$	0.6			µs	
Start Hold Time	$t_{HD:STA}$	0.6			µs	
Stop Setup Time	$t_{SU:STO}$	0.6			µs	
Data Hold Time	$t_{HD:DAT}$	0			µs	When transmitting to the master
Data Hold Time	$t_{HD:DAT}$	0.3			µs	When receiving from the master
Data Setup Time	$t_{SU:DAT}$	0.6			µs	
Clock Low Period	t_{LOW}	1.3			µs	
Clock High Period	t_{HIGH}	0.6			µs	
Clock / Data Fall Time	t_{FALL}			300	ns	Min = 20+0.1C_{LOAD} ns

TABLE 2-2: ELECTRICAL SPECIFICATIONS (CONTINUED)

V_{DD} = 3V to 5.5V, T_A = 0°C to 85°C, all Typical values at T_A = 25°C unless otherwise noted.						
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
Clock / Data Rise Time	t_{RISE}			300	ns	Min = $20+0.1C_{LOAD}$ ns
Capacitive Load	C_{LOAD}			400	pF	per bus line

3.0 COMMUNICATIONS

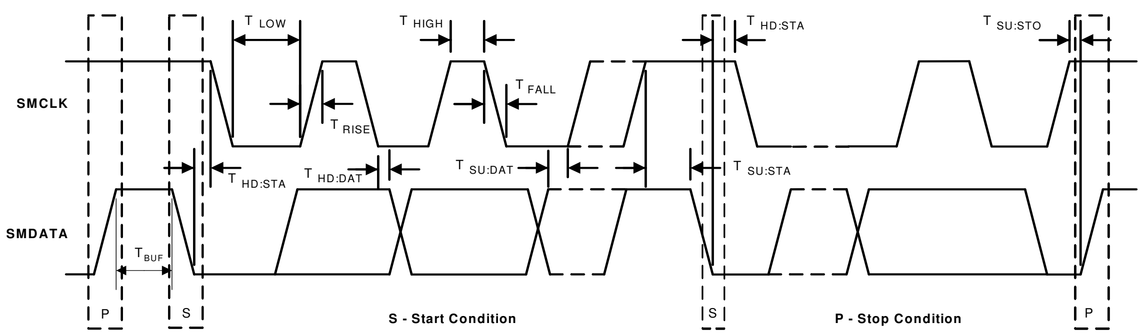
3.1 Communications

The CAP1296 communicates using the SMBus or I^2C protocol.

3.2 System Management Bus

The CAP1296 communicates with a host controller, such as an MCHP SIO, through the SMBus. The SMBus is a two-wire serial communication protocol between a computer host and its peripheral devices. A detailed timing diagram is shown in Figure 3-1. Stretching of the SMCLK signal is supported; however, the CAP1296 will not stretch the clock signal.

FIGURE 3-1: SMBUS TIMING DIAGRAM



3.2.1 SMBUS START BIT

The SMBus Start bit is defined as a transition of the SMBus Data line from a logic ‘1’ state to a logic ‘0’ state while the SMBus Clock line is in a logic ‘1’ state.

3.2.2 SMBUS ADDRESS AND RD / $\overline{\text{WR}}$ BIT

The SMBus Address Byte consists of the 7-bit client address followed by the RD / $\overline{\text{WR}}$ indicator bit. If this RD / $\overline{\text{WR}}$ bit is a logic ‘0’, then the SMBus Host is writing data to the client device. If this RD / $\overline{\text{WR}}$ bit is a logic ‘1’, then the SMBus Host is reading data from the client device.

3.2.3 The CAP1296responds to SMBus address 0101_000(r/w). SMBUS DATA BYTES

All SMBus Data bytes are sent most significant bit first and composed of 8-bits of information.

3.2.4 SMBUS ACK AND NACK BITS

The SMBus client will acknowledge all data bytes that it receives. This is done by the client device pulling the SMBus Data line low after the 8th bit of each byte that is transmitted. This applies to both the Write Byte and Block Write protocols.

The Host will NACK (not acknowledge) the last data byte to be received from the client by holding the SMBus data line high after the 8th data bit has been sent. For the Block Read protocol, the Host will ACK each data byte that it receives except the last data byte.

3.2.5 SMBUS STOP BIT

The SMBus Stop bit is defined as a transition of the SMBus Data line from a logic ‘0’ state to a logic ‘1’ state while the SMBus clock line is in a logic ‘1’ state. When the CAP1296 detects an SMBus Stop bit and it has been communicating with the SMBus protocol, it will reset its client interface and prepare to receive further communications.

3.2.6 SMBUS TIMEOUT

The CAP1296 includes an SMBus timeout feature. Following a 30ms period of inactivity on the SMBus where the SMCLK pin is held low, the device will timeout and reset the SMBus interface.

The timeout function defaults to disabled. It can be enabled by setting the TIMEOUT bit in the Configuration register (see Section 5.6, "Configuration Registers").

3.2.7 SMBUS AND I^{2}C COMPATIBILITY

The major differences between SMBus and I^{2}C devices are highlighted here. For more information, refer to the SMBus 2.0 specification.

1. CAP1296supports I^{2}C fast mode at 400kHz. This covers the SMBus max time of 100kHz.
2. Minimum frequency for SMBus communications is 10kHz.
3. The SMBus client protocol will reset if the clock is held low longer than 30ms (timeout condition). This can be enabled in the CAP1296 by setting the TIMEOUT bit in the Configuration register. I^{2}C does not have a timeout.
4. The SMBus client protocol will reset if both the clock and the data line are high for longer than 200us (idle condition). This can be enabled in the CAP1296by setting the TIMEOUT bit in the Configuration register. I^{2}C does not have an idle condition.
5. I^{2}C devices do not support the Alert Response Address functionality (which is optional for SMBus).
6. I^{2}C devices support block read and write differently. I^{2}C protocol allows for unlimited number of bytes to be sent in either direction. The SMBus protocol requires that an additional data byte indicating number of bytes to read / write is transmitted. The CAP1296 supports I^{2}C formatting only.

3.3 SMBus Protocols

The CAP1296 is SMBus 2.0 compatible and supports Write Byte, Read Byte, Send Byte, and Receive Byte as valid protocols as shown below.

All of the below protocols use the convention in Table 3-1.

TABLE 3-1: PROTOCOL FORMAT

Data Sent to Device	Data Sent to the HOst
Data sent	Data sent

3.3.1 SMBUS WRITE BYTE

The Write Byte is used to write one byte of data to a specific register as shown in Table 3-2.

TABLE 3-2: WRITE BYTE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Register Data	ACK	Stop
1 ->0	0101_000	0	0	XXh	0	XXh	0	0 -> 1

3.3.2 SMBUS READ BYTE

The Read Byte protocol is used to read one byte of data from the registers as shown in Table 3-3.

TABLE 3-3: READ BYTE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Start	Client Address	RD	ACK	Register Data	NACK	Stop
1->0	0101_000	0	0	XXh	0	1 ->0	0101_000	1	0	XXh	1	0 -> 1

3.3.3 SMBUS SEND BYTE

The Send Byte protocol is used to set the internal address register pointer to the correct address location. No data is transferred during the Send Byte protocol as shown in Table 3-4.

APPLICATION NOTE: The Send Byte protocol is not functional in Deep Sleep (i.e., DSLEEP bit is set).

TABLE 3-4: SEND BYTE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Stop
1 -> 0	0101_000	0	0	XXh	0	0 -> 1

3.3.4 SMBUS RECEIVE BYTE

The Receive Byte protocol is used to read data from a register when the internal register address pointer is known to be at the right location (e.g. set via Send Byte). This is used for consecutive reads of the same register as shown in Table 3-5.

APPLICATION NOTE: The Receive Byte protocol is not functional in Deep Sleep (i.e., DSLEEP bit is set).

TABLE 3-5: RECEIVE BYTE PROTOCOL

Start	Slave Address	RD	ACK	Register Data	NACK	Stop
1 -> 0	0101_000	1	0	XXh	1	0 -> 1

3.4 I^2C Protocols

The CAP1296 supports I^2C Block Read and Block Write.

The protocols listed below use the convention in Table 3-1.

3.4.1 BLOCK READ

The Block Read is used to read multiple data bytes from a group of contiguous registers as shown in Table 3-6.

APPLICATION NOTE: When using the Block Read protocol, the internal address pointer will be automatically incremented after every data byte is received. It will wrap from FFh to 00h.

TABLE 3-6: BLOCK READ PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Start	Slave Address	RD	ACK	Register Data
1->0	0101_000	0	0	XXh	0	1 ->0	0101_000	1	0	XXh
ACK	REGISTER DATA	ACK	REGISTER DATA	ACK	REGISTER DATA	ACK	. . .	REGISTER DATA	NACK	STOP

TABLE 3-6: BLOCK READ PROTOCOL

0	XXh	0	XXh	0	XXh	0	. . .	XXh	1	0 -> 1

3.4.2 BLOCK WRITE

The Block Write is used to write multiple data bytes to a group of contiguous registers as shown in Table 3-7.

APPLICATION NOTE: When using the Block Write protocol, the internal address pointer will be automatically incremented after every data byte is received. It will wrap from FFh to 00h.

TABLE 3-7: BLOCK WRITE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Register Data	ACK
1 ->0	0101_000	0	0	XXh	0	XXh	0
Register Data	**ACK**	**Register Data**	**ACK**	**. . .**	**Register Data**	**ACK**	**Stop**
XXh	0	XXh	0	. . .	XXh	0	0 -> 1

4.0 GENERAL DESCRIPTION

The CAP1296 is a multiple channel capacitive touch sensor. It contains six (6) individual capacitive touch sensor inputs with programmable sensitivity for use in touch sensor applications. Each sensor input is calibrated to compensate for system parasitic capacitance and automatically recalibrated to compensate for gradual environmental changes.

In addition, the CAP1296 can be configured to detect proximity on one or more channels with an optional signal guard to reduce noise sensitivity.

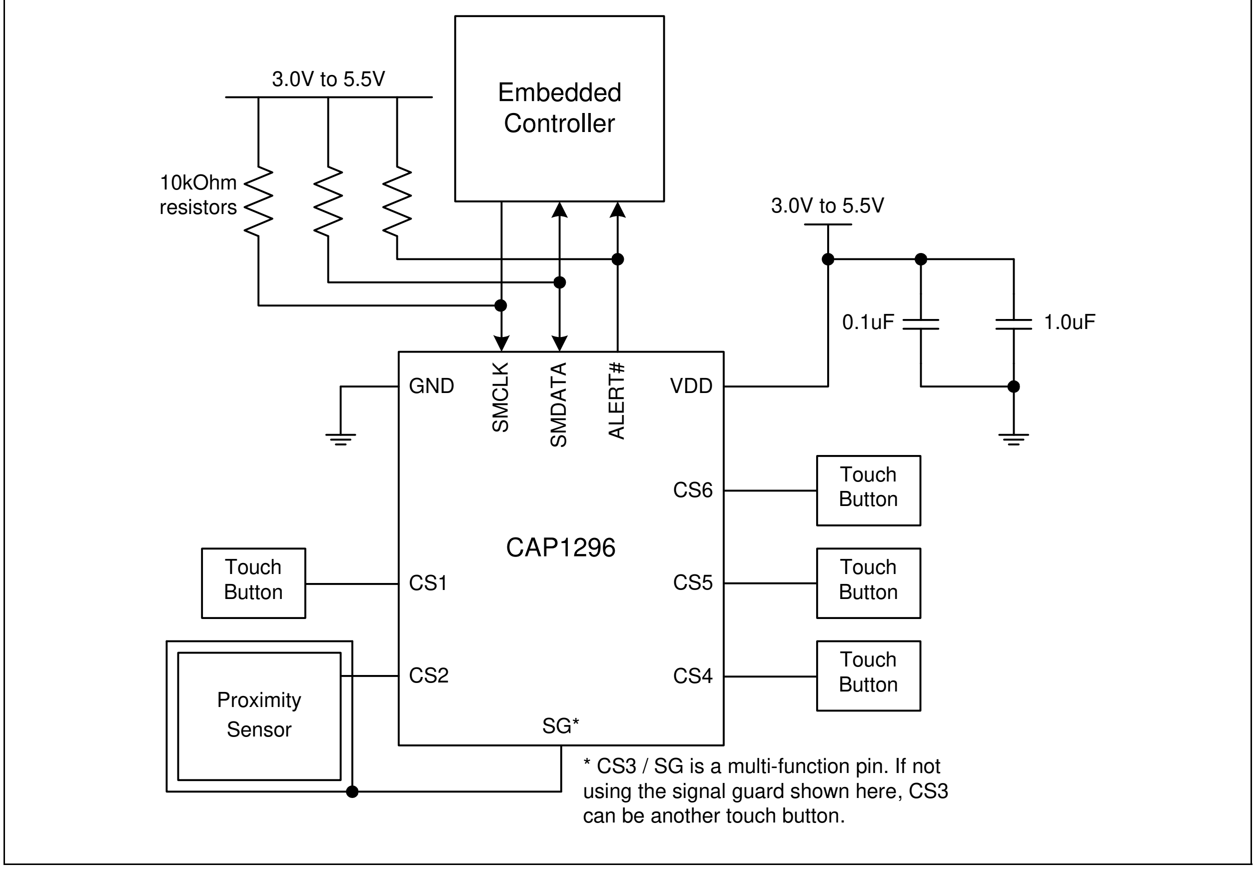
The CAP1296includes Multiple Pattern Touch recognition that allows the user to select a specific set of buttons to be touched simultaneously. If this pattern is detected, a status bit is set and an interrupt is generated.

The CAP1296 has Active and Standby states, each with its own sensor input configuration controls. The Combo state allows a combination of sensor input controls to be used which enables one or more sensor inputs to operate as buttons while another sensor input is operating as a proximity detector. Power consumption in the Standby and Combo states is dependent on the number of sensor inputs enabled as well as averaging, sampling time, and cycle time. Deep Sleep is the lowest power state available, drawing 5µA (typical) of current. In this state, no sensor inputs are active, and communications will wake the device.

The device communicates with a host controller using SMBus / I^2C. The host controller may poll the device for updated information at any time or it may configure the device to flag an interrupt whenever a touch is detected on any sensor pad.

A typical system diagram is shown in FIGURE 4-1:.

FIGURE 4-1: SYSTEM DIAGRAM FOR CAP1296



4.1 Power States

The CAP1296 has 4 power states depending on the status of the STBY, COMBO, and DSLEEP bits. When the device transitions between power states, previously detected touches (for channels that are being de-activated) are cleared and the sensor input status bits are reset.

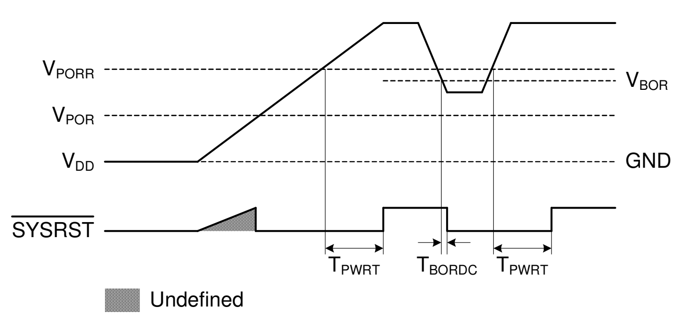
1. Active - The normal mode of operation. The device is monitoring capacitive sensor inputs enabled in the Active state.
2. Standby - When the STBY bit is set, the device is monitoring the capacitive sensor inputs enabled in the Standby state. Interrupts can still be generated based on the enabled channels. The device will still respond to communications normally and can be returned to the Active state of operation by clearing the STBY bit. Power consumption in this state is dependent on the number of sensor inputs enabled as well as averaging, sampling time, and cycle time.
3. Combo - When the COMBO bit is set, the device is monitoring capacitive sensor inputs enabled in the Active state as well as inputs enabled in the Standby state (hence the name “Combo”). Interrupts can still be generated based on the enabled channels. The device will still respond to communications normally and can be returned to the Active state of operation by clearing the COMBO bit. Power consumption in this state is dependent on the number of sensor inputs enabled as well as averaging, sampling time, and cycle time.
4. Deep Sleep - When the DSLEEP bit is set, the device is in its lowest power state. It is not monitoring any capacitive sensor inputs. While in Deep Sleep, the CAP1296 can be awakened by SMBus communications targeting the device. This will not cause the DSLEEP to be cleared so the device will return to Deep Sleep once all communications have stopped. The device can be returned to the Active state of operation by clearing the DSLEEP bit.

4.2 Reset

The Power-On Reset (POR) circuit holds the device in reset until V_{DD} has reached an acceptable level, Power-on Reset Release Voltage (V_{PORR}), for minimum operation. The power-up timer (PWRT) is used to extend the start-up period until all device operation conditions have been met. The power-up timer starts after V_{DD} reaches V_{PORR}. POR and PORR with slow rising V_{DD} is shown in Figure 4-2.

The Brown-Out Reset (BOR) circuit holds the device in reset when V_{DD} falls to a minimum level, V_{BOR} for longer than the BOR reset delay (t_{BORDC}). After a BOR, when V_{DD} rises above V_{PORR}, the power-up timer is started again and must finish before reset is released, as shown in Figure 4-2.

FIGURE 4-2: POR AND PORR WITH SLOW RISING V_{DD} AND BOR WITH FALLING V_{DD}



4.3 Capacitive Touch Sensing

The CAP1296 contains six (6) independent capacitive touch sensor inputs. Each sensor input has dynamic range to detect a change of capacitance due to a touch. Additionally, each sensor input can be configured to be automatically and routinely recalibrated.

4.3.1 CAPACITIVE TOUCH SENSING SETTINGS

Controls for managing capacitive touch sensor inputs are determined by the power state.

4.3.1.1 Active State Sensing Settings

The Active state is used for normal operation. Sensor inputs being monitored are determined by the Sensor Input Enable Register(see Section 5.7, "Sensor Input Enable Register"). Sensitivity is controlled by the Sensitivity Control Register (see Section 5.5, "Sensitivity Control Register"). Averaging, sample time, and cycle time are controlled by the Averaging and Sampling Configuration Register (see Section 5.10, "Averaging and Sampling Configuration Register"). Each channel can have a separate touch detection threshold, as defined in the Sensor Input Threshold registers (see Section 5.19, "Sensor Input Threshold Registers").

4.3.1.2 Standby State Sensing Settings

The Standby state is used for standby operation. In general, fewer sensor inputs are enabled, and they are programmed to have more sensitivity. Sensor inputs being monitored are determined by the Standby Channel Register (see Section 5.21, "Standby Channel Register"). Sensitivity is controlled by the Standby Sensitivity Register (see Section 5.23, "Standby Sensitivity Register"). Averaging, sample time, and cycle time are controlled by the Averaging and Sampling Configuration Register (see Section 5.22, "Standby Configuration Register"). There is one touch detection threshold, which applies to all sensors enabled in Standby, as defined in the Standby Threshold Register (see Section 5.24, "Standby Threshold Register").

4.3.1.3 Combo State Sensing Settings

The Combo state is used when a combination of proximity detection and normal button operation is required. When the COMBO bit is set, the sensing cycle includes sensor inputs enabled in the Active state as well as sensor inputs enabled in the Standby state. Sensor inputs enabled in the Active state will use the Active settings described in Section 4.3.1.1, "Active State Sensing Settings". Sensor inputs enabled in the Standby state will use the Standby settings described in Section 4.3.1.2, "Standby State Sensing Settings". If a sensor input is enabled in both the Active state and in the Standby state, the Active state settings will be used in Combo state. The programmed cycle time is determined by STBY_CY_-TIME[1:0].

The Combo state also has two gain settings. When the COMBO bit is set, the GAIN[1:0] control only applies to the sensors enabled in the Active state, and the C_GAIN[1:0] control applies to the sensors enabled in the Standby state.

4.3.2 SENSING CYCLE

Except when in Deep Sleep, the device automatically initiates a sensing cycle and repeats the cycle every time it finishes. The cycle polls through each enabled sensor input starting with CS1 and extending through CS6. As each capacitive touch sensor input is polled, its measurement is compared against a baseline “not touched” measurement. If the delta measurement is large enough to exceed the applicable threshold, a touch is detected and an interrupt can be generated (see Section 4.9.2, "Capacitive Sensor Input Interrupt Behavior").

The sensing cycle time is programmable (see Section 5.10, "Averaging and Sampling Configuration Register" and Section 5.22, "Standby Configuration Register"). If all enabled inputs can be sampled in less than the cycle time, the device is placed into a lower power state for the remainder of the sensing cycle. If the number of active sensor inputs cannot be sampled within the specified cycle time, the cycle time is extended and the device is not placed in a lower power state.

4.4 Sensor Input Calibration

Calibration sets the Base Count Registers(Section 5.25, "Sensor Input Base Count Registers") which contain the “not touched” values used for touch detection comparisons. Calibration automatically occurs after a power-on reset (POR), when sample time is changed, when the gain is changed, when the calibration sensitivity is changed, and whenever a sensor input is newly enabled (for example, when transitioning from a power state in which it was disabled to a power state in which it is enabled). During calibration, the analog sensing circuits are tuned to the capacitance of the untouched pad. Then, samples are taken from each sensor input so that a base count can be established. After calibration, the untouched delta counts are zero.

APPLICATION NOTE: During the calibration routine, the sensor inputs will not detect a press for up to 200ms and the Sensor Base Count Register values will be invalid. In addition, any press on the corresponding sensor pads will invalidate the calibration.

The host controller can force a calibration for selected sensor inputs at any time using the Calibration Activate and Status RegisterSection 5.10.1, "Calibration Activate and Status Register". When a bit is set, the corresponding capacitive touch sensor input will be calibrated (both analog and digital). The bit is automatically cleared once the calibration routine has successfully finished.

If analog calibration fails for a sensor input, the corresponding bit is not cleared in the Calibration Activate and Status Register, and the ACAL_FAIL bit is set in the General Status Register(Section 5.2, "Status Registers"). An interrupt can be generated. Analog calibration will fail if a noise bit is set or if the calibration value is at the maximum or minimum value. If digital calibration fails to generate base counts for a sensor input in the operating range, which is $\pm$12.5% from the ideal base count (see TABLE 4-1:), indicating the base capacitance is out of range, the corresponding BC_OUTx bit is set in the Base Count Out of Limit Register(Section 5.17, "Base Count Out of Limit Register"), and the BC_OUT bit is set in the General Status Register (Section 5.2, "Status Registers"). An interrupt can be generated. By default, when a base count is out of limit, analog calibration is repeated for the sensor input; alternatively, the sensor input can be sampled using the out of limit base count(Section 5.6, "Configuration Registers"). Calibration sensitivity can be adjusted for each sensor input based on capacitive touch pad capacitance.

TABLE 4-1: IDEAL BASE COUNTS

Ideal Base Count	Sample Time
3,200	320us
6,400	640us
12,800	1.28ms
25,600	2.56ms

During normal operation there are various options for recalibrating the capacitive touch sensor inputs. Recalibration is a digital adjustment of the base counts so that the untouched delta count is zero. After a recalibration, if a sensor input's base count has shifted $\pm$12.5% from the ideal base count, a full calibration will be performed on the sensor input.

4.4.1 AUTOMATIC RECALIBRATION

Each sensor input is regularly recalibrated at a programmable rate(see CAL_CFG[2:0] in Section 5.18, "Recalibration Configuration Register"). By default, the recalibration routine stores the average 64 previous measurements and periodically updates the base "not touched" setting for the capacitive touch sensor input.

APPLICATION NOTE: Automatic recalibration only works when the delta count is below the active sensor input threshold. It is disabled when a touch is detected.

4.4.2 NEGATIVE DELTA COUNT RECALIBRATION

It is possible that the device loses sensitivity to a touch. This may happen as a result of a noisy environment, recalibration when the pad is touched but delta counts do not exceed the threshold, or other environmental changes. When this occurs, the base untouched sensor input may generate negative delta count values. The NEG_DELTA_CNT[1:0] bits(see Section 5.18, "Recalibration Configuration Register") can be set to force a recalibration after a specified number of consecutive negative delta readings. After a delayed recalibration (see Section 4.4.3, "Delayed Recalibration") the negative delta count recalibration can correct after the touch is released.

APPLICATION NOTE: During this recalibration, the device will not respond to touches.

4.4.3 DELAYED RECALIBRATION

It is possible that a "stuck button" occurs when something is placed on a button which causes a touch to be detected for a long period. By setting the MAX_DUR_EN bit(see Section 5.6, "Configuration Registers"), a recalibration can be forced when a touch is held on a button for longer than the duration specified in the MAX_DUR[3:0] bits (see Section 5.8, "Sensor Input Configuration Register").

Note 4-1 Delayed recalibration only works when the delta count is above the active sensor input threshold. If enabled, it is invoked when a sensor pad touch is held longer than the MAX_DUR bit settings.

Note 4-2 For the power button, which requires that the button be held longer than a regular button, the time specified by the MAX_DUR[3:0] bits is added to the time required to trigger the qualifying event. This will prevent the power button from being recalibrated during the time it is supposed to be held.

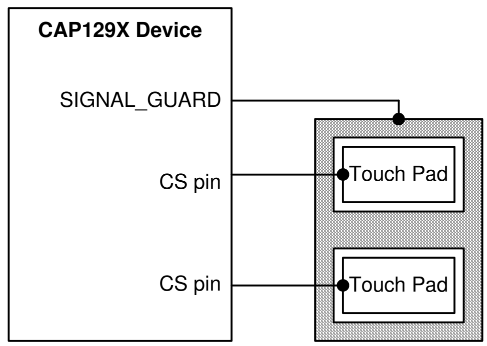
4.5 Proximity Detection

Each sensor input can be configured to detect changes in capacitance due to proximity of a touch. This circuitry detects the change of capacitance that is generated as an object approaches, but does not physically touch, the enabled sensor pad(s). Generally, sensor inputs used to detect proximity have physically larger pads than standard buttons. In addition, gain should be increased to increase sensitivity. To improve the signal, the signal guard feature may be used.

4.5.1 SIGNAL GUARD

The signal guard isolates the signal from virtual grounds, as shown in Figure 4-3. It can be used to isolate the proximity antenna from nearby conductive surfaces that would otherwise attenuate the e-field.

FIGURE 4-3: SIGNAL GUARD



4.6 Power Button

The CAP1296 has a “power button” feature. In general, buttons are set for quick response to a touch, especially when buttons are used for number keypads. However, there are cases where a quick response is not desired, such as when accidentally brushing the power button causes a device to turn off or on unexpectedly.

The power button feature allows a sensor input to be designated as the “power button” (see Section 5.26, "Power Button Register"). The power button is configured so that a touch must be held on the button for a designated period of time before an interrupt is generated; different times can be selected for the Standby and the Active states (see Section 5.27, "Power Button Configuration Register"). The feature can also be enabled / disabled for both states separately.

APPLICATION NOTE: For the power button feature to work in the Standby and/or Active states, the sensor input must be enabled in the applicable state. If the power button feature is enabled for both Standby and Active and the COMBO bit is set, the Standby power button settings will be used.

After the designated power button has been held for the designated time, an interrupt is generated and the PWR bit is set in the General Status Register (see Section 5.2, "Status Registers").

4.7 Multiple Touch Pattern Detection

The multiple touch pattern (MTP) detection circuitry can be used to detect lid closure or other similar events. An event can be flagged based on either a minimum number of sensor inputs or on specific sensor inputs simultaneously exceeding an MTP threshold or having their Noise Flag Status Register bits set. An interrupt can also be generated. During an MTP event, all touches are blocked (see Section 5.15, "Multiple Touch Pattern Configuration Register").

4.8 Noise Controls

4.8.1 LOW FREQUENCY NOISE DETECTION

Each sensor input has a low frequency noise detector that will sense if low frequency noise is injected onto the input with sufficient power to corrupt the readings. By default, if this occurs, the device will reject the corrupted samplesee DIS_ANA_NOISE bit in Section 5.6.1, "Configuration - 20h") and the corresponding bit is set to a logic '1' in the Noise Flag Status register (see SHOW_RF_NOISE bit in Section 5.6.2, "Configuration 2 - 44h").

4.8.2 RF NOISE DETECTION

Each sensor input contains an integrated RF noise detector. This block will detect injected RF noise on the CS pin. The detector threshold is dependent upon the noise frequency. By default, if RF noise is detected on a CS line, that sample is removed and not compared against the threshold (see DIS_RF_NOISE bit in Section 5.6.2, "Configuration 2 - 44h").

4.8.3 NOISE STATUS AND CONFIGURATION

The Noise Flag Status (see Section 5.3, "Noise Flag Status Registers") bits can be used to indicate RF and/or other noise. If the SHOW_RF_NOISE bit in the Configuration Register (see Section 5.6, "Configuration Registers") is set to 0, the Noise Flag Status bit for the capacitive sensor input is set if any analog noise is detected. If the SHOW_RF_NOISE bit is set to 1, the Noise Flag Status bits will only be set if RF noise is detected.

The CAP1208 offers optional noise filtering controls for both analog and digital noise.

For analog noise, there are options for whether the data should be considered invalid. By default, the DIS_ANA_NOISE bit (see Section 5.6.1, "Configuration - 20h") will block a touch on a sensor input if low frequency analog noise is detected; the sample is discarded. By default, the DIS_RF_NOISE bit (see Section 5.6.2, "Configuration 2 - 44h") will block a touch on a sensor input if RF noise is detected; the sample is discarded.

For digital noise, sensor input noise thresholds can be set (see Section 5.20, "Sensor Input Noise Threshold Register"). If a capacitive touch sensor input exceeds the Sensor Noise Threshold but does not exceed the touch threshold (Sensor Threshold (see Section 5.19, "Sensor Input Threshold Registers") in the Active state or Sensor Standby Threshold in the Standby state (Section 5.24, "Standby Threshold Register")), it is determined to be caused by a noise spike. The DIS_DIG_NOISE bit (see Section 5.6.1, "Configuration - 20h") can be set to discard samples that indicate a noise spike so they are not used in the automatic recalibration routine (see Section 4.4.1, "Automatic Recalibration").

4.9 Interrupts

Interrupts are indicated by the setting of the INT bit in the Main Control Register(see Section 5.1, "Main Control Register") and by assertion of the ALERT# pin. The ALERT# pin is cleared when the INT bit is cleared by the user. When the INT bit is cleared by the user, status bits may be cleared (see Section 5.2, "Status Registers").

4.9.1 ALERT# PIN

The ALERT# pin is an active low output that is driven when an interrupt event is detected.

4.9.2 CAPACITIVE SENSOR INPUT INTERRUPT BEHAVIOR

Each sensor input can be programmed to enable / disable interrupts(see Section 5.11, "Interrupt Enable Register").

When enabled for a sensor input and the sensor input is not the designated power button, interrupts are generated in one of two ways:

1. An interrupt is generated when a touch is detected and, as a user selectable option, when a release is detected (by default - see INT_REL_n in Section 5.6.2, "Configuration 2 - 44h"). See FIGURE 4-5:.
2. If the repeat rate is enabled then, so long as the touch is held, another interrupt will be generated based on the programmed repeat rate (see FIGURE 4-4:).

When the repeat rate is enabled for a sensor input (see Section 5.12, "Repeat Rate Enable Register"), the device uses an additional control called MPRESS that determines whether a touch is flagged as a simple "touch" or a "press and hold" (see Section 5.9, "Sensor Input Configuration 2 Register"). The MPRESS[3:0] bits set a minimum press timer. When the button is touched, the timer begins. If the sensor pad is released before the minimum press timer expires, it is flagged as a touch and an interrupt (if enabled) is generated upon release. If the sensor input detects a touch for longer than this timer value, it is flagged as a "press and hold" event. So long as the touch is held, interrupts will be generated at the programmed repeat rate (see Section 5.8, "Sensor Input Configuration Register") and upon release (if enabled).

If a sensor input is the designated power button, an interrupt is not generated as soon as a touch is detected and repeat rate is not applicable. See Section 4.9.3, "Interrupts for the Power Button".

APPLICATION NOTE: FIGURE 4-4: and FIGURE 4-5: show default operation which is to generate an interrupt upon sensor pad release.

APPLICATION NOTE: The host may need to poll the device twice to determine that a release has been detected.

FIGURE 4-4: SENSOR INTERRUPT BEHAVIOR - REPEAT RATE ENABLED

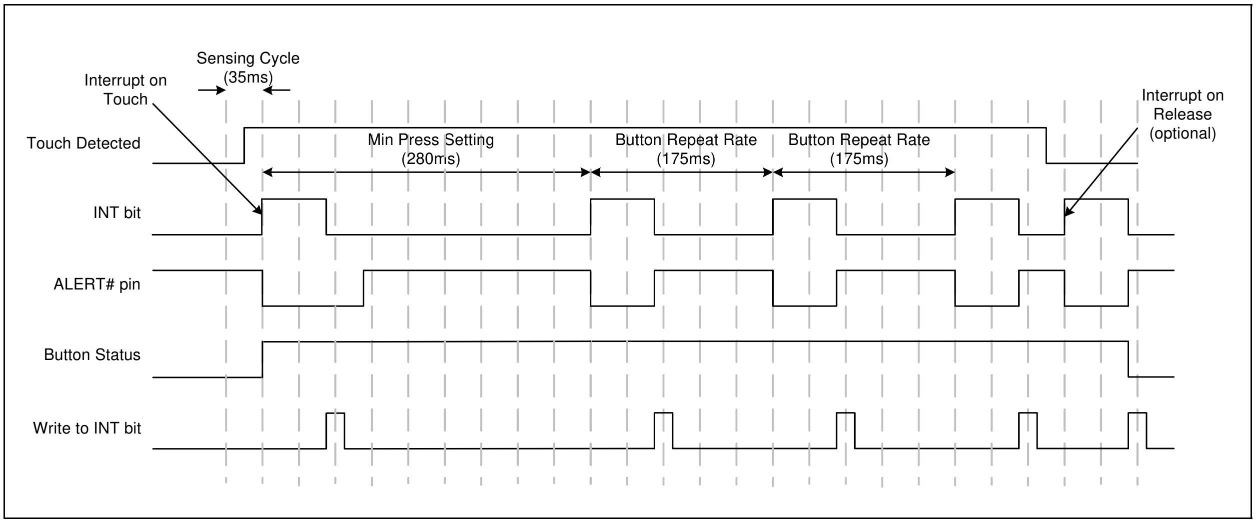
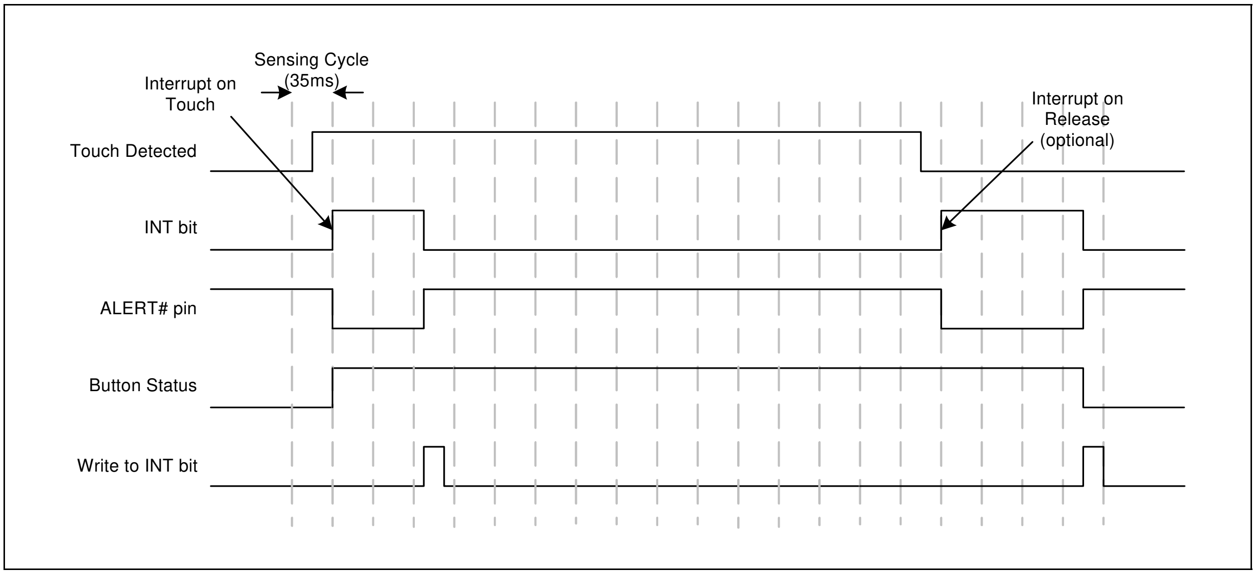


FIGURE 4-5: SENSOR INTERRUPT BEHAVIOR - NO REPEAT RATE ENABLED



4.9.3 INTERRUPTS FOR THE POWER BUTTON

Interrupts are automatically enabled for the power button when the feature is enabled (see Section 4.6, "Power Button"). A touch must be held on the power button for the designated period of time before an interrupt is generated.

4.9.4 INTERRUPTS FOR MULTIPLE TOUCH PATTERN DETECTION

An interrupt can be generated when the MTP pattern is matched (see Section 5.15, "Multiple Touch Pattern Configuration Register").

4.9.5 INTERRUPTS FOR SENSOR INPUT CALIBRATION FAILURES

An interrupt can be generated when the ACAL_FAIL bit is set, indicating the failure to complete analog calibration of one or more sensor inputs(see Section 5.2, "Status Registers"). This interrupt can be enabled by setting the ACAL_-FAIL_INT bit (see Section 5.6, "Configuration Registers").

An interrupt can be generated when the BC_OUT bit is set, indicating the base count is out of limit for one or more sensor inputs(see Section 5.2, "Status Registers"). This interrupt can be enabled by setting the BC_OUT_INT bit (see Section 5.6, "Configuration Registers").

5.0 REGISTER DESCRIPTION

The registers shown in Table 5-1 are accessible through the communications protocol. An entry of '-' indicates that the bit is not used and will always read '0'.

TABLE 5-1: REGISTER SET IN HEXADECIMAL ORDER

Register Address	R/W	Register Name	Function	Default Value	Page
00h	R/W	Main Control	Controls power states and indicates an interrupt	00h	Page 26
02h	R/W	General Status	Stores general status bits	00h	Page 28
03h	R	Sensor Input Status	Returns the state of the sampled capacitive touch sensor inputs	00h	Page 28
0Ah	R	Noise Flag Status	Stores the noise flags for sensor inputs	00h	Page 29
10h	R	Sensor Input 1 Delta Count	Stores the delta count for CS1	00h	Page 29
11h	R	Sensor Input 2 Delta Count	Stores the delta count for CS2	00h	Page 29
12h	R	Sensor Input 3 Delta Count	Stores the delta count for CS3	00h	Page 29
13h	R	Sensor Input 4 Delta Count	Stores the delta count for CS4	00h	Page 29
14h	R	Sensor Input 5 Delta Count	Stores the delta count for CS5	00h	Page 29
15h	R	Sensor Input 6 Delta Count	Stores the delta count for CS6	00h	Page 29
1Fh	R/W	Sensitivity Control	Controls the sensitivity of the threshold and delta counts and data scaling of the base counts	2Fh	Page 30
20h	R/W	Configuration	Controls general functionality	20h	Page 31
21h	R/W	Sensor Input Enable	Controls which sensor inputs are monitored in Active	3Fh	Page 33
22h	R/W	Sensor Input Configuration	Controls max duration and auto-repeat delay	A4h	Page 33
23h	R/W	Sensor Input Configuration 2	Controls the MPRESS ("press and hold") setting	07h	Page 35
24h	R/W	Averaging and Sampling Config	Controls averaging and sampling window for Active	39h	Page 36
26h	R/W	Calibration Activate and Status	Forces calibration for capacitive touch sensor inputs and indicates calibration failure	00h	Page 37
27h	R/W	Interrupt Enable	Determines which capacitive sensor inputs can generate interrupts	3Fh	Page 38

TABLE 5-1: REGISTER SET IN HEXADECIMAL ORDER (CONTINUED)

Register Address	R/W	Register Name	Function	Default Value	Page
28h	R/W	Repeat Rate Enable	Enables repeat rate for specific sensor inputs	3Fh	Page 39
29h	R/W	Signal Guard Enable	Enables the signal guard for specific sensor inputs	00h	Page 39
2Ah	R/W	Multiple Touch Configuration	Determines the number of simultaneous touches to flag a multiple touch condition	80h	Page 40
2Bh	R/W	Multiple Touch Pattern Configuration	Determines the multiple touch pattern (MTP) configuration	00h	Page 40
2Dh	R/W	Multiple Touch Pattern	Determines the pattern or number of sensor inputs used by the MTP circuitry	3Fh	Page 41
2Eh	R	Base Count Out of Limit	Indicates whether sensor inputs have a base count out of limit	00h	Page 42
2Fh	R/W	Recalibration Configuration	Determines recalibration timing and sampling window	8Ah	Page 43
30h	R/W	Sensor Input 1 Threshold	Stores the touch detection threshold for Active for CS1	40h	Page 44
31h	R/W	Sensor Input 2 Threshold	Stores the touch detection threshold for Active for CS2	40h	Page 44
32h	R/W	Sensor Input 3 Threshold	Stores the touch detection threshold for Active for CS3	40h	Page 44
33h	R/W	Sensor Input 4 Threshold	Stores the touch detection threshold for Active for CS4	40h	Page 44
34h	R/W	Sensor Input 5 Threshold	Stores the touch detection threshold for Active for CS5	40h	Page 44
35h	R/W	Sensor Input 6 Threshold	Stores the touch detection threshold for Active for CS6	40h	Page 44
38h	R/W	Sensor Input Noise Threshold	Stores controls for selecting the noise threshold for all sensor inputs	01h	Page 45
Standby Configuration Registers					
40h	R/W	Standby Channel	Controls which sensor inputs are enabled for Standby	00h	Page 45
41h	R/W	Standby Configuration	Controls averaging and sensing cycle time for Standby	39h	Page 46
42h	R/W	Standby Sensitivity	Controls sensitivity settings used for Standby	02h	Page 47
43h	R/W	Standby Threshold	Stores the touch detection threshold for Standby	40h	Page 48
44h	R/W	Configuration 2	Stores additional configuration controls for the device	40h	Page 31

TABLE 5-1: REGISTER SET IN HEXADECIMAL ORDER (CONTINUED)

Register Address	R/W	Register Name	Function	Default Value	Page
Base Count Registers					
50h	R	Sensor Input 1 Base Count	Stores the reference count value for sensor input 1	C8h	Page 48
51h	R	Sensor Input 2 Base Count	Stores the reference count value for sensor input 2	C8h	Page 48
52h	R	Sensor Input 3 Base Count	Stores the reference count value for sensor input 3	C8h	Page 48
53h	R	Sensor Input 4 Base Count	Stores the reference count value for sensor input 4	C8h	Page 48
54h	R	Sensor Input 5 Base Count	Stores the reference count value for sensor input 5	C8h	Page 48
55h	R	Sensor Input 6 Base Count	Stores the reference count value for sensor input 6	C8h	Page 48
Power Button Registers					
60h	R/W	Power Button	Specifies the power button	00h	Page 49
61h	R/W	Power Button Configuration	Configures the power button feature	22h	Page 50
Calibration Sensitivity Configuration Registers					
80h	R/W	Calibration Sensitivity Configuration 1	Stores calibration sensitivity settings for proximity	00h	Page 51
81h	R/W	Calibration Sensitivity Configuration 2	Stores calibration sensitivity settings for proximity	00h	Page 51
Calibration Registers					
B1h	R	Sensor Input 1 Calibration	Stores the upper 8-bit calibration value for CS1	00h	Page 50
B2h	R	Sensor Input 2 Calibration	Stores the upper 8-bit calibration value for CS2	00h	Page 50
B3h	R	Sensor Input 3 Calibration	Stores the upper 8-bit calibration value for CS3	00h	Page 50
B4h	R	Sensor Input 4 Calibration	Stores the upper 8-bit calibration value for CS4	00h	Page 50
B5h	R	Sensor Input 5 Calibration	Stores the upper 8-bit calibration value for CS5	00h	Page 50
B6h	R	Sensor Input 6 Calibration	Stores the upper 8-bit calibration value for CS6	00h	Page 50
B9h	R	Sensor Input Calibration LSB 1	Stores the 2 LSBs of the calibration value for CS1 - CS4	00h	Page 50
BAh	R	Sensor Input Calibration LSB 2	Stores the 2 LSBs of the calibration value for CS5 - CS6	00h	Page 50
ID Registers					