CAP1128

8 Channel Capacitive Touch Sensor with 2 LED Drivers

General Description

The CAP1128, which incorporates RightTouch® technology, is a multiple channel Capacitive Touch sensor with multiple power LED drivers. It contains eight (8) individual capacitive touch sensor inputs with programmable sensitivity for use in touch sensor applications. Each sensor input automatically recalibrates to compensate for gradual environmental changes.

The CAP1128 also contains two (2) LED drivers that offer full-on / off, variable rate blinking, dimness controls, and breathing. Each of the LED drivers may be linked to one of the sensor inputs to be actuated when a touch is detected. As well, each LED driver may be individually controlled via a host controller.

The CAP1128 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, then a status bit is set and an interrupt generated.

Additionally, the CAP1128 includes circuitry and support for enhanced sensor proximity detection.

The CAP1128 offers multiple power states operating at low quiescent currents. In the Standby state of operation, one or more capacitive touch sensor inputs are active and all LEDs may be used. If a touch is detected, it will wake the system using the WAKE/SPI_MOSI pin.

Deep Sleep is the lowest power state available, drawing 5uA (typical) of current. In this state, no sensor inputs are active. Driving the WAKE/SPI_MOSI pin or communications will wake the device.

Applications

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

Features

- Eight (8) Capacitive Touch Sensor Inputs
  - Programmable sensitivity
  - Automatic recalibration
  - Individual thresholds for each button
- Proximity Detection
- Multiple Button Pattern Detection
- Calibrates for Parasitic Capacitance
- Analog Filtering for System Noise Sources
- Press and Hold feature for Volume-like Applications
- Multiple Communication Interfaces
  - SMBus / I^2C compliant interface
  - SPI communications
  - Pin selectable communications protocol and multiple slave addresses (SMBus / I^2C only)
- Low Power Operation
  - 5uA quiescent current in Deep Sleep
  - 50uA quiescent current in Standby (1 sensor input monitored)
  - Samples one or more channels in Standby
- Two (2) LED Driver Outputs
  - Open Drain or Push-Pull
  - Programmable blink, breathe, and dimness controls
  - Can be linked to Capacitive Touch Sensor inputs
- Dedicated Wake output flags touches in low power state
- System RESET pin
- Available in 20-pin 4mm x 4mm QFN RoHS compliant package

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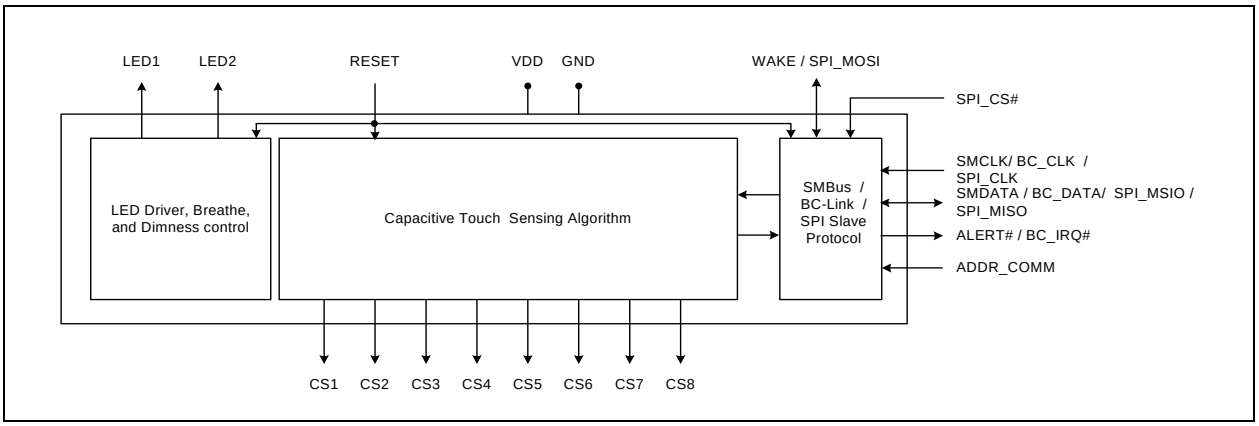
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1.0 BLOCK DIAGRAM



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2.0 PIN DESCRIPTION

FIGURE 2-1: *CAP1128 Pin Diagram (20-Pin QFN)*

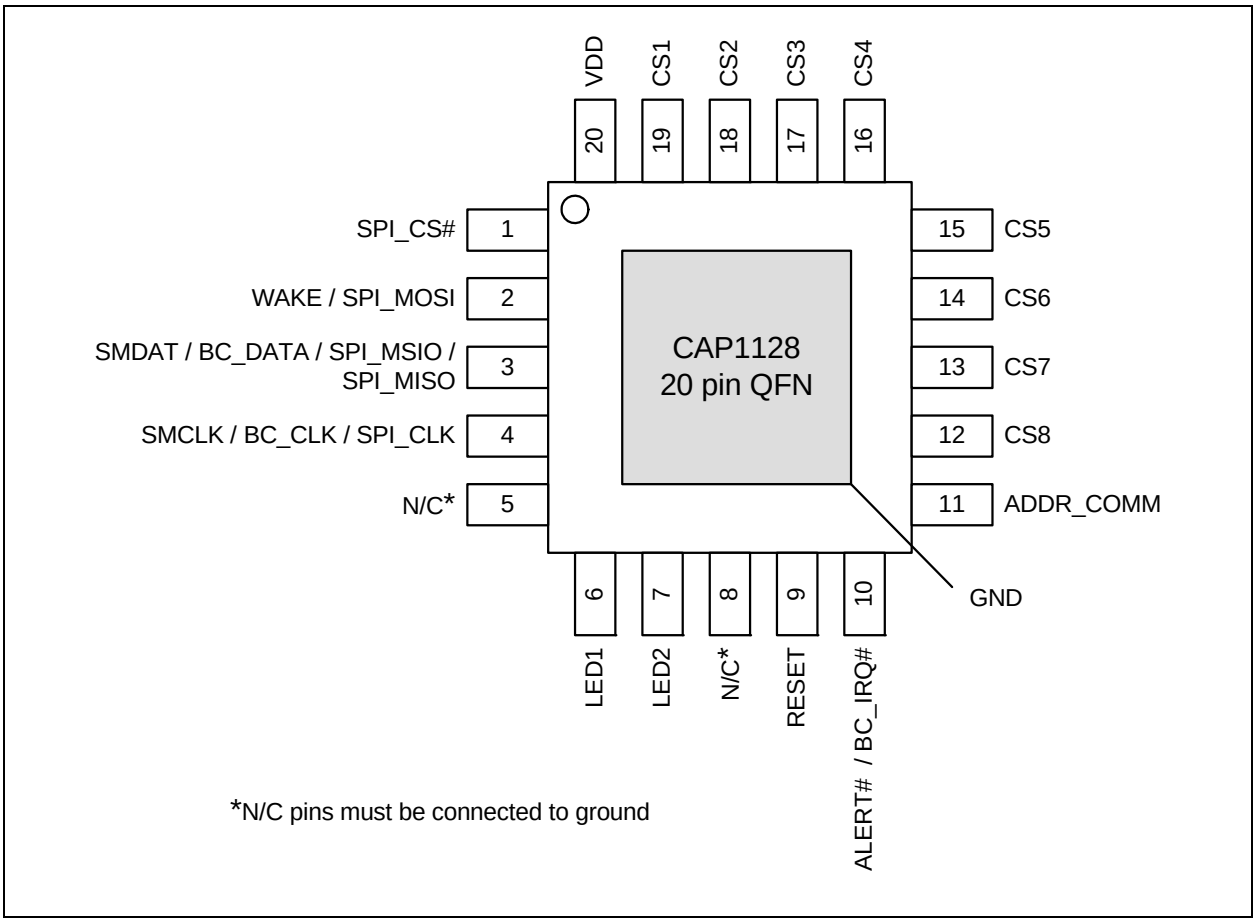


TABLE 2-1: PIN DESCRIPTION FOR CAP1128

Pin Number	Pin Name	Pin Function	Pin Type	Unused Connection
1	SPI_CS#	Active low chip-select for SPI bus	DI (5V)	Connect to Ground
2	WAKE / SPI_-MOSI	WAKE - Active high wake / interrupt output Standby power state - requires pull-down resistor	DO	Pull-down Resistor
		WAKE - Active high wake input - requires pull-down resistor Deep Sleep power state	DI	
		SPI_MOSI - SPI Master-Out-Slave-In port when used in normal mode	DI (5V)	Connect to Ground

TABLE 2-1: PIN DESCRIPTION FOR CAP1128 (CONTINUED)

Pin Number	Pin Name	Pin Function	Pin Type	Unused Connection
3	SMDATA / SPI_MSIO / SPI_MISO	SMDATA - Bi-directional, open-drain SMBus data - requires pull-up resistor	DIOD (5V)	n/a
		SPI_MSIO - SPI Master-Slave-In-Out bidirectional port when used in bi-directional mode	DIO	
		SPI_MISO - SPI Master-In-Slave-Out port when used in normal mode	DO	
4	SMCLK / SPI_-CLK	SMCLK - SMBus clock input - requires pull-up resistor	DI (5V)	n/a
		SPI_CLK - SPI clock input	DI (5V)	
5	N/C	Not Internally Connected	n/a	Connect to Ground
6	LED1	Open drain LED 1 driver (default)	OD (5V)	Connect to Ground
		Push-pull LED 1 driver	DO	leave open or connect to Ground
7	LED2	Open drain LED 2 driver (default)	OD (5V)	Connect to Ground
		Push-pull LED 2 driver	DO	leave open or connect to Ground
8	N/C	Not Internally Connected	n/a	Connect to Ground
9	RESET	Active high soft reset for system - resets all registers to default values. If not used, connect to ground.	DI (5V)	Connect to Ground
10	ALERT#	ALERT# - Active low alert / interrupt output for SMBus alert or SPI interrupt	OD (5V)	Connect to Ground
		ALERT# - Active high push-pull alert / interrupt output for SMBus alert or SPI interrupt	DO	leave open
11	ADDR_COMM	Address / communications select pin - pull-down resistor determines address / communications mechanism	AI	n/a
12	CS8	Capacitive Touch Sensor Input 8	AIO	Connect to Ground
13	CS7	Capacitive Touch Sensor Input 7	AIO	Connect to Ground
14	CS6	Capacitive Touch Sensor Input 6	AIO	Connect to Ground
15	CS5	Capacitive Touch Sensor Input 5	AIO	Connect to Ground
16	CS4	Capacitive Touch Sensor Input 4	AIO	Connect to Ground

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TABLE 2-1: PIN DESCRIPTION FOR CAP1128 (CONTINUED)

Pin Number	Pin Name	Pin Function	Pin Type	Unused Connection
17	CS3	Capacitive Touch Sensor Input 3	AIO	Connect to Ground
18	CS2	Capacitive Touch Sensor Input 2	AIO	Connect to Ground
19	CS1	Capacitive Touch Sensor Input 1	AIO	Connect to Ground
20	VDD	Positive Power supply	Power	n/a
Bottom Pad	GND	Ground	Power	n/a

APPLICATION NOTE: When the ALERT# pinis configured as an active low output, it will be open drain. When it is configured as an active high output, it will be push-pull.

APPLICATION NOTE: For the 5V tolerant pins that have a pull-up resistor, the pull-up voltage must not exceed 3.6V when the CAP1128 is unpowered.

APPLICATION NOTE: The SPI_CS# pin should be grounded when SMBus, or I^2C,communications are used.

The pin types are described in Table 2-2. All pins labeled with (5V) are 5V tolerant.

TABLE 2-2: 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.
DO	Push-pull Digital Output - This pin is used as a digital output and can sink and source current.
DIO	Push-pull Digital Input / Output - This pin is used as an I/O for digital signals.

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3.0 ELECTRICAL SPECIFICATIONS

TABLE 3-1: ABSOLUTE MAXIMUM RATINGS

Voltage on 5V tolerant pins (V_{5VT_PIN})	-0.3 to 5.5	V
Voltage on 5V tolerant pins ($\|V_{5VT_PIN} - V_{DD}\|$) Note 3-2	0 to 3.6	V
Voltage on VDD pin	-0.3 to 4	V
Voltage on any other pin to GND	-0.3 to VDD + 0.3	V
Package Power Dissipation up to T_A = 85°C for 20 pin QFN (see Note 3-3)	0.9	W
Junction to Ambient (θ_{JA}) (see Note 3-4)	58	°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 3-1 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 3-2 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 3-3 The Package Power Dissipation specification assumes a recommended thermal via design consisting of a 3x3 matrix of 0.3mm (12mil) vias at 1.0mm pitch connected to the ground plane with a 2.5 x 2.5mm thermal landing.

Note 3-4 Junction to Ambient (θ_{JA}) is dependent on the design of the thermal vias. Without thermal vias and a thermal landing, the θ_{JA} is approximately 60°C/W including localized PCB temperature increase.

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TABLE 3-2: ELECTRICAL SPECIFICATIONS

V_{DD} = 3V to 3.6V, T_A = 0°C to 85°C, all typical values at T_A = 27°C unless otherwise noted.						
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
DC Power						
Supply Voltage	V_{DD}	3.0	3.3	3.6	V	
Supply Current	I_{STBY}		120	170	uA	Standby state active 1 sensor input monitored No LEDs active Default conditions (8 avg, 70ms cycle time)
	I_{STBY}		50		uA	Standby state active 1 sensor input monitored No LEDs active 1 avg, 140ms cycle time,
	I_{DSLEEP}		5	15	uA	Deep Sleep state active LEDs at 100% or 0% Duty Cycle No communications T_A < 40°C 3.135 < V_{DD} < 3.465V
	I_{DD}		500	600	uA	Capacitive Sensing Active No LEDs active
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 (1 avg, 35ms cycle time, 1x sensitivity)
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 Maximum sensitivity Negative Delta Counts disabled All other parameters default
Timing						
RESET Pin Delay	t_{RST_DLY}	10			ms	
Time to communications ready	t_{COMM_DLY}			15	ms	
Time to first conversion ready	t_{CONV_DLY}		170	200	ms	
LED Drivers						
Duty Cycle	$DUTY_{LED}$	0		100	%	Programmable
Drive Frequency	f_{LED}		2		kHz	
Sinking Current	I_{SINK}			24	mA	V_{OL} = 0.4
Sourcing Current	I_{SOURCE}			24	mA	V_{OH} = V_{DD} - 0.4
Leakage Current	I_{LEAK}			±5	uA	powered or unpowered TA < 85°C pull-up voltage ≤ 3.6V if unpowered
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

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TABLE 3-2: ELECTRICAL SPECIFICATIONS (CONTINUED)

V_{DD} = 3V to 3.6V, T_A = 0°C to 85°C, all typical values at T_A = 27°C unless otherwise noted.						
Characteristic	**Symbol**	**Min**	**Typ**	**Max**	**Unit**	**Conditions**
Input High Voltage	V_{IH}	2.0			V	
Input Low Voltage	V_{IL}			0.8	V	
Leakage Current	I_{LEAK}			±5	uA	powered or unpowered T_A < 85°C pull-up voltage ≤ 3.6V if unpowered
RESET Pin Release to conversion ready	t_{RESET}		170	200	ms	
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			us	
Start Setup Time	$t_{SU:STA}$	0.6			us	
Start Hold Time	$t_{HD:STA}$	0.6			us	
Stop Setup Time	$t_{SU:STO}$	0.6			us	
Data Hold Time	$t_{HD:DAT}$	0			us	When transmitting to the master
Data Hold Time	$t_{HD:DAT}$	0.3			us	When receiving from the master
Data Setup Time	$t_{SU:DAT}$	0.6			us	
Clock Low Period	t_{LOW}	1.3			us	
Clock High Period	t_{HIGH}	0.6			us	
Clock / Data Fall Time	t_{FALL}			300	ns	Min = 20+0.1C_{LOAD} ns
Clock / Data Rise Time	t_{RISE}			300	ns	Min = 20+0.1C_{LOAD} ns
Capacitive Load	C_{LOAD}			400	pF	per bus line
SPI Timing						
Clock Period	t_P	250			ns	
Clock Low Period	t_{LOW}	0.4 x t_P		0.6 x t_P	ns	
Clock High Period	t_{HIGH}	0.4 x t_P		0.6 x t_P	ns	
Clock Rise / Fall time	t_{RISE} / t_{FALL}			0.1 x t_P	ns	
Data Output Delay	$t_{D:CLK}$			10	ns	
Data Setup Time	$t_{SU:DAT}$	20			ns	
Data Hold Time	$t_{HD:DAT}$	20			ns	
SPI_CS# to SPI_CLK setup time	$t_{SU:CS}$	0			ns	
Wake Time	t_{WAKE}	10		20	us	SPI_CS# asserted to CLK assert

Note 3-5 The ALERT pin will not glitch high or low at power up if connected to VDD or another voltage.

Note 3-6 The SMCLK and SMDATA pins will not glitch low at power up if connected to VDD or another voltage.

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4.0 COMMUNICATIONS

4.1 Communications

The CAP1128communicates using the 2-wire SMBus or I^{2}C bus, the 2-wire proprietary BC-Link, or the SPI bus. If the proprietary BC-Link protocol is required for your application, please contact your Microchip representative for ordering instructions. Regardless of communication mechanism, the device functionality remains unchanged. The communications mechanism as well as the SMBus (or I^{2}C) slave address is determined by the resistor connected between the ADDR_COMM pin and ground as shown in Table 4-1.

TABLE 4-1: ADDR_COMM PIN DECODE

Pull-Down Resistor (+/- 5%)	Protocol Used	SMBus Address
GND	SPI Communications using Normal 4-wire Protocol Used	n/a
56k	SPI Communications using Bi-Directional 3-wire Protocol Used	n/a
68k	Reserved	n/a
82k	SMBus / I^{2}C	0101_100(r/w)
100k	SMBus / I^{2}C	0101_011(r/w)
120k	SMBus / I^{2}C	0101_010(r/w)
150k	SMBus / I^{2}C	0101_001(r/w)
VDD	SMBus / I^{2}C	0101_000(r/w)

4.1.1 SMBUS (I^{2}C) COMMUNICATIONS

When configured to communicate via the SMBus, the CAP1128 supports the following protocols: Send Byte, Receive Byte, Read Byte, Write Byte, Read Block, and Write Block. In addition, the device supports I^{2}C formatting for block read and block write protocols.

APPLICATION NOTE: For SMBus/I^{2}C communications, the SPI_CS# pin is not used and should be grounded; any data presented to this pin will be ignored.

See Section 4.2 and Section 4.3 for more information on the SMBus bus and protocols respectively.

4.1.2 SPI COMMUNICATIONS

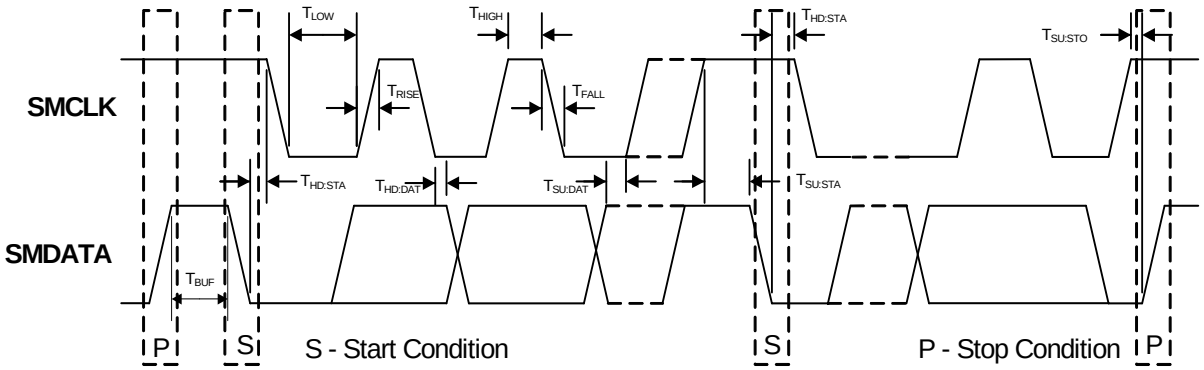
When configured to communicate via the SPI bus, the CAP1128supports both bi-directional 3-wire and normal 4-wire protocols and uses the SPI_CS# pin to enable communications.

APPLICATION NOTE: See Section 4.5 and Section 4.6 for more information on the SPI bus and protocols respectively.Upon power up, the CAP1128 will not respond to any communications for up to 15ms. After this time, full functionality is available.

4.2 System Management Bus

The CAP1128 communicates with a host controller, such as an 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 4-1. Stretching of the SMCLK signal is supported; however, the CAP1128 will not stretch the clock signal.

FIGURE 4-1: *SMBus Timing Diagram*



4.2.1 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.

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

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

See Table 4-1 for available SMBus addresses.

4.2.3 SMBUS DATA BYTES

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

4.2.4 SMBUS ACK AND NACK BITS

The SMBus slave will acknowledge all data bytes that it receives. This is done by the slave 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 slave 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.

4.2.5 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 CAP1128 detects an SMBus Stop bit and it has been communicating with the SMBus protocol, it will reset its slave interface and prepare to receive further communications.

4.2.6 SMBUS TIMEOUT

The CAP1128 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 6.6, "Configuration Registers").

4.2.7 SMBUS AND I^2C COMPATIBILITY

The major differences between SMBus and I^2C devices are highlighted here. For more information, refer to the SMBus 2.0 and I^2C specifications. For information on using the CAP1128 in an I^2C system, refer to AN 14.0 Dedicated Slave Devices in I^2C Systems.

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1. CAP1128 supports I^2C fast mode at 400kHz. This covers the SMBus max time of 100kHz.
2. Minimum frequency for SMBus communications is 10kHz.
3. The SMBus slave protocol will reset if the clock is held at a logic ‘0’ for longer than 30ms. This timeout functionality is disabled by default in the CAP1128 and can be enabled by writing to the TIMEOUT bit. I^2C does not have a timeout.
4. The SMBus slave protocol will reset if both the clock and data lines are held at a logic ‘1’ for longer than 200µs (idle condition). This function is disabled by default in the CAP1128 and can be enabled by writing to the TIMEOUT bit. I^2C does not have an idle condition.
5. I^2C devices do not support the Alert Response Address functionality (which is optional for SMBus).
6. I^2C devices support block read and write differently. I^2C 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 CAP1128 supports I^2C formatting only.

4.3 SMBus Protocols

The CAP1128 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 4-2.

TABLE 4-2: PROTOCOL FORMAT

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

4.3.1 SMBUS WRITE BYTE

The Write Byte is used to write one byte of data to a specific register as shown in Table 4-3.

TABLE 4-3: WRITE BYTE PROTOCOL

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

4.3.2 SMBUS READ BYTE

The Read Byte protocol is used to read one byte of data from the registers as shown in Table 4-4.

TABLE 4-4: READ BYTE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Start	Slave Address	RD	ACK	Register Data	NACK	Stop
1->0	YYYY_YYY	0	0	XXh	0	1 ->0	YYYY_YYY	1	0	XXh	1	0 -> 1

4.3.3 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 4-5.

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

TABLE 4-5: SEND BYTE PROTOCOL

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

4.3.4 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 4-6.

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

TABLE 4-6: RECEIVE BYTE PROTOCOL

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

4.4 I²C Protocols

The CAP1128 supports I²C Block Write and Block Read.

The protocols listed below use the convention in Table 4-2.

4.4.1 BLOCK WRITE

The Block Write is used to write multiple data bytes to a group of contiguous registers as shown in Table 4-7.

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 4-7: BLOCK WRITE PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Register Data	ACK
1 ->0	YYYY_YYY	0	0	XXh	0	XXh	0
Register Data	ACK	Register Data	ACK	. . .	Register Data	ACK	Stop
XXh	0	XXh	0	. . .	XXh	0	0 -> 1

4.4.2 BLOCK READ

The Block Read is used to read multiple data bytes from a group of contiguous registers as shown in Table 4-8.

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 4-8: BLOCK READ PROTOCOL

Start	Slave Address	WR	ACK	Register Address	ACK	Start	Slave Address	RD	ACK	Register Data
1->0	YYYY_YYY	0	0	XXh	0	1 ->0	YYYY_YYY	1	0	XXh
ACK	Register Data	ACK	Register Data	ACK	Register Data	ACK	. . .	Register Data	NACK	Stop
0	XXh	0	XXh	0	XXh	0	. . .	XXh	1	0 -> 1

4.5 SPI Interface

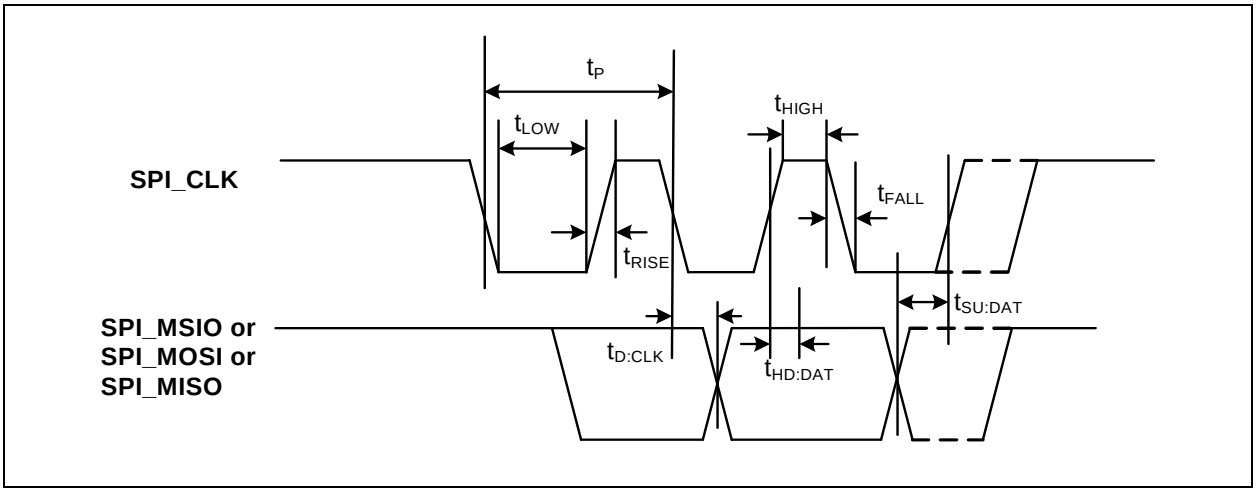
The SMBus has a predefined packet structure, the SPI does not. The SPI Bus can operate in two modes of operation, normal 4-wire mode and bi-directional 3-wire mode. All SPI commands consist of 8-bit packets sent to a specific slave device (identified by the CS pin).

The SPI bus will latch data on the rising edge of the clock and the clock and data both idle high.

All commands are supported via both operating modes. The supported commands are: Reset Serial interface, set address pointer, write command and read command. Note that all other codes received during the command phase are ignored and have no effect on the operation of the device.

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FIGURE 4-2: *SPI Timing*



4.5.1 SPI NORMAL MODE

The SPI Bus can operate in two modes of operation, normal and bi-directional mode. In the normal mode of operation, there are dedicated input and output data lines. The host communicates by sending a command along the CAP1128 SPI_MOSI data line and reading data on the SPI_MISO data line. Both communications occur simultaneously which allows for larger throughput of data transactions.

All basic transfers consist of two 8 bit transactions from the Master device while the slave device is simultaneously sending data at the current address pointer value.

Data writes consist of two or more 8-bit transactions. The host sends a specific write command followed by the data to write the address pointer. Data reads consist of one or more 8-bit transactions. The host sends the specific read data command and continues clocking for as many data bytes as it wishes to receive.

4.5.2 SPI BI-DIRECTIONAL MODE

In the bi-directional mode of operation, the SPI data signals are combined into the SPI_MSIO line, which is shared for data received by the device and transmitted by the device. The protocol uses a simple handshake and turn around sequence for data communications based on the number of clocks transmitted during each phase.

All basic transfers consist of two 8 bit transactions. The first is an 8 bit command phase driven by the Master device. The second is by an 8 bit data phase driven by the Master for writes, and by the CAP1128 for read operations.

The auto increment feature of the address pointer allows for successive reads or writes. The address pointer will return to 00h after reaching FFh.

4.5.3 SPI_CS# PIN

The SPI Bus is a single master, multiple slave serial bus. Each slave has a dedicated CS pin (chip select) that the master asserts low to identify that the slave is being addressed. There are no formal addressing options.

4.5.4 ADDRESS POINTER

All data writes and reads are accessed from the current address pointer. In both Bi-directional mode and Full Duplex mode, the Address pointer is automatically incremented following every read command or every write command.

The address pointer will return to 00h after reaching FFh.

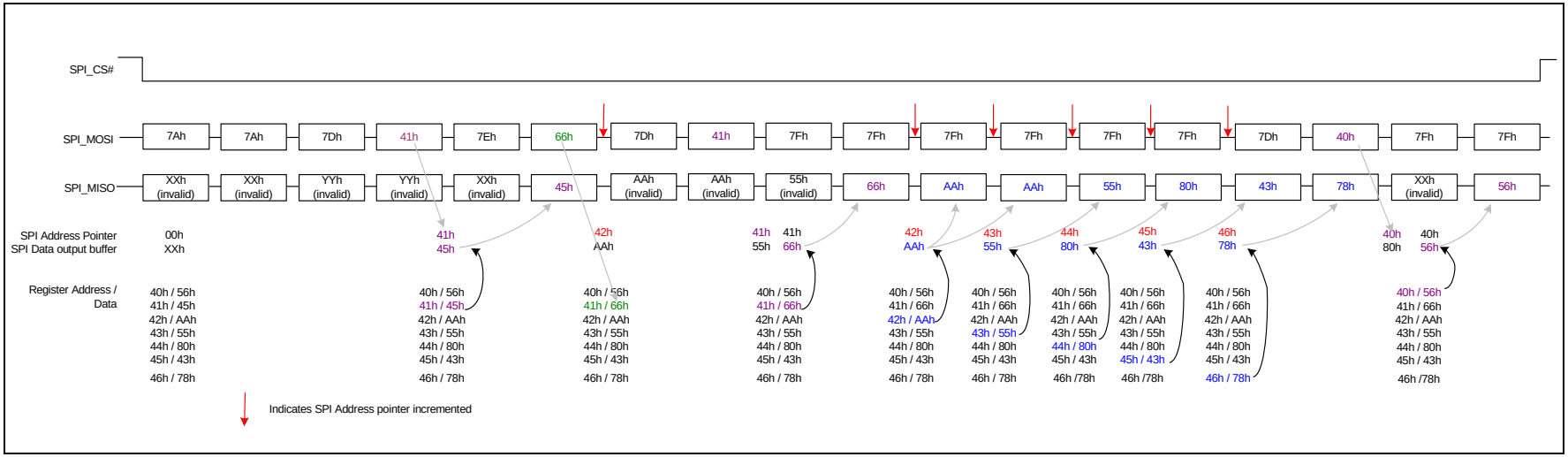
4.5.5 SPI TIMEOUT

The CAP1128 does not detect any timeout conditions on the SPI bus.

4.6 Normal SPI Protocols

When operating in normal mode, the SPI bus internal address pointer is incremented depending upon which command has been transmitted. Multiple commands may be transmitted sequentially so long as the SPI_CS# pin is asserted low. Figure 4-3 shows an example of this operation.

FIGURE 4-3: *Example SPI Bus Communication - Normal Mode*

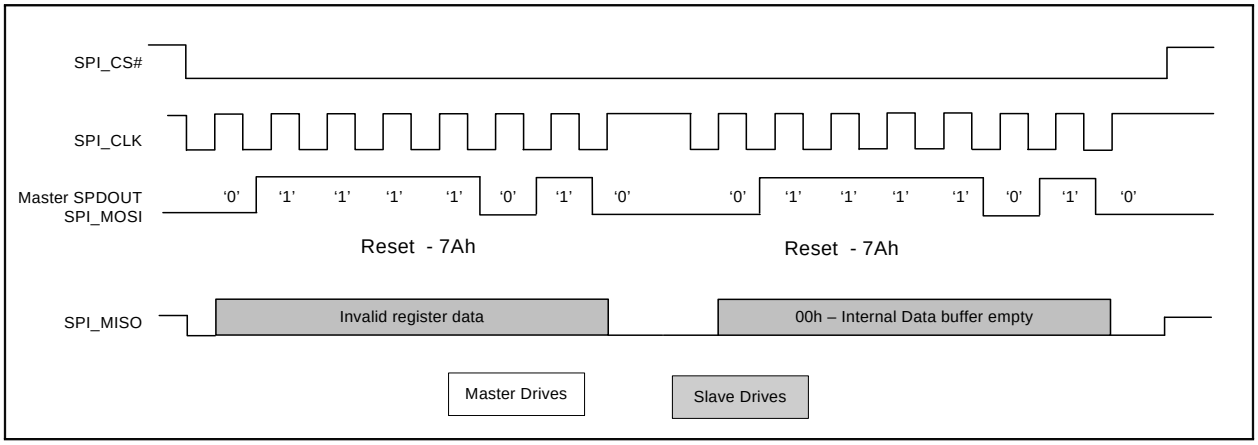


4.6.1 RESET INTERFACE

Resets the Serial interface whenever two successive 7Ah codes are received. Regardless of the current phase of the transaction - command or data, the receipt of the successive reset commands resets the Serial communication interface only. All other functions are not affected by the reset operation.

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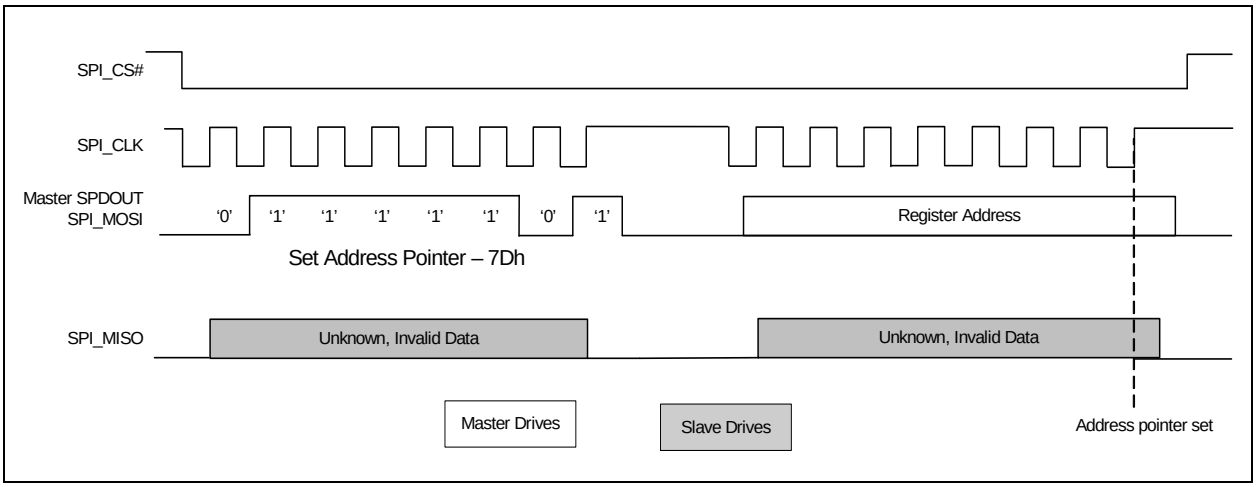
FIGURE 4-4: *SPI Reset Interface Command - Normal Mode*



4.6.2 SET ADDRESS POINTER

The Set Address Pointer command sets the Address pointer for subsequent reads and writes of data. The pointer is set on the rising edge of the final data bit. At the same time, the data that is to be read is fetched and loaded into the internal output buffer but is not transmitted.

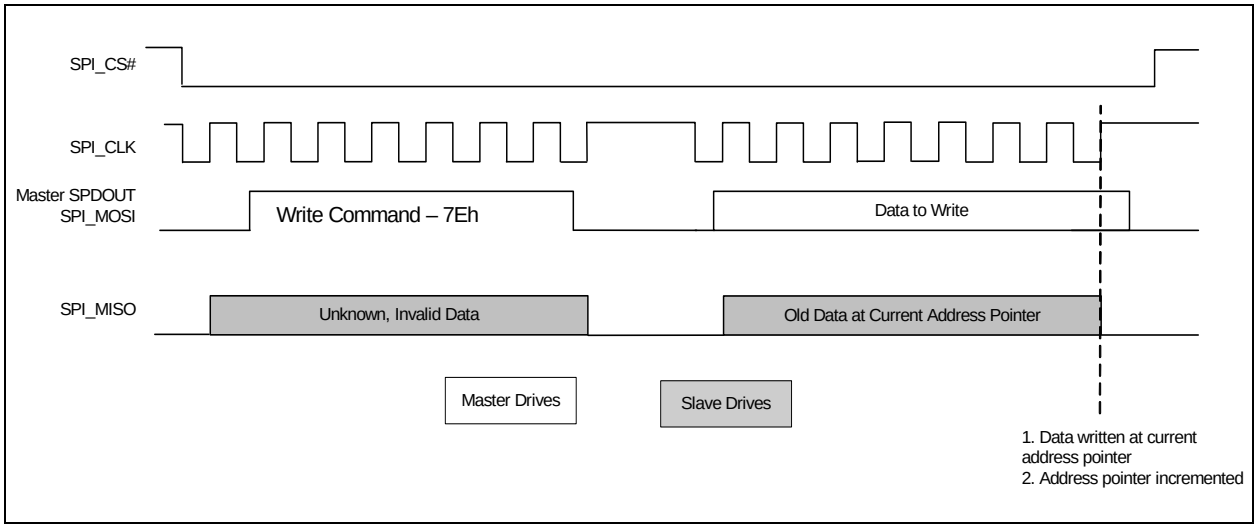
FIGURE 4-5: *SPI Set Address Pointer Command - Normal Mode*



4.6.3 WRITE DATA

The Write Data protocol updates the contents of the register referenced by the address pointer. As the command is processed, the data to be read is fetched and loaded into the internal output buffer but not transmitted. Then, the register is updated with the data to be written. Finally, the address pointer is incremented.

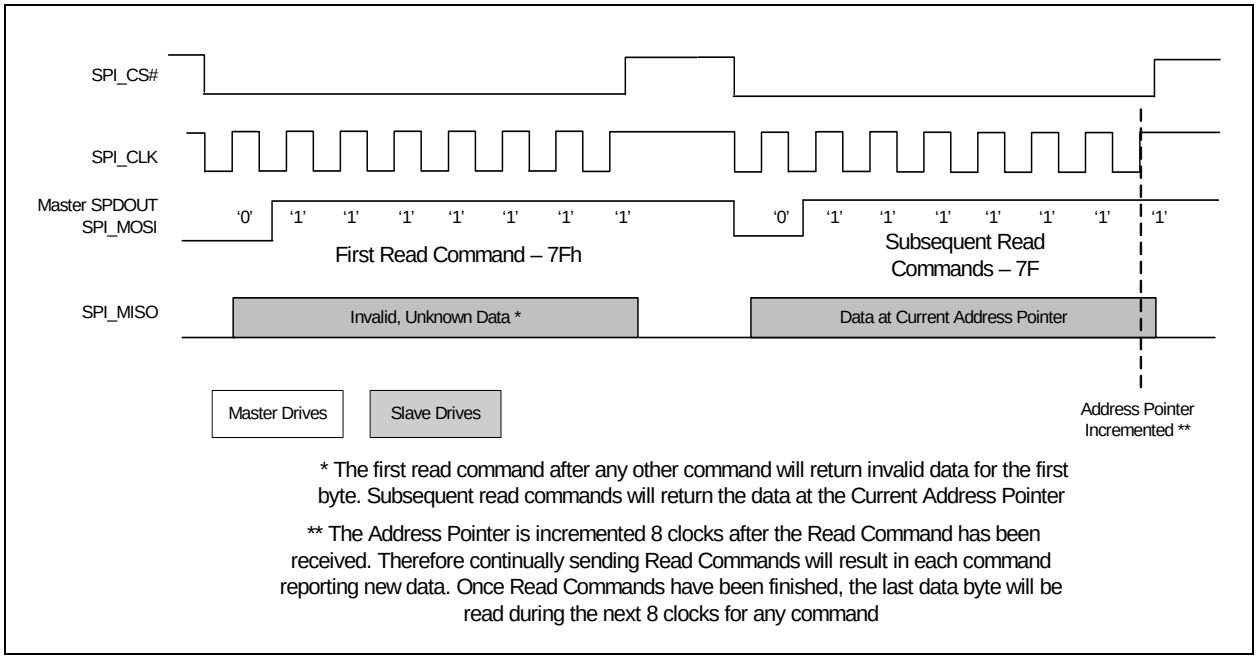
FIGURE 4-6: *SPI Write Command - Normal Mode*



4.6.4 READ DATA

The Read Data protocol is used to read data from the device. During the normal mode of operation, while the device is receiving data, the CAP1128 is simultaneously transmitting data to the host. For the Set Address commands and the Write Data commands, this data may be invalid and it is recommended that the Read Data command is used.

FIGURE 4-7: *SPI Read Command - Normal Mode*

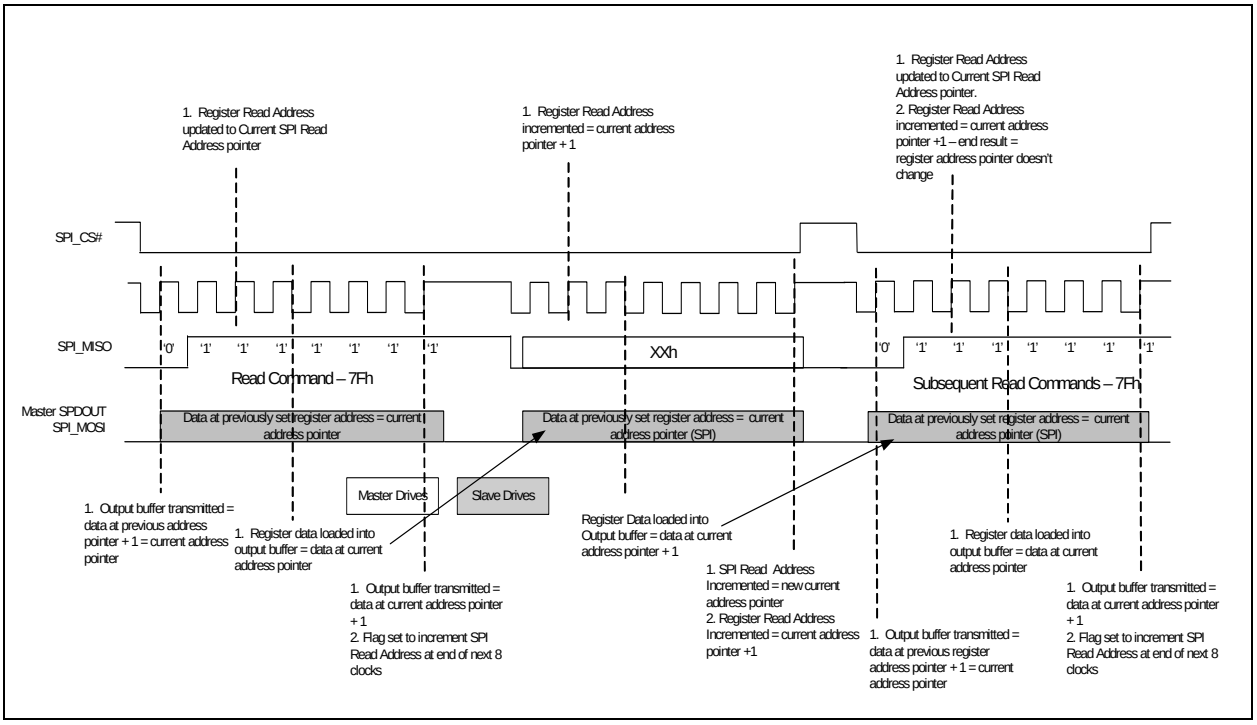


* The first read command after any other command will return invalid data for the first byte. Subsequent read commands will return the data at the Current Address Pointer

** The Address Pointer is incremented 8 clocks after the Read Command has been received. Therefore continually sending Read Commands will result in each command reporting new data. Once Read Commands have been finished, the last data byte will be read during the next 8 clocks for any command

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FIGURE 4-8: *SPI Read Command - Normal Mode - Full*

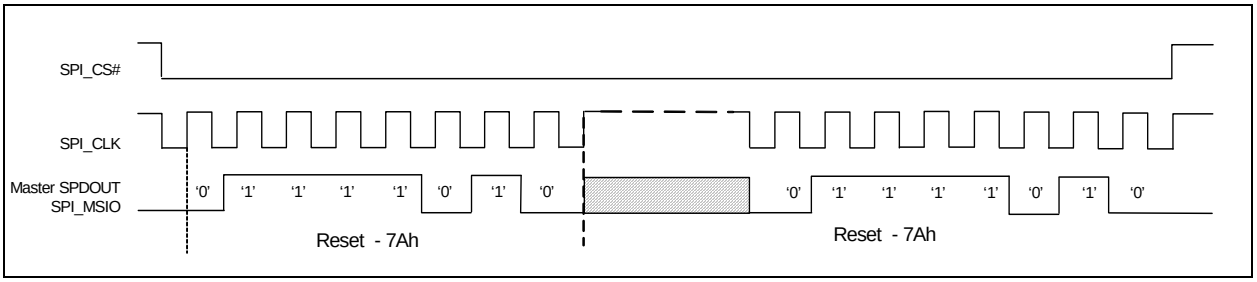


4.7 Bi-Directional SPI Protocols

4.7.1 RESET INTERFACE

Resets the Serial interface whenever two successive 7Ah codes are received. Regardless of the current phase of the transaction - command or data, the receipt of the successive reset commands resets the Serial communication interface only. All other functions are not affected by the reset operation.

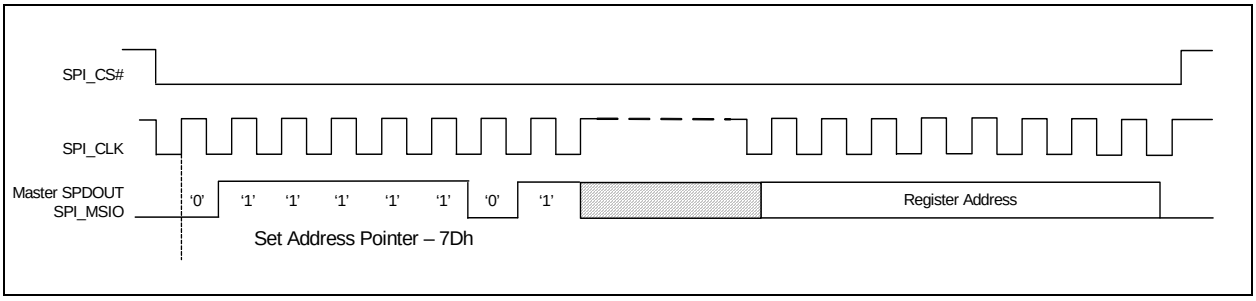
FIGURE 4-9: *SPI Reset Interface Command - Bi-directional Mode*



4.7.2 SET ADDRESS POINTER

Sets the address pointer to the register to be accessed by a read or write command. This command overrides the auto-incrementing of the address pointer.

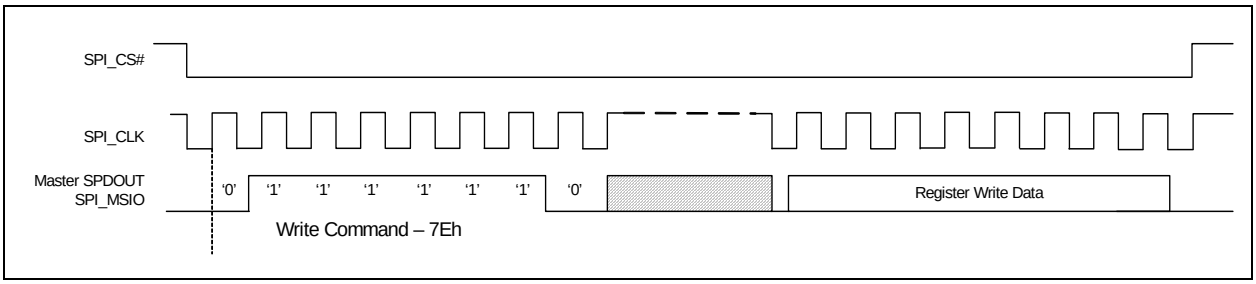
FIGURE 4-10: *SPI Set Address Pointer Command - Bi-directional Mode*



4.7.3 WRITE DATA

Writes data value to the register address stored in the address pointer. Performs auto increment of address pointer after the data is loaded into the register.

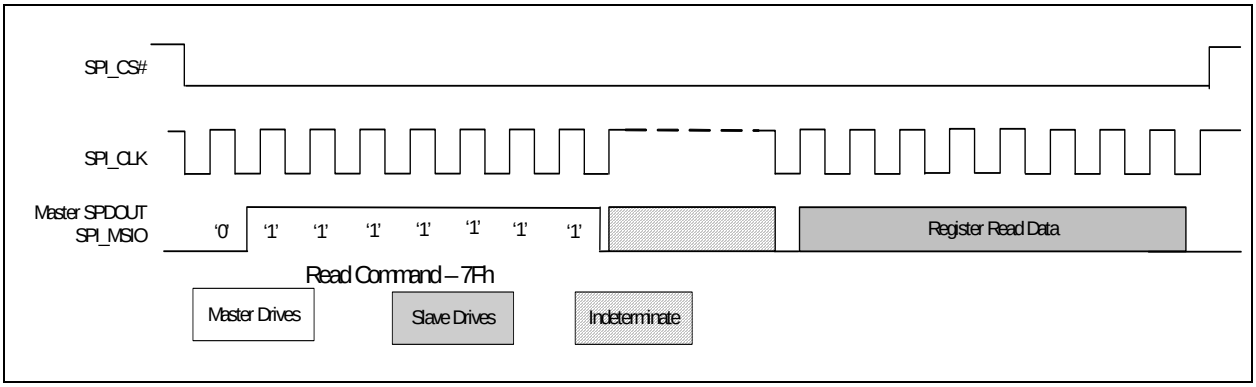
FIGURE 4-11: *SPI Write Data Command - Bi-directional Mode*



4.7.4 READ DATA

Reads data referenced by the address pointer. Performs auto increment of address pointer after the data is transferred to the Master.

FIGURE 4-12: *SPI Read Data Command - Bi-directional Mode*



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4.8 BC-Link Interface

The BC-Link is a proprietary bus developed to allow communication between a host controller device to a companion device. This device uses this serial bus to read and write registers and for interrupt processing. The interface uses a data port concept, where the base interface has an address register, data register and a control register, defined in the 8051's SFR space.

Refer to documentation for the BC-Link compatible host controller for details on how to access the CAP1128 via the BC-Link Interface.

5.0 GENERAL DESCRIPTION

The CAP1128 is a multiple channel Capacitive Touch sensor with multiple power LED drivers. It contains eight (8) individual capacitive touch sensor inputs with programmable sensitivity for use in touch sensor applications. Each sensor input automatically recalibrates to compensate for gradual environmental changes.

The CAP1128 also contains two (2) low side (or push-pull) LED drivers that offer full-on / off, variable rate blinking, dimness controls, and breathing. Each of the LED drivers may be linked to one of the sensor inputs to be actuated when a touch is detected. As well, each LED driver may be individually controlled via a host controller.

Finally, the device contains a dedicated RESET pin to act as a soft reset by the system.

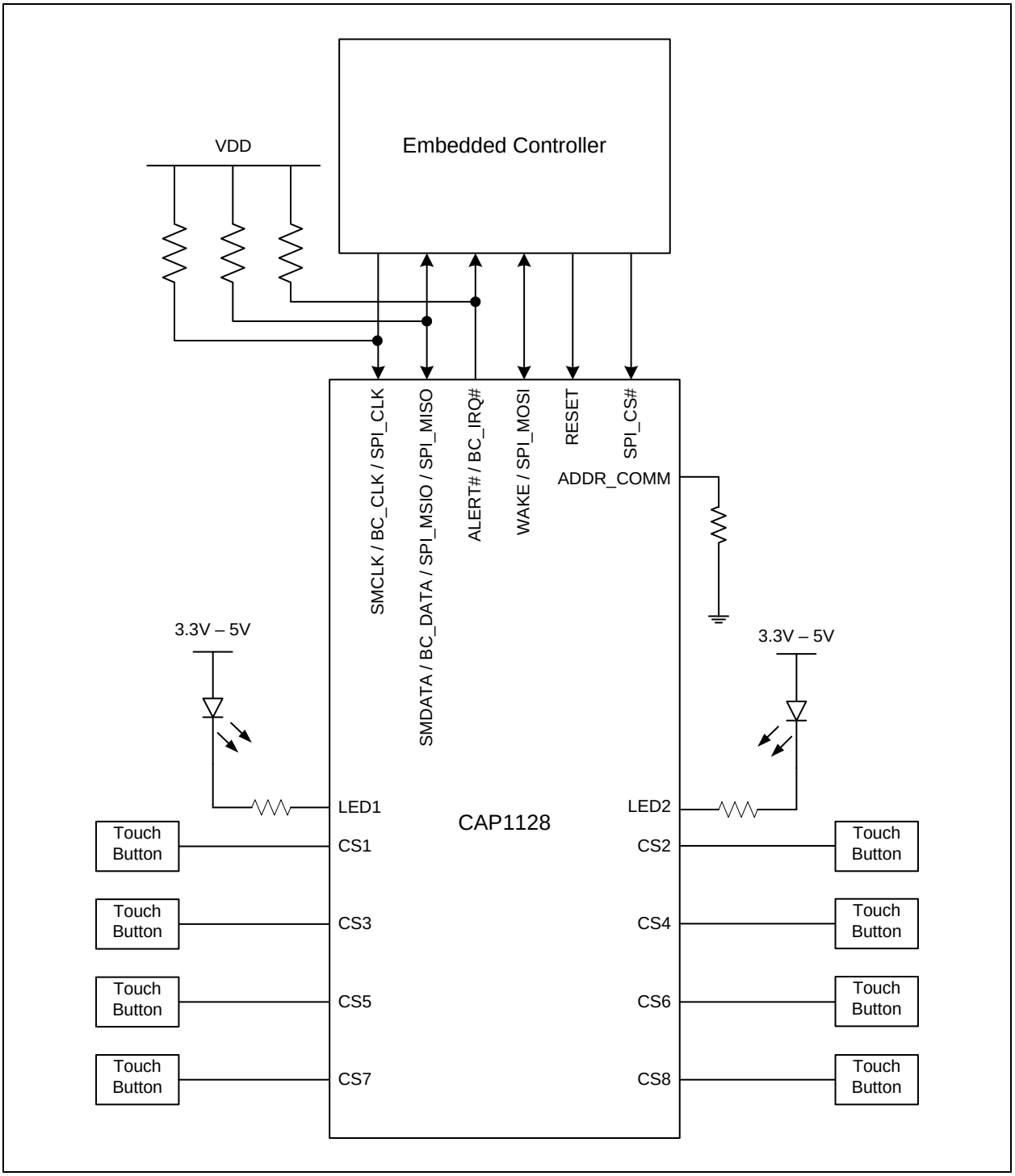
The CAP1128 offers multiple power states. It operates at the lowest quiescent current during its Deep Sleep state. In the low power Standby state, it can monitor one or more channels and respond to communications normally. The device contains a wake pin (WAKE/SPI_MOSI) output to wake the system when a touch is detected in Standby and to wake the device from Deep Sleep.

The device communicates with a host controller using the SPI bus, or via 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 5-1.

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FIGURE 5-1: *System Diagram for CAP1128*



5.1 Power States

The CAP1128 has three operating states depending on the status of the STBY and DSLEEP bits. When the device transitions between power states, previously detected touches (for inactive channels) are cleared and the status bits reset.

1. Fully Active - The device is fully active. It is monitoring all active capacitive sensor inputs and driving all LED channels as defined.
2. Standby - The device is in a lower power state. It will measure a programmable number of channels using the Standby Configuration controls (see Section 6.20 through Section 6.22). Interrupts will still be generated based on the active channels. The device will still respond to communications normally and can be returned to the Fully Active state of operation by clearing the STBY bit.
3. Deep Sleep - The device is in its lowest power state. It is not monitoring any capacitive sensor inputs and not driving any LEDs. All LEDs will be driven to their programmed non-actuated state and no PWM operations will be done. While in Deep Sleep, the device can be awakened by SMBus or SPI 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.

If the device is not communicating via the 4-wire SPI bus, then during this state of operation, if the WAKE/SPI_MOSI pin is driven high by an external source, the device will clear the DSLEEP bit and return to Fully Active.

APPLICATION NOTE: In the Deep Sleep state, the LED output will be either high or low and will not be PWM'd at the min or max duty cycle.

5.2 RESET Pin

The RESET pin is an active high reset that is driven from an external source. While it is asserted high, all the internal blocks will be held in reset including the communications protocol used. No capacitive touch sensor inputs will be sampled and the LEDs will not be driven. All configuration settings will be reset to default states and all readings will be cleared.

The device will be held in Deep Sleep that can only be removed by driving the RESET pin low. This will cause the RESET status bit to be set to a logic '1' and generate an interrupt.

5.3 WAKE/SPI_MOSI Pin Operation

The WAKE / SPI_MOSI pin is a multi-function pin depending on device operation. When the device is configured to communicate using the 4-wire SPI bus, this pin is an input.

However, when the CAP1128 is placed in Standby and is not communicating using the 4-wire SPI protocol, the WAKE pin is an active high output. In this condition, the device will assert the WAKE/SPI_MOSI pin when a touch is detected on one of its sampled sensor inputs. The pin will remain asserted until the INT bit has been cleared and then it will be de-asserted.

When the CAP1128 is placed in Deep Sleep and it is not communicating using the 4-wire SPI protocol, the WAKE/SPI_-MOSI pin is monitored by the device as an input. If the WAKE/SPI_MOSI pin is driven high by an external source, the CAP1128will clear the DSLEEP bit causing the device to return to Fully Active.

When the device is placed in Deep Sleep, this pin is a High-Z input and must have a pull-down resistor to GND for proper operation.

5.4 LED Drivers

The CAP1128 contains two (2) LED drivers. Each LED driver can be linked to its respective capacitive touch sensor input or it can be controlled by the host. Each LED driver can be configured to operate in one of the following modes with either push-pull or open drain drive.

1. Direct - The LED is configured to be on or off when the corresponding input stimulus is on or off (or inverted). The brightness of the LED can be programmed from full off to full on (default). Additionally, the LED contains controls to individually configure ramping on, off, and turn-off delay.
2. Pulse 1 - The LED is configured to "Pulse" (transition ON-OFF-ON) a programmable number of times with programmable rate and min / max brightness. This behavior may be actuated when a press is detected or when a release is detected.
3. Pulse 2 - The LED is configured to "Pulse" while actuated and then "Pulse" a programmable number of times with programmable rate and min / max brightness when the sensor pad is released.

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4. Breathe - The LED is configured to transition continuously ON-OFF-ON (i.e. to “Breathe”) with a programmable rate and min / max brightness.

When an LED is not linked to a sensor and is actuated by the host, there’s an option to assert the ALERT# pin when the initiated LED behavior has completed.

5.4.1 LINKING LEDS TO CAPACITIVE TOUCH SENSOR INPUTS

All LEDs can be linked to the corresponding capacitive touch sensor input so that when the sensor input detects a touch, the corresponding LED will be actuated at one of the programmed responses.

5.5 Capacitive Touch Sensing

The CAP1128 contains eight (8) 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 re-calibrated.

5.5.1 SENSING CYCLE

Each capacitive touch sensor input has controls to be activated and included in the sensing cycle. When the device is active, it automatically initiates a sensing cycle and repeats the cycle every time it finishes. The cycle polls through each active sensor input starting with CS1 and extending through CS8. 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, a touch is detected and an interrupt is generated.

The sensing cycle time is programmable (see Section 6.10, "Averaging and Sampling Configuration Register").

5.5.2 RECALIBRATING SENSOR INPUTS

There are various options for recalibrating the capacitive touch sensor inputs. Recalibration re-sets the Base Count Registers (Section 6.24, "Sensor Input Base Count Registers") which contain the “not touched” values used for touch detection comparisons.

APPLICATION NOTE: The device will recalibrate all sensor inputs that were disabled when it transitions from Standby. Likewise, the device will recalibrate all sensor inputs when waking out of Deep Sleep.

5.5.2.1 Manual Recalibration

The Calibration Activate Registers (Section 6.11, "Calibration Activate Register") force recalibration of selected sensor inputs. When a bit is set, the corresponding capacitive touch sensor input will be recalibrated (both analog and digital). The bit is automatically cleared once the recalibration routine has finished.

Note:	During this recalibration 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 recalibration.

5.5.2.2 Automatic Recalibration

Each sensor input is regularly recalibrated at a programmable rate (see Section 6.17, "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.

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

5.5.2.3 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, an accidental recalibration during a touch, or other environmental changes. When this occurs, the base untouched sensor input may generate negative delta count values. The NEG_DELTA_CNT bits (see Section 6.17, "Recalibration Configuration Register") can be set to force a recalibration after a specified number of consecutive negative delta readings.

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

5.5.2.4 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 6.6, "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 bits (see Section 6.8, "Sensor Input Configuration Register").

Note:	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 setting.

5.5.3 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). When a sensor input is selected to perform proximity detection, it will be sampled from 1x to 128x per sampling cycle. The larger the number of samples that are taken, the greater the range of proximity detection is available at the cost of an increased overall sampling time.

5.5.4 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 6.15, "Multiple Touch Pattern Configuration Register").

5.5.5 LOW FREQUENCY NOISE DETECTION

Each sensor input has an EMI noise detector that will sense if low frequency noise is injected onto the input with sufficient power to corrupt the readings. If this occurs, the device will reject the corrupted sample and set the corresponding bit in the Noise Status register to a logic ‘1’.

5.5.6 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. If RF noise is detected on a CS line, that sample is removed and not compared against the threshold.

5.6 ALERT# Pin

The ALERT# pin is an active low (or active high when configured) output that is driven when an interrupt event is detected.

Whenever an interrupt is generated, the INT bit (see Section 6.1, "Main Control Register") is set. The ALERT# pin is cleared when the INT bit is cleared by the user. Additionally, when the INT bit is cleared by the user, status bits are only cleared if no touch is detected.

5.6.1 SENSOR INTERRUPT BEHAVIOR

The sensor 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 Section 6.6). See Figure 5-3.
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 5-2).

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When the repeat rate is enabled, the device uses an additional control called MPRESS that determines whether a touch is flagged as a simple “touch” or a “press and hold”. 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 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 and upon release (if enabled).

APPLICATION NOTE: Figure 5-2 and Figure 5-3 show default operation which is to generate an interrupt upon sensor pad release and an active-low ALERT# pin.

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

FIGURE 5-2: *Sensor Interrupt Behavior - Repeat Rate Enabled*

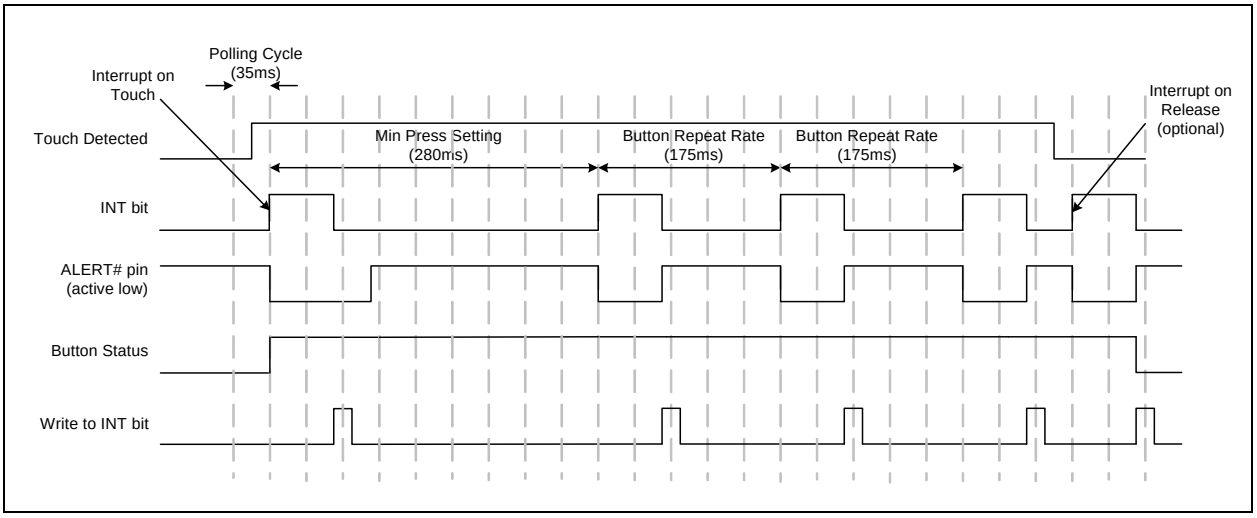
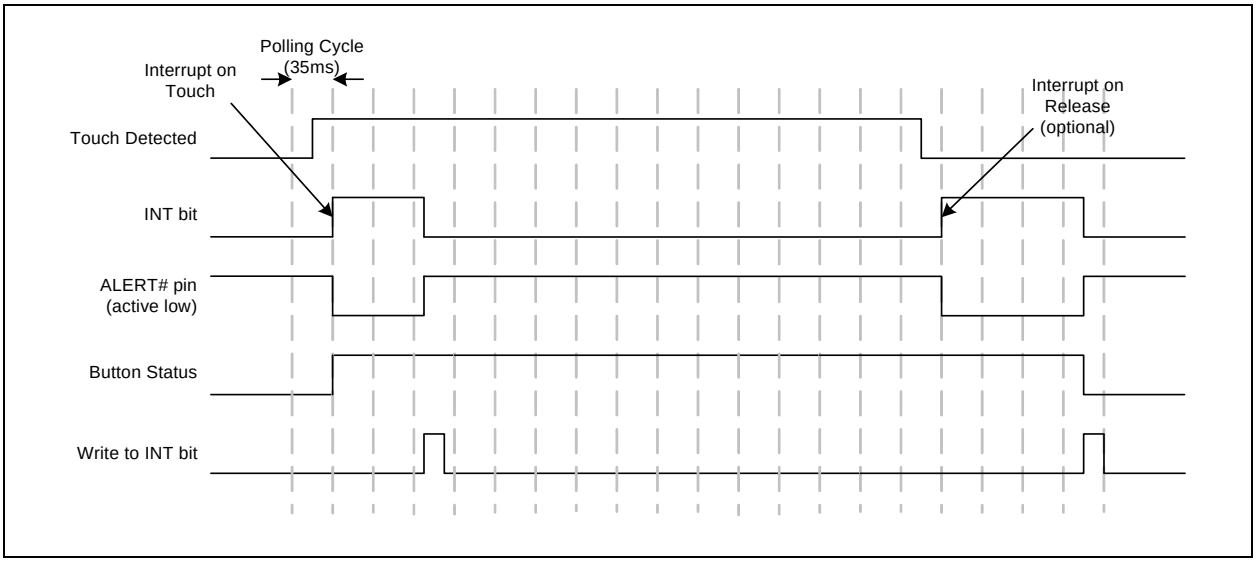


FIGURE 5-3: *Sensor Interrupt Behavior - No Repeat Rate Enabled*



6.0 REGISTER DESCRIPTION

The registers shown in Table 6-1 are accessible through the communications protocol. An entry of '-' indicates that the bit is not used and will always read '0'.

TABLE 6-1: REGISTER SET IN HEXADECIMAL ORDER

Register Address	R/W	Register Name	Function	Default Value	Page
00h	R/W	Main Control	Controls general power states and power dissipation	00h	Page 31
02h	R	General Status	Stores general status bits	00h	Page 32
03h	R	Sensor Input Status	Returns the state of the sampled capacitive touch sensor inputs	00h	Page 32
04h	R	LED Status	Stores status bits for LEDs	00h	Page 32
0Ah	R	Noise Flag Status	Stores the noise flags for sensor inputs	00h	Page 33
10h	R	Sensor Input 1 Delta Count	Stores the delta count for CS1	00h	Page 34
11h	R	Sensor Input 2 Delta Count	Stores the delta count for CS2	00h	Page 34
12h	R	Sensor Input 3 Delta Count	Stores the delta count for CS3	00h	Page 34
13h	R	Sensor Input 4 Delta Count	Stores the delta count for CS4	00h	Page 34
14h	R	Sensor Input 5 Delta Count	Stores the delta count for CS5	00h	Page 34
15h	R	Sensor Input 6 Delta Count	Stores the delta count for CS6	00h	Page 34
16h	R	Sensor Input 7 Delta Count	Stores the delta count for CS7	00h	Page 34
17h	R	Sensor Input 8 Delta Count	Stores the delta count for CS8	00h	Page 34
1Fh	R/W	Sensitivity Control	Controls the sensitivity of the threshold and delta counts and data scaling of the base counts	2Fh	Page 34
20h	R/W	Configuration	Controls general functionality	20h	Page 36
21h	R/W	Sensor Input Enable	Controls whether the capacitive touch sensor inputs are sampled	FFh	Page 37
22h	R/W	Sensor Input Configuration	Controls max duration and auto-repeat delay for sensor inputs operating in the full power state	A4h	Page 38
23h	R/W	Sensor Input Configuration 2	Controls the MPRESS controls for all sensor inputs	07h	Page 39
24h	R/W	Averaging and Sampling Config	Controls averaging and sampling window	39h	Page 39
26h	R/W	Calibration Activate	Forces re-calibration for capacitive touch sensor inputs	00h	Page 41
27h	R/W	Interrupt Enable	Enables Interrupts associated with capacitive touch sensor inputs	FFh	Page 41
28h	R/W	Repeat Rate Enable	Enables repeat rate for all sensor inputs	FFh	Page 42
2Ah	R/W	Multiple Touch Configuration	Determines the number of simultaneous touches to flag a multiple touch condition	80h	Page 42

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TABLE 6-1: REGISTER SET IN HEXADECIMAL ORDER (CONTINUED)

Register Address	R/W	Register Name	Function	Default Value	Page
2Bh	R/W	Multiple Touch Pattern Configuration	Determines the multiple touch pattern (MTP) configuration	00h	Page 43
2Dh	R/W	Multiple Touch Pattern	Determines the pattern or number of sensor inputs used by the MTP circuitry	FFh	Page 44
2Fh	R/W	Recalibration Configuration	Determines re-calibration timing and sampling window	8Ah	Page 44
30h	R/W	Sensor Input 1 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 1	40h	Page 46
31h	R/W	Sensor Input 2 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 2	40h	Page 46
32h	R/W	Sensor Input 3 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 3	40h	Page 46
33h	R/W	Sensor Input 4 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 4	40h	Page 46
34h	R/W	Sensor Input 5 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 5	40h	Page 46
35h	R/W	Sensor Input 6 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 6	40h	Page 46
36h	R/W	Sensor Input 7 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 7	40h	Page 46
37h	R/W	Sensor Input 8 Threshold	Stores the delta count threshold to determine a touch for Capacitive Touch Sensor Input 8	40h	
38h	R/W	Sensor Input Noise Threshold	Stores controls for selecting the noise threshold for all sensor inputs	01h	Page 46
Standby Configuration Registers					
40h	R/W	Standby Channel	Controls which sensor inputs are enabled while in standby	00h	Page 47
41h	R/W	Standby Configuration	Controls averaging and cycle time while in standby	39h	Page 47
42h	R/W	Standby Sensitivity	Controls sensitivity settings used while in standby	02h	Page 48
43h	R/W	Standby Threshold	Stores the touch detection threshold for active sensor inputs in standby	40h	Page 49
44h	R/W	Configuration 2	Stores additional configuration controls for the device	40h	Page 36
Base Count Registers					
50h	R	Sensor Input 1 Base Count	Stores the reference count value for sensor input 1	C8h	Page 49
51h	R	Sensor Input 2 Base Count	Stores the reference count value for sensor input 2	C8h	Page 49

TABLE 6-1: REGISTER SET IN HEXADECIMAL ORDER (CONTINUED)

Register Address	R/W	Register Name	Function	Default Value	Page
52h	R	Sensor Input 3 Base Count	Stores the reference count value for sensor input 3	C8h	Page 49
53h	R	Sensor Input 4 Base Count	Stores the reference count value for sensor input 4	C8h	Page 49
54h	R	Sensor Input 5 Base Count	Stores the reference count value for sensor input 5	C8h	Page 49
55h	R	Sensor Input 6 Base Count	Stores the reference count value for sensor input 6	C8h	Page 49
56h	R	Sensor Input 7 Base Count	Stores the reference count value for sensor input 7	C8h	Page 49
57h	R	Sensor Input 8 Base Count	Stores the reference count value for sensor input 8	C8h	Page 49
LED Controls					
71h	R/W	LED Output Type	Controls the output type for the LED outputs	00h	Page 50
72h	R/W	Sensor Input LED Linking	Controls linking of sensor inputs to LED channels	00h	Page 50
73h	R/W	LED Polarity	Controls the output polarity of LEDs	00h	Page 50
74h	R/W	LED Output Control	Controls the output state of the LEDs	00h	Page 51
77h	R/W	Linked LED Transition Control	Controls the transition when LEDs are linked to CS channels	00h	Page 52
79h	R/W	LED Mirror Control	Controls the mirroring of duty cycles for the LEDs	00h	Page 53
81h	R/W	LED Behavior 1	Controls the behavior and response of LEDs 1 - 2	00h	Page 53
84h	R/W	LED Pulse 1 Period	Controls the period of each breathe during a pulse	20h	Page 55
85h	R/W	LED Pulse 2 Period	Controls the period of the breathing during breathe and pulse operation	14h	Page 56
86h	R/W	LED Breathe Period	Controls the period of an LED breathe operation	5Dh	Page 57
88h	R/W	LED Config	Controls LED configuration	04h	Page 58
90h	R/W	LED Pulse 1 Duty Cycle	Determines the min and max duty cycle for the pulse operation	F0h	Page 58
91h	R/W	LED Pulse 2 Duty Cycle	Determines the min and max duty cycle for breathe and pulse operation	F0h	Page 58
92h	R/W	LED Breathe Duty Cycle	Determines the min and max duty cycle for the breathe operation	F0h	Page 58
93h	R/W	LED Direct Duty Cycle	Determines the min and max duty cycle for Direct mode LED operation	F0h	Page 58
94h	R/W	LED Direct Ramp Rates	Determines the rising and falling edge ramp rates of the LEDs	00h	Page 59
95h	R/W	LED Off Delay	Determines the off delay for all LED behaviors	00h	Page 60
B1h	R	Sensor Input 1 Calibration	Stores the upper 8-bit calibration value for sensor input 1	00h	Page 63
B2h	R	Sensor Input 2 Calibration	Stores the upper 8-bit calibration value for sensor input 2	00h	Page 63

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TABLE 6-1: REGISTER SET IN HEXADECIMAL ORDER (CONTINUED)

Register Address	R/W	Register Name	Function	Default Value	Page
B3h	R	Sensor Input 3 Calibration	Stores the upper 8-bit calibration value for sensor input 3	00h	Page 63
B4h	R	Sensor Input 4 Calibration	Stores the upper 8-bit calibration value for sensor input 4	00h	Page 63
B5h	R	Sensor Input 5 Calibration	Stores the upper 8-bit calibration value for sensor input 5	00h	Page 63
B6h	R	Sensor Input 6 Calibration	Stores the upper 8-bit calibration value for sensor input 6	00h	Page 63
B7h	R	Sensor Input 7 Calibration	Stores the upper 8-bit calibration value for sensor input 7	00h	Page 63
B8h	R	Sensor Input 8 Calibration	Stores the upper 8-bit calibration value for sensor input 8	00h	Page 63
B9h	R	Sensor Input Calibration LSB 1	Stores the 2 LSBs of the calibration value for sensor inputs 1 - 4	00h	Page 63
BAh	R	Sensor Input Calibration LSB 2	Stores the 2 LSBs of the calibration value for sensor inputs 5 - 8	00h	Page 63
FDh	R	Product ID	Stores a fixed value that identifies each product	52h	Page 63
FEh	R	Manufacturer ID	Stores a fixed value that identifies Microchip	5Dh	Page 64
FFh	R	Revision	Stores a fixed value that represents the revision number	83h	Page 64

During Power-On-Reset (POR), the default values are stored in the registers. A POR is initiated when power is first applied to the part and the voltage on the VDD supply surpasses the POR level as specified in the electrical characteristics. Any reads to undefined registers will return 00h. Writes to undefined registers will not have an effect.

When a bit is “set”, this means that the user writes a logic ‘1’ to it. When a bit is “cleared”, this means that the user writes a logic ‘0’ to it.

6.1 Main Control Register

TABLE 6-2: MAIN CONTROL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
00h	R/W	Main Control	GAIN[1:0]		STBY	DSLEEP	-	-	-	INT	00h

The Main Control register controls the primary power state of the device.

Bits 7 - 6 - GAIN[1:0] - Controls the gain used by the capacitive touch sensing circuitry. As the gain is increased, the effective sensitivity is likewise increased as a smaller delta capacitance is required to generate the same delta count values. The sensitivity settings may need to be adjusted along with the gain settings such that data overflow does not occur.

APPLICATION NOTE: The gain settings apply to both Standby and Active states.

TABLE 6-3: GAIN BIT DECODE

GAIN[1:0]		Capacitive Touch Sensor Gain
1	0	
0	0	1
0	1	2

TABLE 6-3: GAIN BIT DECODE (CONTINUED)

GAIN[1:0]		Capacitive Touch Sensor Gain
1	**0**	
1	0	4
1	1	8

Bit 5 - STBY - Enables Standby.

- '0' (default) - Sensor input scanning is active and LEDs are functional.
- '1' - Capacitive touch sensor input scanning is limited to the sensor inputs set in the Standby Channel register (see Section 6.20). The status registers will not be cleared until read. LEDs that are linked to capacitive touch sensor inputs will remain linked and active. Sensor inputs that are no longer sampled will flag a release and then remain in a non-touched state. LEDs that are manually controlled will be unaffected.
- Bit 4 - DSLEEP - Enables Deep Sleep by deactivating all functions. This bit will be cleared when the WAKE pin is driven high. '0' (default) - Sensor input scanning is active and LEDs are functional.
- '1' - All sensor input scanning is disabled. All LEDs are driven to their programmed non-actuated state and no PWM operations will be done. The status registers are automatically cleared and the INT bit is cleared.

Bit 0 - INT - Indicates that there is an interrupt. When this bit is set, it asserts the ALERT# pin. If a channel detects a touch and its associated interrupt enable bit is not set to a logic '1', no action is taken.

This bit is cleared by writing a logic '0' to it. When this bit is cleared, the ALERT# pin will be deasserted and all status registers will be cleared if the condition has been removed. If the WAKE/SPI_MOSI pin is asserted as a result of a touch detected while in Standby, it will likewise be deasserted when this bit is cleared.

Note that the WAKE / SPI_MOSI pin is not driven when communicating via the 4-wire SPI protocol.

- '0' - No interrupt pending.
- '1' - A touch has been detected on one or more channels and the interrupt has been asserted.

6.2 Status Registers

TABLE 6-4: STATUS REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
02h	R	General Status	-	-	-	LED	RESET	MULT	MTP	TOUCH	00h
03h	R	Sensor Input Status	CS8	CS7	CS6	CS5	CS4	CS3	CS2	CS1	00h
04h	R	LED Status	-	-	-	-	-	-	LED2_DN	LED1_DN	00h

All status bits are cleared when the device enters the Deep Sleep (DSLEEP = '1' - see Section 6.1).

6.2.1 GENERAL STATUS - 02H

Bit 4 - LED - Indicates that one or more LEDs have finished their programmed activity. This bit is set if any bit in the LED Status register is set.

Bit 3 - RESET - Indicates that the device has come out of reset. This bit is set when the device exits a POR state or when the RESET pin has been deasserted and qualified via the RESET pin filter (see Section 5.2). This bit will cause the INT bit to be set and is cleared when the INT bit is cleared.

Bit 2 - MULT - Indicates that the device is blocking detected touches due to the Multiple Touch detection circuitry (see Section 6.14). This bit will not cause the INT bit to be set and hence will not cause an interrupt.

Bit 1 - MTP - Indicates that the device has detected a number of sensor inputs that exceed the MTP threshold either via the pattern recognition or via the number of sensor inputs (see Section 6.15). This bit will cause the INT bit to be set if the MTP_ALERT bit is also set. This bit will not be cleared until the condition that caused it to be set has been removed.

Bit 0 - TOUCH - Indicates that a touch was detected. This bit is set if any bit in the Sensor Input Status register is set.

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6.2.2 SENSOR INPUT STATUS - 03H

The Sensor Input Status Register stores status bits that indicate a touch has been detected. A value of '0' in any bit indicates that no touch has been detected. A value of '1' in any bit indicates that a touch has been detected.

All bits are cleared when the INT bit is cleared and if a touch on the respective capacitive touch sensor input is no longer present. If a touch is still detected, the bits will not be cleared (but this will not cause the interrupt to be asserted - see Section 6.6).

Bit 7 - CS8 - Indicates that a touch was detected on Sensor Input 8.

Bit 6 - CS7 - Indicates that a touch was detected on Sensor Input 7.

Bit 5 - CS6 - Indicates that a touch was detected on Sensor Input 6.

Bit 4 - CS5 - Indicates that a touch was detected on Sensor Input 5.

Bit 3 - CS4 - Indicates that a touch was detected on Sensor Input 4.

Bit 2 - CS3 - Indicates that a touch was detected on Sensor Input 3.

Bit 1 - CS2 - Indicates that a touch was detected on Sensor Input 2. This sensor input can be linked to LED2.

Bit 0 - CS1 - Indicates that a touch was detected on Sensor Input 1. This sensor input can be linked to LED1.

6.2.3 LED STATUS - 04H

The LED Status Registers indicate when an LED has completed its configured behavior (see Section 6.31, "LED Behavior Register") after being actuated by the host (see Section 6.28, "LED Output Control Register"). These bits are ignored when the LED is linked to a capacitive sensor input. All LED Status bits are cleared when the INT bit is cleared.

Bit 1 - LED2_DN - Indicates that LED2 has finished its behavior after being actuated by the host.

Bit 0 - LED1_DN - Indicates that LED1 has finished its behavior after being actuated by the host.

6.3 Noise Flag Status Registers

TABLE 6-5: NOISE FLAG STATUS REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
0Ah	R	Noise Flag Status	CS8_ NOISE	CS7_ NOISE	CS6_ NOISE	CS5_ NOISE	CS4_ NOISE	CS3_ NOISE	CS2_ NOISE	CS1_ NOISE	00h

The Noise Flag Status registers store status bits that are generated from the analog block if the detected noise is above the operating region of the analog detector or the RF noise detector. These bits indicate that the most recently received data from the sensor input is invalid and should not be used for touch detection. So long as the bit is set for a particular channel, the delta count value is reset to 00h and thus no touch is detected.

These bits are not sticky and will be cleared automatically if the analog block does not report a noise error.

APPLICATION NOTE: If the MTP detection circuitry is enabled, these bits count as sensor inputs above the MTP threshold (see Section 5.5.4, "Multiple Touch Pattern Detection") even if the corresponding delta count is not. If the corresponding delta count also exceeds the MTP threshold, it is not counted twice.

APPLICATION NOTE: Regardless of the state of the Noise Status bits, if low frequency noise is detected on a sensor input, that sample will be discarded unless the DIS_ANA_NOISE bit is set. As well, if RF noise is detected on a sensor input, that sample will be discarded unless the DIS_RF_NOISE bit is set.

6.4 Sensor Input Delta Count Registers

TABLE 6-6: SENSOR INPUT DELTA COUNT REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
10h	R	Sensor Input 1 Delta Count	Sign	64	32	16	8	4	2	1	00h
11h	R	Sensor Input 2 Delta Count	Sign	64	32	16	8	4	2	1	00h
12h	R	Sensor Input 3 Delta Count	Sign	64	32	16	8	4	2	1	00h
13h	R	Sensor Input 4 Delta Count	Sign	64	32	16	8	4	2	1	00h
14h	R	Sensor Input 5 Delta Count	Sign	64	32	16	8	4	2	1	00h
15h	R	Sensor Input 6 Delta Count	Sign	64	32	16	8	4	2	1	00h
16h	R	Sensor Input 7 Delta Count	Sign	64	32	16	8	4	2	1	00h
17h	R	Sensor Input 8 Delta Count	Sign	64	32	16	8	4	2	1	00h

The Sensor Input Delta Count registers store the delta count that is compared against the threshold used to determine if a touch has been detected. The count value represents a change in input due to the capacitance associated with a touch on one of the sensor inputs and is referenced to a calibrated base “Not Touched” count value. The delta is an instantaneous change and is updated once per sensor input per sensing cycle (see Section 5.5.1, "Sensing Cycle").

The value presented is a standard 2’s complement number. In addition, the value is capped at a value of 7Fh. A reading of 7Fh indicates that the sensitivity settings are too high and should be adjusted accordingly (see Section 6.5).

The value is also capped at a negative value of 80h for negative delta counts which may result upon a release.

6.5 Sensitivity Control Register

TABLE 6-7: SENSITIVITY CONTROL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
1Fh	R/W	Sensitivity Control	-	DELTA_SENSE[2:0]			BASE_SHIFT[3:0]				2Fh

The Sensitivity Control register controls the sensitivity of a touch detection.

Bits 6-4 DELTA_SENSE[2:0] - Controls the sensitivity of a touch detection. The sensitivity settings act to scale the relative delta count value higher or lower based on the system parameters. A setting of 000b is the most sensitive while a setting of 111b is the least sensitive. At the more sensitive settings, touches are detected for a smaller delta capacitance corresponding to a “lighter” touch. These settings are more sensitive to noise, however, and a noisy environment may flag more false touches with higher sensitivity levels.

APPLICATION NOTE: A value of 128x is the most sensitive setting available. At the most sensitivity settings, the MSB of the Delta Count register represents 64 out of ~25,000 which corresponds to a touch of approximately 0.25% of the base capacitance (or a ΔC of 25fF from a 10pF base capacitance). Conversely, a value of 1x is the least sensitive setting available. At these settings, the MSB of the Delta Count register corresponds to a delta count of 8192 counts out of ~25,000 which corresponds to a touch of approximately 33% of the base capacitance (or a ΔC of 3.33pF from a 10pF base capacitance).

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TABLE 6-8: DELTA_SENSE BIT DECODE

DELTA_SENSE[2:0]			Sensitivity Multiplier
2	**1**	**0**	
0	0	0	128x (most sensitive)
0	0	1	64x
0	1	0	32x (default)
0	1	1	16x
1	0	0	8x
1	0	1	4x
1	1	0	2x
1	1	1	1x - (least sensitive)

Bits 3 - 0 - BASE_SHIFT[3:0] - Controls the scaling and data presentation of the Base Count registers. The higher the value of these bits, the larger the range and the lower the resolution of the data presented. The scale factor represents the multiplier to the bit-weighting presented in these register descriptions.

APPLICATION NOTE: The BASE_SHIFT[3:0] bits normally do not need to be updated. These settings will not affect touch detection or sensitivity. These bits are sometimes helpful in analyzing the Cap Sensing board performance and stability.

TABLE 6-9: BASE_SHIFT BIT DECODE

BASE_SHIFT[3:0]				Data Scaling Factor
3	**2**	**1**	**0**	
0	0	0	0	1x
0	0	0	1	2x
0	0	1	0	4x
0	0	1	1	8x
0	1	0	0	16x
0	1	0	1	32x
0	1	1	0	64x
0	1	1	1	128x
1	0	0	0	256x
All others				256x (default = 1111b)

6.6 Configuration Registers

TABLE 6-10: CONFIGURATION REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
20h	R/W	Configuration	TIMEOUT	WAKE_ CFG	DIS_ DIG_ NOISE	DIS_ ANA_ NOISE	MAX_ DUR_EN	-	-	-	A0h (Rev B) 20h (rev C)
44h	R/W	Configuration 2	INV_LINK_ TRAN	ALT_ POL	BLK_PWR_ CTRL	BLK_POL_ MIR	SHOW_ RF_ NOISE	DIS_ RF_ NOISE	-	INT_ REL_n	40h

The Configuration registers control general global functionality that affects the entire device.

6.6.1 CONFIGURATION - 20H

Bit 7 - TIMEOUT - Enables the timeout and idle functionality of the SMBus protocol.

- '0' (default for Functional Revision C) - The SMBus timeout and idle functionality are disabled. The SMBus interface will not time out if the clock line is held low. Likewise, it will not reset if both the data and clock lines are held high for longer than 200us. This is used for I^2C compliance.
- '1' (default for Functional Revision B) - The SMBus timeout and idle functionality are enabled. The SMBus interface will time out if the clock line is held low for longer than 30ms. Likewise, it will reset if both the data and clock lines are held high for longer than 200us.

Bit 6 - WAKE_CFG - Configures the operation of the WAKE pin.

- '0' (default) - The WAKE pin is not asserted when a touch is detected while the device is in Standby. It will still be used to wake the device from Deep Sleep when driven high.
- '1' - The WAKE pin will be asserted high when a touch is detected while the device is in Standby. It will also be used to wake the device from Deep Sleep when driven high.

Bit 5 - DIS_DIG_NOISE - Determines whether the digital noise threshold (see Section 6.19, "Sensor Input Noise Threshold Register") is used by the device. Setting this bit disables the feature.

- '0' - The digital noise threshold is used. If a delta count value exceeds the noise threshold but does not exceed the touch threshold, the sample is discarded and not used for the automatic re-calibration routine.
- '1' (default) - The noise threshold is disabled. Any delta count that is less than the touch threshold is used for the automatic re-calibration routine.

Bit 4 - DIS_ANA_NOISE - Determines whether the analog noise filter is enabled. Setting this bit disables the feature.

- '0' (default) - If low frequency noise is detected by the analog block, the delta count on the corresponding channel is set to 0. Note that this does not require that Noise Status bits be set.
- '1' - A touch is not blocked even if low frequency noise is detected.

Bit 3 - MAX_DUR_EN - Determines whether the maximum duration recalibration is enabled.

- '0' (default) - The maximum duration recalibration functionality is disabled. A touch may be held indefinitely and no re-calibration will be performed on any sensor input.
- '1' - The maximum duration recalibration functionality is enabled. If a touch is held for longer than the MAX_DUR bit settings, then the re-calibration routine will be restarted (see Section 6.8).

6.6.2 CONFIGURATION 2 - 44H

Bit 7 - INV_LINK_TRAN - Determines the behavior of the Linked LED Transition controls (see Section 6.29).

- '0' (default) - The Linked LED Transition controls set the min duty cycle equal to the max duty cycle.
- '1' - The Linked LED Transition controls will invert the touch signal. For example, a touch signal will be inverted to a non-touched signal.

Bit 6 - ALT_POL - Determines the ALERT# pin polarity and behavior.

- '0' - The ALERT# pin is active high and push-pull.
- '1' (default) - The ALERT# pin is active low and open drain.

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Bit 5 - BLK_PWR_CTRL - Determines whether the device will reduce power consumption while waiting between conversion time completion and the end of the polling cycle.

- '0' (default) - The device will always power down as much as possible during the time between the end of the last conversion and the end of the polling cycle.
- '1' - The device will not power down the Cap Sensor during the time between the end of the last conversion and the end of the polling cycle.

Bit 4 - BLK_POL_MIR - Determines whether the LED Mirror Control register bits are linked to the LED Polarity bits. Setting this bit blocks the normal behavior which is to automatically set and clear the LED Mirror Control bits when the LED Polarity bits are set or cleared.

- '0' (default) - When the LED Polarity controls are set, the corresponding LED Mirror control is automatically set. Likewise, when the LED Polarity controls are cleared, the corresponding LED Mirror control is also cleared.
- '1' - When the LED Polarity controls are set, the corresponding LED Mirror control is not automatically set.

Bit 3 - SHOW_RF_NOISE - Determines whether the Noise Status bits will show RF Noise as the only input source.

- '0' (default) - The Noise Status registers will show both RF noise and low frequency EMI noise if either is detected on a capacitive touch sensor input.
- '1' - The Noise Status registers will only show RF noise if it is detected on a capacitive touch sensor input. EMI noise will still be detected and touches will be blocked normally; however, the status bits will not be updated.

Bit 2 - DIS_RF_NOISE - Determines whether the RF noise filter is enabled. Setting this bit disables the feature.

- '0' (default) - If RF noise is detected by the analog block, the delta count on the corresponding channel is set to 0. Note that this does not require that Noise Status bits be set.
- '1' - A touch is not blocked even if RF noise is detected.

Bit 0 - INT_REL_n - Controls the interrupt behavior when a release is detected on a button.

- '0' (default) - An interrupt is generated when a press is detected and again when a release is detected and at the repeat rate (if enabled - see Section 6.13).
- '1' - An interrupt is generated when a press is detected and at the repeat rate but not when a release is detected.

6.7 Sensor Input Enable Registers

TABLE 6-11: SENSOR INPUT ENABLE REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
21h	R/W	Sensor Input Enable	CS8_EN	CS7_EN	CS6_EN	CS5_EN	CS4_EN	CS3_EN	CS2_EN	CS1_EN	FFh

The Sensor Input Enable registers determine whether a capacitive touch sensor input is included in the sampling cycle. The length of the sampling cycle is not affected by the number of sensor inputs measured.

Bit 7 - CS8_EN - Enables the CS8 input to be included during the sampling cycle.

- '0' - The CS8 input is not included in the sampling cycle.
- '1' (default) - The CS8 input is included in the sampling cycle.

Bit 6 - CS7_EN - Enables the CS7 input to be included during the sampling cycle.

Bit 5 - CS6_EN - Enables the CS6 input to be included during the sampling cycle.

Bit 4 - CS5_EN - Enables the CS5 input to be included during the sampling cycle.

Bit 3 - CS4_EN - Enables the CS4 input to be included during the sampling cycle.

Bit 2 - CS3_EN - Enables the CS3 input to be included during the sampling cycle.

Bit 1 - CS2_EN - Enables the CS2 input to be included during the sampling cycle.

Bit 0 - CS1_EN - Enables the CS1 input to be included during the sampling cycle.

6.8 Sensor Input Configuration Register

TABLE 6-12: SENSOR INPUT CONFIGURATION REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
22h	R/W	Sensor Input Configuration	MAX_DUR[3:0]				RPT_RATE[3:0]				A4h

The Sensor Input Configuration Register controls timings associated with the Capacitive sensor inputs 1 - 8.

Bits 7 - 4 - MAX_DUR[3:0] - (default 1010b) - Determines the maximum time that a sensor pad is allowed to be touched until the capacitive touch sensor input is recalibrated, as shown in Table 6-13.

TABLE 6-13: MAX_DUR BIT DECODE

MAX_DUR[3:0]				Time Before Recalibration
3	2	1	0	
0	0	0	0	560ms
0	0	0	1	840ms
0	0	1	0	1120ms
0	0	1	1	1400ms
0	1	0	0	1680ms
0	1	0	1	2240ms
0	1	1	0	2800ms
	1	1	1	3360ms
1	0	0	0	3920ms
1	0	0	1	4480ms
1	0	1	0	5600ms (default)
1	0	1	1	6720ms
1	1	0	0	7840ms
1	1	0	1	8906ms
1	1	1	0	10080ms
1	1	1	1	11200ms

Bits 3 - 0 - RPT_RATE[3:0] - (default 0100b) Determines the time duration between interrupt assertions when auto repeat is enabled. The resolution is 35ms the range is from 35ms to 560ms as shown in Table 6-14.

TABLE 6-14: RPT_RATE BIT DECODE

RPT_RATE[3:0]				Interrupt Repeat RATE
3	2	1	0	
0	0	0	0	35ms
0	0	0	1	70ms
0	0	1	0	105ms
0	0	1	1	140ms
0	1	0	0	175ms (default)
0	1	0	1	210ms
0	1	1	0	245ms
0	1	1	1	280ms
1	0	0	0	315ms
1	0	0	1	350ms
1	0	1	0	385ms

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TABLE 6-14: RPT_RATE BIT DECODE (CONTINUED)

RPT_RATE[3:0]				Interrupt Repeat RATE
3	2	1	0	
1	0	1	1	420ms
1	1	0	0	455ms
1	1	0	1	490ms
1	1	1	0	525ms
1	1	1	1	560ms

6.9 Sensor Input Configuration 2 Register

TABLE 6-15: SENSOR INPUT CONFIGURATION 2 REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
23h	R/W	Sensor Input Configuration 2	-	-	-	-	M_PRESS[3:0]				07h

Bits 3 - 0 - M_PRESS[3:0] - (default 0111b) - Determines the minimum amount of time that sensor inputs configured to use auto repeat must detect a sensor pad touch to detect a “press and hold” event. If the sensor input detects a touch for longer than the M_PRESS[3:0] settings, a “press and hold” event is detected. If a sensor input detects a touch for less than or equal to the M_PRESS[3:0] settings, a touch event is detected.

The resolution is 35ms the range is from 35ms to 560ms as shown in Table 6-16.

TABLE 6-16: M_PRESS BIT DECODE

M_PRESS[3:0]				M_PRESS SETTINGS
3	2	1	0	
0	0	0	0	35ms
0	0	0	1	70ms
0	0	1	0	105ms
0	0	1	1	140ms
0	1	0	0	175ms
0	1	0	1	210ms
0	1	1	0	245ms
0	1	1	1	280ms (default)
1	0	0	0	315ms
1	0	0	1	350ms
1	0	1	0	385ms
1	0	1	1	420ms
1	1	0	0	455ms
1	1	0	1	490ms
1	1	1	0	525ms
1	1	1	1	560ms

6.10 Averaging and Sampling Configuration Register

TABLE 6-17: AVERAGING AND SAMPLING CONFIGURATION REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
24h	R/W	Averaging and Sampling Config		AVG[2:0]			SAMP_TIME[1:0]		CYCLE_TIME [1:0]		39h

The Averaging and Sampling Configuration register controls the number of samples taken and the total sensor input cycle time for all active sensor inputs while the device is functioning in Active state.

Bits 6 - 4 - AVG[2:0] - Determines the number of samples that are taken for all active channels during the sensor cycle as shown in Table 6-18. All samples are taken consecutively on the same channel before the next channel is sampled and the result is averaged over the number of samples measured before updating the measured results.

For example, if CS1, CS2, and CS3 are sampled during the sensor cycle, and the AVG[2:0] bits are set to take 4 samples per channel, then the full sensor cycle will be: CS1, CS1, CS1, CS1, CS2, CS2, CS2, CS2, CS3, CS3, CS3, CS3.

TABLE 6-18: AVG BIT DECODE

AVG[2:0]			Number of Samples Taken per Measurement
2	**1**	**0**	
0	0	0	1
0	0	1	2
0	1	0	4
0	1	1	8 (default)
1	0	0	16
1	0	1	32
1	1	0	64
1	1	1	128

Bits 3 - 2 - SAMP_TIME[1:0] - Determines the time to take a single sample as shown in Table 6-19.

TABLE 6-19: SAMP_TIME BIT DECODE

SAMP_TIME[1:0]		Sample Time
1	**0**	
0	0	320us
0	1	640us
1	0	1.28ms (default)
1	1	2.56ms

Bits 1 - 0 - CYCLE_TIME[1:0] - Determines the overall cycle time for all measured channels during normal operation as shown in Table 6-20. All measured channels are sampled at the beginning of the cycle time. If additional time is remaining, then the device is placed into a lower power state for the remaining duration of the cycle.

TABLE 6-20: CYCLE_TIME BIT DECODE

CYCLE_TIME[1:0]		Overall Cycle Time
1	**0**	
0	0	35ms
0	1	70ms (default)
1	0	105ms
1	1	140ms

APPLICATION NOTE: The programmed cycle time is only maintained if the total averaging time for all samples is less than the programmed cycle. The AVG[2:0] bits will take priority so that if more samples are required than would normally be allowed during the cycle time, the cycle time will be extended as necessary to accommodate the number of samples to be measured.

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6.11 Calibration Activate Register

TABLE 6-21: CALIBRATION ACTIVATE REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
26h	R/W	Calibration Activate	CS8_ CAL	CS7_ CAL	CS6_ CAL	CS5_ CAL	CS4_ CAL	CS3_ CAL	CS2_ CAL	CS1_ CAL	00h

The Calibration Activate register forces the respective sensor inputs to be re-calibrated affecting both the analog and digital blocks. During the re-calibration routine, the sensor inputs will not detect a press for up to 600ms and the Sensor Input Base Count register values will be invalid. During this time, any press on the corresponding sensor pads will invalidate the re-calibration. When finished, the CALX[9:0] bits will be updated (see Section 6.39).

When the corresponding bit is set, the device will perform the calibration and the bit will be automatically cleared once the re-calibration routine has finished.

Bit 7 - CS8_CAL - When set, the CS8 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 6 - CS7_CAL - When set, the CS7 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 5 - CS6_CAL - When set, the CS6 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 4 - CS5_CAL - When set, the CS5 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 3 - CS4_CAL - When set, the CS4 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 2 - CS3_CAL - When set, the CS3 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 1 - CS2_CAL - When set, the CS2 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

Bit 0 - CS1_CAL - When set, the CS1 input is re-calibrated. This bit is automatically cleared once the sensor input has been re-calibrated successfully.

6.12 Interrupt Enable Register

TABLE 6-22: INTERRUPT ENABLE REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
27h	R/W	Interrupt Enable	CS8_ INT_EN	CS7_ INT_EN	CS6_ INT_EN	CS5_ INT_EN	CS4_ INT_EN	CS3_ INT_EN	CS2_ INT_EN	CS1_ INT_EN	FFh

The Interrupt Enable register determines whether a sensor pad touch or release (if enabled) causes the interrupt pin to be asserted.

Bit 7 - CS8_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS8 (associated with the CS8 status bit).

- '0' - The interrupt pin will not be asserted if a touch is detected on CS8 (associated with the CS8 status bit).
- '1' (default) - The interrupt pin will be asserted if a touch is detected on CS8 (associated with the CS8 status bit).

Bit 6 - CS7_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS7 (associated with the CS7 status bit).

Bit 5 - CS6_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS6 (associated with the CS6 status bit).

Bit 4 - CS5_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS5 (associated with the CS5 status bit).

Bit 3 - CS4_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS4 (associated with the CS4 status bit).

Bit 2 - CS3_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS3 (associated with the CS3 status bit).

Bit 1 - CS2_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS2 (associated with the CS2 status bit).

Bit 0 - CS1_INT_EN - Enables the interrupt pin to be asserted if a touch is detected on CS1 (associated with the CS1 status bit).

6.13 Repeat Rate Enable Register

TABLE 6-23: REPEAT RATE ENABLE REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
28h	R/W	Repeat Rate Enable	CS8_ RPT_EN	CS7_ RPT_EN	CS6_ RPT_EN	CS5_ RPT_EN	CS4_ RPT_EN	CS3_ RPT_EN	CS2_ RPT_EN	CS1_ RPT_EN	FFh

The Repeat Rate Enable register enables the repeat rate of the sensor inputs as described in Section 5.6.1.

Bit 7 - CS8_RPT_EN - Enables the repeat rate for capacitive touch sensor input 8.

- '0' - The repeat rate for CS8 is disabled. It will only generate an interrupt when a touch is detected and when a release is detected (if enabled) no matter how long the touch is held for.
- '1' (default) - The repeat rate for CS8 is enabled. In the case of a "touch" event, it will generate an interrupt when a touch is detected and a release is detected (as determined by the INT_REL_n bit - see Section 6.6). In the case of a "press and hold" event, it will generate an interrupt when a touch is detected and at the repeat rate so long as the touch is held.

Bit 6 - CS7_RPT_EN - Enables the repeat rate for capacitive touch sensor input 7.

Bit 5 - CS6_RPT_EN - Enables the repeat rate for capacitive touch sensor input 6.

Bit 4 - CS5_RPT_EN - Enables the repeat rate for capacitive touch sensor input 5.

Bit 3 - CS4_RPT_EN - Enables the repeat rate for capacitive touch sensor input 4.

Bit 2 - CS3_RPT_EN - Enables the repeat rate for capacitive touch sensor input 3.

Bit 1 - CS2_RPT_EN - Enables the repeat rate for capacitive touch sensor input 2.

Bit 0 - CS1_RPT_EN - Enables the repeat rate for capacitive touch sensor input 1.

6.14 Multiple Touch Configuration Register

TABLE 6-24: MULTIPLE TOUCH CONFIGURATION

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
2Ah	R/W	Multiple Touch Config	MULT_ BLK_ EN	-	-	-	B_MULT_T[1:0]		-	-	80h

The Multiple Touch Configuration register controls the settings for the multiple touch detection circuitry. These settings determine the number of simultaneous buttons that may be pressed before additional buttons are blocked and the MULT status bit is set.

Bit 7 - MULT_BLK_EN - Enables the multiple button blocking circuitry.

- '0' - The multiple touch circuitry is disabled. The device will not block multiple touches.
- '1' (default) - The multiple touch circuitry is enabled. The device will flag the number of touches equal to programmed multiple touch threshold and block all others. It will remember which sensor inputs are valid and block all others until that sensor pad has been released. Once a sensor pad has been released, the N detected touches (determined via the cycle order of CS1 - CS8) will be flagged and all others blocked.

Bits 3 - 2 - B_MULT_T[1:0] - Determines the number of simultaneous touches on all sensor pads before a Multiple Touch Event is detected and sensor inputs are blocked. The bit decode is given by Table 6-25.

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TABLE 6-25: B_MULT_T BIT DECODE

B_MULT_T[1:0]		Number of Simultaneous Touches
1	**0**	
0	0	1 (default)
0	1	2
1	0	3
1	1	4

6.15 Multiple Touch Pattern Configuration Register

TABLE 6-26: MULTIPLE TOUCH PATTERN CONFIGURATION

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
2Bh	R/W	Multiple Touch Pattern Config	MTP_ EN	-	-		MTP_TH[1:0]		COMP_ PTRN	MTP_ ALERT	00h

The Multiple Touch Pattern Configuration register controls the settings for the multiple touch pattern detection circuitry. This circuitry works like the multiple touch detection circuitry with the following differences:

1. The detection threshold is a percentage of the touch detection threshold as defined by the MTP_TH[1:0] bits whereas the multiple touch circuitry uses the touch detection threshold.
2. The MTP detection circuitry either will detect a specific pattern of sensor inputs as determined by the Multiple Touch Pattern register settings or it will use the Multiple Touch Pattern register settings to determine a minimum number of sensor inputs that will cause the MTP circuitry to flag an event. When using pattern recognition mode, if all of the sensor inputs set by the Multiple Touch Pattern register have a delta count greater than the MTP threshold or have their corresponding Noise Flag Status bits set, the MTP bit will be set. When using the absolute number mode, if the number of sensor inputs with thresholds above the MTP threshold or with Noise Flag Status bits set is equal to or greater than this number, the MTP bit will be set.
3. When an MTP event occurs, all touches are blocked and an interrupt is generated.
4. All sensor inputs will remain blocked so long as the requisite number of sensor inputs are above the MTP threshold or have Noise Flag Status bits set. Once this condition is removed, touch detection will be restored. Note that the MTP status bit is only cleared by writing a ‘0’ to the INT bit once the condition has been removed.

Bit 7 - MTP_EN - Enables the multiple touch pattern detection circuitry.

- ‘0’ (default) - The MTP detection circuitry is disabled.
- ‘1’ - The MTP detection circuitry is enabled.

Bits 3-2 - MTP_TH[1:0] - Determine the MTP threshold, as shown in Table 6-27. This threshold is a percentage of sensor input threshold (see Section 6.18, "Sensor Input Threshold Registers") when the device is in the Fully Active state or of the standby threshold (see Section 6.23, "Standby Threshold Register") when the device is in the Standby state.

TABLE 6-27: MTP_TH BIT DECODE

MTP_TH[1:0]		Threshold Divide Setting
1	**0**	
0	0	12.5% (default)
0	1	25%
1	0	37.5%
1	1	100%

Bit 1 - COMP_PTRN - Determines whether the MTP detection circuitry will use the Multiple Touch Pattern register as a specific pattern of sensor inputs or as an absolute number of sensor inputs.

- ‘0’ (default) - The MTP detection circuitry will use the Multiple Touch Pattern register bit settings as an absolute minimum number of sensor inputs that must be above the threshold or have Noise Flag Status bits set. The number will be equal to the number of bits set in the register.

- '1' - The MTP detection circuitry will use pattern recognition. Each bit set in the Multiple Touch Pattern register indicates a specific sensor input that must have a delta count greater than the MTP threshold or have a Noise Flag Status bit set. If the criteria are met, the MTP status bit will be set.

Bit 0 - MTP_ALERT - Enables an interrupt if an MTP event occurs. In either condition, the MTP status bit will be set.

- '0' (default) - If an MTP event occurs, the ALERT# pin is not asserted.
- '1' - If an MTP event occurs, the ALERT# pin will be asserted.

6.16 Multiple Touch Pattern Register

TABLE 6-28: MULTIPLE TOUCH PATTERN REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
2Dh	R/W	Multiple Touch Pattern	CS8_ PTRN	CS7_ PTRN	CS6_ PTRN	CS5_ PTRN	CS4_ PTRN	CS3_ PTRN	CS2_ PTRN	CS1_ PTRN	FFh

The Multiple Touch Pattern register acts as a pattern to identify an expected sensor input profile for diagnostics or other significant events. There are two methods for how the Multiple Touch Pattern register is used: as specific sensor inputs or number of sensor input that must exceed the MTP threshold or have Noise Flag Status bits set. Which method is used is based on the COMP_PTRN bit (see Section 6.15). The methods are described below.

1. Specific Sensor Inputs: If, during a single polling cycle, the specific sensor inputs above the MTP threshold or with Noise Flag Status bits set match those bits set in the Multiple Touch Pattern register, an MTP event is flagged.
2. Number of Sensor Inputs: If, during a single polling cycle, the number of sensor inputs with a delta count above the MTP threshold or with Noise Flag Status bits set is equal to or greater than the number of pattern bits set, an MTP event is flagged.

Bit 7 - CS8_PTRN - Determines whether CS8 is considered as part of the Multiple Touch Pattern.

- '0' - CS8 is not considered a part of the pattern.
- '1' - CS8 is considered a part of the pattern, or the absolute number of sensor inputs that must have a delta count greater than the MTP threshold or have the Noise Flag Status bit set is increased by 1.

Bit 6 - CS7_PTRN - Determines whether CS7 is considered as part of the Multiple Touch Pattern.

Bit 5 - CS6_PTRN - Determines whether CS6 is considered as part of the Multiple Touch Pattern.

Bit 4 - CS5_PTRN - Determines whether CS5 is considered as part of the Multiple Touch Pattern.

Bit 3 - CS4_PTRN - Determines whether CS4 is considered as part of the Multiple Touch Pattern.

Bit 2 - CS3_PTRN - Determines whether CS3 is considered as part of the Multiple Touch Pattern.

Bit 1 - CS2_PTRN - Determines whether CS2 is considered as part of the Multiple Touch Pattern.

Bit 0 - CS1_PTRN - Determines whether CS1 is considered as part of the Multiple Touch Pattern.

6.17 Recalibration Configuration Register

TABLE 6-29: RECALIBRATION CONFIGURATION REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
2Fh	R/W	Recalibration Configuration	BUT_ LD_TH	NO_ CLR_ INTD	NO_ CLR_ NEG	NEG_DELTA_ CNT[1:0]		CAL_CFG[2:0]			8Ah

The Recalibration Configuration register controls the automatic re-calibration routine settings as well as advanced controls to program the Sensor Input Threshold register settings.

Bit 7 - BUT_LD_TH - Enables setting all Sensor Input Threshold registers by writing to the Sensor Input 1 Threshold register.

- '0' - Each Sensor Input X Threshold register is updated individually.
- '1' (default) - Writing the Sensor Input 1 Threshold register will automatically overwrite the Sensor Input Threshold registers for all sensor inputs (Sensor Input Threshold 1 through Sensor Input Threshold 8). The individual Sensor

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Input X Threshold registers (Sensor Input 2 Threshold through Sensor Input 8 Threshold) can be individually updated at any time.

Bit 6 - NO_CLR_INTD - Controls whether the accumulation of intermediate data is cleared if the noise status bit is set.

- '0' (default) - The accumulation of intermediate data is cleared if the noise status bit is set.
- '1' - The accumulation of intermediate data is not cleared if the noise status bit is set.

APPLICATION NOTE: Bits 5 and 6 should both be set to the same value. Either both should be set to '0' or both should be set to '1'.

Bit 5 - NO_CLR_NEG - Controls whether the consecutive negative delta counts counter is cleared if the noise status bit is set.

- '0' (default) - The consecutive negative delta counts counter is cleared if the noise status bit is set.
- '1' - The consecutive negative delta counts counter is not cleared if the noise status bit is set.

Bits 4 - 3 - NEG_DELTA_CNT[1:0] - Determines the number of negative delta counts necessary to trigger a digital re-calibration as shown in Table 6-30.

TABLE 6-30: NEG_DELTA_CNT BIT DECODE

NEG_DELTA_CNT[1:0]		Number of Consecutive Negative Delta Count Values
1	**0**	
0	0	8
0	1	16 (default)
1	0	32
1	1	None (disabled)

Bits 2 - 0 - CAL_CFG[2:0] - Determines the update time and number of samples of the automatic re-calibration routine. The settings apply to all sensor inputs universally (though individual sensor inputs can be configured to support re-calibration - see Section 6.11).

TABLE 6-31: CAL_CFG BIT DECODE

CAL_CFG[2:0]			Recalibration Samples (see Note 6-1)	Update Time (see Note 6-2)
2	**1**	**0**		
0	0	0	16	16
0	0	1	32	32
0	1	0	64	64 (default)
0	1	1	128	128
1	0	0	256	256
1	0	1	256	1024
1	1	0	256	2048
1	1	1	256	4096

Note 6-1 Recalibration Samples refers to the number of samples that are measured and averaged before the Base Count is updated however does not control the base count update period.

Note 6-2 Update Time refers to the amount of time (in polling cycle periods) that elapses before the Base Count is updated. The time will depend upon the number of channels active, the averaging setting, and the programmed cycle time.

6.18 Sensor Input Threshold Registers

TABLE 6-32: SENSOR INPUT THRESHOLD REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
30h	R/W	Sensor Input 1 Threshold	-	64	32	16	8	4	2	1	40h
31h	R/W	Sensor Input 2 Threshold	-	64	32	16	8	4	2	1	40h
32h	R/W	Sensor Input 3 Threshold	-	64	32	16	8	4	2	1	40h
33h	R/W	Sensor Input 4 Threshold	-	64	32	16	8	4	2	1	40h
34h	R/W	Sensor Input 5 Threshold	-	64	32	16	8	4	2	1	40h
35h	R/W	Sensor Input 6 Threshold	-	64	32	16	8	4	2	1	40h
36h	R/W	Sensor Input 7 Threshold	-	64	32	16	8	4	2	1	40h
37h	R/W	Sensor Input 8 Threshold	-	64	32	16	8	4	2	1	40h

The Sensor Input Threshold registers store the delta threshold that is used to determine if a touch has been detected. When a touch occurs, the input signal of the corresponding sensor pad changes due to the capacitance associated with a touch. If the sensor input change exceeds the threshold settings, a touch is detected.

When the BUT_LD_TH bit is set (see Section 6.17 - bit 7), writing data to the Sensor Input 1 Threshold register will update all of the sensor input threshold registers (31h - 37h inclusive).

6.19 Sensor Input Noise Threshold Register

TABLE 6-33: SENSOR INPUT NOISE THRESHOLD REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
38h	R/W	Sensor Input Noise Threshold							CS_BN_TH [1:0]		01h

The Sensor Input Noise Threshold register controls the value of a secondary internal threshold to detect noise and improve the automatic recalibration routine. If a capacitive touch sensor input exceeds the Sensor Input Noise Threshold but does not exceed the sensor input threshold, it is determined to be caused by a noise spike. That sample is not used by the automatic re-calibration routine. This feature can be disabled by setting the DIS_DIG_NOISE bit.

Bits 1-0 - CS1_BN_TH[1:0] - Controls the noise threshold for all capacitive touch sensor inputs, as shown in Table 6-34. The threshold is proportional to the threshold setting.

TABLE 6-34: CSX_BN_TH BIT DECODE

CS_BN_TH[1:0]		Percent Threshold Setting
1	**0**	
0	0	25%
0	1	37.5% (default)
1	0	50%
1	1	62.5%

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6.20 Standby Channel Register

TABLE 6-35: STANDBY CHANNEL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
40h	R/W	Standby Channel	CS8_ STBY	CS7_ STBY	CS6_ STBY	CS5_ STBY	CS4_ STBY	CS3_ STBY	CS2_ STBY	CS1_ STBY	00h

The Standby Channel register controls which (if any) capacitive touch sensor inputs are active during Standby.

Bit 7 - CS8_STBY - Controls whether the CS8 channel is active in Standby.

- '0' (default) - The CS8 channel not be sampled during Standby.
- '1' - The CS8 channel will be sampled during Standby. It will use the Standby threshold setting, and the standby averaging and sensitivity settings.

Bit 6 - CS7_STBY - Controls whether the CS7 channel is active in Standby.

Bit 5 - CS6_STBY - Controls whether the CS6 channel is active in Standby.

Bit 4 - CS5_STBY - Controls whether the CS5 channel is active in Standby.

Bit 3 - CS4_STBY - Controls whether the CS4 channel is active in Standby.

Bit 2 - CS3_STBY - Controls whether the CS3 channel is active in Standby.

Bit 1 - CS2_STBY - Controls whether the CS2 channel is active in Standby.

Bit 0 - CS1_STBY - Controls whether the CS1 channel is active in Standby.

6.21 Standby Configuration Register

TABLE 6-36: STANDBY CONFIGURATION REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
41h	R/W	Standby Config-uration	AVG_ SUM	STBY_AVG[2:0]			STBY_SAMP_ TIME[1:0]		STBY_CY_TIME [1:0]		39h

The Standby Configuration register controls averaging and cycle time for those sensor inputs that are active in Standby. This register is useful for detecting proximity on a small number of sensor inputs as it allows the user to change averaging and sample times on a limited number of sensor inputs and still maintain normal functionality in the fully active state.

Bit 7 - AVG_SUM - Determines whether the active sensor inputs will average the programmed number of samples or whether they will accumulate for the programmed number of samples.

- '0' - (default) - The active sensor input delta count values will be based on the average of the programmed number of samples when compared against the threshold.
- '1' - The active sensor input delta count values will be based on the summation of the programmed number of samples when compared against the threshold. This bit should only be set when performing proximity detection as a physical touch will overflow the delta count registers and may result in false readings.

Bits 6 - 4 - STBY_AVG[2:0] - Determines the number of samples that are taken for all active channels during the sensor cycle as shown in Table 6-37. All samples are taken consecutively on the same channel before the next channel is sampled and the result is averaged over the number of samples measured before updating the measured results.

TABLE 6-37: STBY_AVG BIT DECODE

STBY_AVG[2:0]			Number of Samples Taken per Measurement
2	1	0	
0	0	0	1
0	0	1	2
0	1	0	4
0	1	1	8 (default)
1	0	0	16

TABLE 6-37: STBY_AVG BIT DECODE (CONTINUED)

STBY_AVG[2:0]			Number of Samples Taken per Measurement
2	**1**	**0**	
1	0	1	32
1	1	0	64
1	1	1	128

Bit 3-2 - STBY SAMP_TIME[1:0] - Determines the time to take a single sample when the device is in Standby as shown in Table 6-38.

TABLE 6-38: STBY_SAMP_TIME BIT DECODE

STBY_SAMP_TIME[1:0]		Sampling Time
1	**0**	
0	0	320us
0	1	640us
1	0	1.28ms (default)
1	1	2.56ms

Bits 1 - 0 - STBY_CY_TIME[2:0] - Determines the overall cycle time for all measured channels during standby operation as shown in Table 6-39. All measured channels are sampled at the beginning of the cycle time. If additional time is remaining, the device is placed into a lower power state for the remaining duration of the cycle.

TABLE 6-39: STBY_CY_TIME BIT DECODE

STBY_CY_TIME[1:0]		Overall Cycle Time
1	**0**	
0	0	35ms
0	1	70ms (default)
1	0	105ms
1	1	140ms

APPLICATION NOTE: The programmed cycle time is only maintained if the total averaging time for all samples is less than the programmed cycle. The STBY_AVG[2:0] bits will take priority so that if more samples are required than would normally be allowed during the cycle time, the cycle time will be extended as necessary to accommodate the number of samples to be measured.

6.22 Standby Sensitivity Register

TABLE 6-40: STANDBY SENSITIVITY REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
42h	R/W	Standby Sensitivity	-	-	-	-	-	STBY_SENSE[2:0]			02h

The Standby Sensitivity register controls the sensitivity for sensor inputs that are active in Standby.

Bits 2 - 0 - STBY_SENSE[2:0] - Controls the sensitivity for sensor inputs that are active in Standby. The sensitivity settings act to scale the relative delta count value higher or lower based on the system parameters. A setting of 000b is the most sensitive while a setting of 111b is the least sensitive. At the more sensitive settings, touches are detected for a smaller delta C corresponding to a “lighter” touch. These settings are more sensitive to noise however and a noisy environment may flag more false touches than higher sensitivity levels.

APPLICATION NOTE: A value of 128x is the most sensitive setting available. At the most sensitivity settings, the MSB of the Delta Count register represents 64 out of ~25,000 which corresponds to a touch

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of approximately 0.25% of the base capacitance (or a ΔC of 25fF from a 10pF base capacitance). Conversely a value of 1x is the least sensitive setting available. At these settings, the MSB of the Delta Count register corresponds to a delta count of 8192 counts out of ~25,000 which corresponds to a touch of approximately 33% of the base capacitance (or a ΔC of 3.33pF from a 10pF base capacitance).

TABLE 6-41: STBY_SENSE BIT DECODE

STBY_SENSE[2:0]			Sensitivity Multiplier
2	1	0	
0	0	0	128x (most sensitive)
0	0	1	64x
0	1	0	32x (default)
0	1	1	16x
1	0	0	8x
1	0	1	4x
1	1	0	2x
1	1	1	1x - (least sensitive)

6.23 Standby Threshold Register

TABLE 6-42: STANDBY THRESHOLD REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
43h	R/W	Standby Threshold	-	64	32	16	8	4	2	1	40h

The Standby Threshold register stores the delta threshold that is used to determine if a touch has been detected. When a touch occurs, the input signal of the corresponding sensor pad changes due to the capacitance associated with a touch. If the sensor input change exceeds the threshold settings, a touch is detected.

6.24 Sensor Input Base Count Registers

TABLE 6-43: SENSOR INPUT BASE COUNT REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
50h	R	Sensor Input 1 Base Count	128	64	32	16	8	4	2	1	C8h
51h	R	Sensor Input 2 Base Count	128	64	32	16	8	4	2	1	C8h
52h	R	Sensor Input 3 Base Count	128	64	32	16	8	4	2	1	C8h
53h	R	Sensor Input 4 Base Count	128	64	32	16	8	4	2	1	C8h
54h	R	Sensor Input 5 Base Count	128	64	32	16	8	4	2	1	C8h
55h	R	Sensor Input 6 Base Count	128	64	32	16	8	4	2	1	C8h
56h	R	Sensor Input 7 Base Count	128	64	32	16	8	4	2	1	C8h
57h	R	Sensor Input 8 Base Count	128	64	32	16	8	4	2	1	C8h

The Sensor Input Base Count registers store the calibrated “Not Touched” input value from the capacitive touch sensor inputs. These registers are periodically updated by the re-calibration routine.

The routine uses an internal adder to add the current count value for each reading to the sum of the previous readings until sample size has been reached. At this point, the upper 16 bits are taken and used as the Sensor Input Base Count. The internal adder is then reset and the re-calibration routine continues.

The data presented is determined by the BASE_SHIFT[3:0] bits (see Section 6.5).

6.25 LED Output Type Register

TABLE 6-44: LED OUTPUT TYPE REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
71h	R/W	LED Output Type	-	-	-	-	-	-	LED2_OT	LED1_OT	00h

The LED Output Type register controls the type of output for the LED pins. Each pin is controlled by a single bit. Refer to application note 21.4 CAP1128Family LED Configuration Options for more information about implementing LEDs.

Bit 1 - LED2_OT - Determines the output type of the LED2 pin.

- '0' (default) - The LED2 pin is an open-drain output with an external pull-up resistor. When the appropriate pin is set to the "active" state (logic '1'), the pin will be driven low. Conversely, when the pin is set to the "inactive" state (logic '0'), then the pin will be left in a High Z state and pulled high via an external pull-up resistor.
- '1' - The LED2 pin is a push-pull output. When driving a logic '1', the pin is driven high. When driving a logic '0', the pin is driven low.

Bit 0 - LED1_OT - Determines the output type of the LED1 pin.

6.26 Sensor Input LED Linking Register

TABLE 6-45: SENSOR INPUT LED LINKING REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
72h	R/W	Sensor Input LED Linking	-	-	-	-	-	-	CS2_LED2	CS1_LED1	00h

The Sensor Input LED Linking register controls whether a capacitive touch sensor input is linked to an LED output. If the corresponding bit is set, then the appropriate LED output will change states defined by the LED Behavior controls (see Section 6.31) in response to the capacitive touch sensor input.

Bit 1 - CS2_LED2 - Links the LED2 output to a detected touch on the CS2 sensor input. When a touch is detected, the LED is actuated and will behave as determined by the LED Behavior controls.

- '0' (default) - The LED 2 output is not associated with the CS2 input. If a touch is detected on the CS2 input, the LED will not automatically be actuated. The LED is enabled and controlled via the LED Output Control register (see Section 6.28) and the LED Behavior registers (see Section 6.31).
- '1' - The LED 2 output is associated with the CS2 input. If a touch is detected on the CS2 input, the LED will be actuated and behave as defined in Table 6-52.

Bit 0 - CS1_LED1 - Links the LED1 output to a detected touch on the CS1 sensor input. When a touch is detected, the LED is actuated and will behave as determined by the LED Behavior controls.

6.27 LED Polarity Register

TABLE 6-46: LED POLARITY REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
73h	R/W	LED Polarity	-	-	-	-	-	-	LED2_POL	LED1_POL	00h

The LED Polarity register controls the logical polarity of the LED outputs. When these bits are set or cleared, the corresponding LED Mirror controls are also set or cleared (unless the BLK_POL_MIR bit is set - see Section 6.6, "Configuration Registers"). Table 6-48, "LED Polarity Behavior" shows the interaction between the polarity controls, output controls, and relative brightness.

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APPLICATION NOTE: The polarity controls determine the final LED pin drive. A touch on a linked capacitive touch sensor input is treated in the same way as the LED Output Control bit being set to a logic ‘1’.

APPLICATION NOTE: The LED drive assumes that the LEDs are configured such that if the LED pin is driven to a logic ‘0’ then the LED will be on and that the CAP1128 LED pin is sinking the LED current. Conversely, if the LED pin is driven to a logic ‘1’, the LED will be off and there is no current flow. See Figure 5-1, "System Diagram for CAP1128".

APPLICATION NOTE: This application note applies when the LED polarity is inverted (LEDx_POL = ‘0’). For LED operation, the duty cycle settings determine the % of time that the LED pin will be driven to a logic ‘0’ state in. The Max Duty Cycle settings define the maximum % of time that the LED pin will be driven low (i.e. maximum % of time that the LED is **on**) while the Min Duty Cycle settings determine the minimum % of time that the LED pin will be driven low (i.e. minimum % of time that the LED is **on**). When there is no touch detected or the LED Output Control register bit is at a logic ‘0’, the LED output will be driven at the minimum duty cycle setting. Breathe operations will ramp the duty cycle from the minimum duty cycle to the maximum duty cycle.

APPLICATION NOTE: This application note applies when the LED polarity is non-inverted (LEDx_POL = ‘1’). For LED operation, the duty cycle settings determine the % of time that the LED pin will be driven to a logic ‘1’ state. The Max Duty Cycle settings define the maximum % of time that the LED pin will be driven high (i.e. maximum % of time that the LED is **off**) while the Min Duty Cycle settings determine the minimum % of time that the LED pin will be driven high (i.e. minimum % of time that the LED is **off**). When there is no touch detected or the LED Output Control register bit is at a logic ‘0’, the LED output will be driven at 100 minus the minimum duty cycle setting. Breathe operations will ramp the duty cycle from 100 minus the minimum duty cycle to 100 minus the maximum duty cycle.

APPLICATION NOTE: The LED Mirror controls (see Section 6.30, "LED Mirror Control Register") work with the polarity controls with respect to LED brightness but will not have a direct effect on the output pin drive.

Bit 1 - LED2_POL - Determines the polarity of the LED2 output.

- ‘0’ (default) - The LED2 output is inverted. For example, a setting of ‘1’ in the LED Output Control register will cause the LED pin output to be driven to a logic ‘0’.
- ‘1’ - The LED2 output is non-inverted. For example, a setting of ‘1’ in the LED Output Control register will cause the LED pin output to be driven to a logic ‘1’ or left in the high-z state as determined by its output type.

Bit 0 - LED1_POL - Determines the polarity of the LED1 output.

6.28 LED Output Control Register

TABLE 6-47: LED OUTPUT CONTROL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
74h	R/W	LED Output Control	-	-	-	-	-	-	LED2_DR	LED1_DR	00h

The LED Output Control Register controls the output state of the LED pins that are not linked to sensor inputs.

Note: If an LED is linked to a sensor input in the Sensor Input LED Linking Register (Section 6.26, "Sensor Input LED Linking Register"), the corresponding bit in the LED Output Control Register is ignored (i.e. a linked LED cannot be host controlled).

The LED Polarity Control Register will determine the non actuated state of the LED pins. The actuated LED behavior is determined by the LED behavior controls (see Section 6.31, "LED Behavior Register").

Table 6-48 shows the interaction between the polarity controls, output controls, and relative brightness.

Bit 1 - LED2_DR - Determines whether LED2 output is driven high or low.

- '0' (default) - The LED2 output is driven at the minimum duty cycle or not actuated.
- '1' - The LED2 output is High Z or driven at the maximum duty cycle or actuated.

Bit 0 - LED1_DR - Determines whether LED1 output is driven high or low.

TABLE 6-48: LED POLARITY BEHAVIOR

LED Output Control Register or Touch	Polarity	Max Duty	Min Duty	Brightness	LED Appearance
0	inverted ('0')	not used	minimum % of time that the LED is on (logic 0)	maximum brightness at min duty cycle	on at min duty cycle
1	inverted ('0')	maximum % of time that the LED is on (logic 0)	minimum % of time that the LED is on (logic 0)	maximum brightness at max duty cycle. Brightness ramps from min duty cycle to max duty cycle	according to LED behavior
0	non-inverted ('1')	not used	minimum % of time that the LED is off (logic 1)	maximum brightness at 100 minus min duty cycle.	on at 100 - min duty cycle
1	non-inverted ('1')	maximum % of time that the LED is off (logic 1)	minimum % of time that the LED is off (logic 1)	For Direct behavior, maximum brightness is 100 minus max duty cycle. When breathing, max brightness is 100 minus min duty cycle. Brightness ramps from 100 - min duty cycle to 100 - max duty cycle.	according to LED behavior

6.29 Linked LED Transition Control Register

TABLE 6-49: LINKED LED TRANSITION CONTROL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
77h	R/W	Linked LED Transition Control	-	-	-	-	-	-	LED2_LTRAN	LED1_LTRAN	00h

The Linked LED Transition Control register controls the LED drive when the LED is linked to a capacitive touch sensor input. These controls work in conjunction with the INV_LINK_TRAN bit (see Section 6.6.2, "Configuration 2 - 44h") to create smooth transitions from host control to linked LEDs.

Bit 1 - LED2_LTRAN - Determines the transition effect when LED2 is linked to CS2.

- '0' (default) - When the LED output control bit for LED2 is '1', and then LED2 is linked to CS2 and no touch is detected, the LED will change states.
- '1' - If the INV_LINK_TRAN bit is '1', when the LED output control bit for CS2 is '1', and then CS2 is linked to LED2 and no touch is detected, the LED will not change states. In addition, the LED state will change when the sensor pad is touched. If the INV_LINK_TRAN bit is '0', when the LED output control bit for CS2 is '1', and then CS2 is linked to LED2 and no touch is detected, the LED will not change states. However, the LED state will not change when the sensor pad is touched.

APPLICATION NOTE: If the LED behavior is not "Direct" and the INV_LINK_TRAN bit it '0', the LED will not perform as expected when the LED2_LTRAN bit is set to '1'. Therefore, if breathe and pulse behaviors are used, set the INV_LINK_TRAN bit to '1'.

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Bit 0 - LED1_LTRAN - Determines the transition effect when LED1 is linked to CS1.

6.30 LED Mirror Control Register

TABLE 6-50: LED MIRROR CONTROL REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
79h	R/W	LED Mirror Control	-	-	-	-	-	-	LED2_MIR_EN	LED1_MIR_EN	00h

The LED Mirror Control Registers determine the meaning of duty cycle settings when polarity is non-inverted for each LED channel. When the polarity bit is set to '1' (non-inverted), to obtain correct steps for LED ramping, pulse, and breathe behaviors, the min and max duty cycles need to be relative to 100%, rather than the default, which is relative to 0%.

APPLICATION NOTE: The LED drive assumes that the LEDs are configured such that if the LED pin is driven to a logic '0', the LED will be on and the CAP1128 LED pin is sinking the LED current. When the polarity bit is set to '1', it is considered non-inverted. For systems using the opposite LED configuration, mirror controls would apply when the polarity bit is '0'.

These bits are changed automatically if the corresponding LED Polarity bit is changed (unless the BLK_POL_MIR bit is set - see Section 6.6).

Bit 1 - LED2_MIR_EN - Determines whether the duty cycle settings are "biased" relative to 0% or 100% duty cycle.

- '0' (default) - The duty cycle settings are determined relative to 0% and are determined directly with the settings.
- '1' - The duty cycle settings are determined relative to 100%.

Bit 0 - LED1_MIR_EN - Determines whether the duty cycle settings are "biased" relative to 0% or 100% duty cycle.

6.31 LED Behavior Register

TABLE 6-51: LED BEHAVIOR REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
81h	R/W	LED Behavior 1	-	-	-	-	LED2_CTL[1:0]		LED1_CTL[1:0]		00h

The LED Behavior register controls the operation of LEDs. Each LED pin is controlled by a 2-bit field and the behavior is determined by whether the LED is linked to a capacitive touch sensor input or not.

If the corresponding LED output is linked to a capacitive touch sensor input, the appropriate behavior will be enabled / disabled based on touches and releases.

If the LED output is not associated with a capacitive touch sensor input, the appropriate behavior will be enabled / disabled by the LED Output Control register. If the respective LEDx_DR bit is set to a logic '1', this will be associated as a "touch", and if the LEDx_DR bit is set to a logic '0', this will be associated as a "release".

Table 6-52, "LEDx_CTL Bit Decode" shows the behavior triggers. The defined behavior will activate when the Start Trigger is met and will stop when the Stop Trigger is met. Note the behavior of the Breathe Hold and Pulse Release option.

The LED Polarity Control register will determine the non actuated state of the LED outputs (see Section 6.27, "LED Polarity Register").

APPLICATION NOTE: If an LED is not linked to a capacitive touch sensor input and is breathing (via the Breathe or Pulse behaviors), it must be unactuated and then re-actuated before changes to behavior are processed. For example, if the LED output is breathing and the Maximum duty cycle is changed, this change will not take effect until the LED output control register is set to '0' and then re-set to '1'.

APPLICATION NOTE: If an LED is not linked to the capacitive touch sensor input and configured to operate using Pulse 1 Behavior, then the circuitry will only be actuated when the corresponding output control bit is set. It will not check the bit condition until the Pulse 1 behavior is finished. The device will not remember if the bit was cleared and reset while it was actuated.

APPLICATION NOTE: If an LED is actuated and not linked and the desired LED behavior is changed, this new behavior will take effect immediately; however, the first instance of the changed behavior may act incorrectly (e.g. if changed from Direct to Pulse 1, the LED output may 'breathe' 4 times and then end at minimum duty cycle). LED Behaviors will operate normally once the LED has been un-actuated and then re-actuated.

APPLICATION NOTE: If an LED is actuated and it is switched from linked to a capacitive touch sensor input to unlinked (or vice versa), the LED will respond to the new command source immediately if the behavior was Direct or Breathe. For Pulse behaviors, it will complete the behavior already in progress. For example, if a linked LED was actuated by a touch and the control is changed so that it is unlinked, it will check the status of the corresponding LED Output Control bit. If that bit is '0', then the LED will behave as if a release was detected. Likewise, if an unlinked LED was actuated by the LED Output Control register and the control is changed so that it is linked and no touch is detected, then the LED will behave as if a release was detected.

Bits 3 - 2 - LED2_CTL[1:0] - Determines the behavior of LED2 as shown in Table 6-52.

Bits 1 - 0 - LED1_CTL[1:0] - Determines the behavior of LED1 as shown in Table 6-52.

TABLE 6-52: LEDX_CTL BIT DECODE

LEDx_CTL [1:0]		Operation	Description	Start TRigger	Stop Trigger
1	0				
0	0	Direct	The LED is driven to the programmed state (active or inactive). See Figure 6-7	Touch Detected or LED Output Control bit set	Release Detected or LED Output Control bit cleared
0	1	Pulse 1	The LED will "Pulse" a programmed number of times. During each "Pulse" the LED will breathe up to the maximum brightness and back down to the minimum brightness so that the total "Pulse" period matches the programmed value.	Touch or Release Detected or LED Output Control bit set or cleared (see Section 6.32)	n/a
1	0	Pulse 2	The LED will "Pulse" when the start trigger is detected. When the stop trigger is detected, it will "Pulse" a programmable number of times then return to its minimum brightness.	Touch Detected or LED Output Control bit set	Release Detected or LED Output Control bit cleared
1	1	Breathe	The LED will breathe. It will be driven with a duty cycle that ramps up from the programmed minimum duty cycle (default 0%) to the programmed maximum duty cycle duty cycle (default 100%) and then back down. Each ramp takes up 50% of the programmed period. The total period of each "breath" is determined by the LED Breathe Period controls - see Section 6.34.	Touch Detected or LED Output Control bit set	Release Detected or LED Output Control bit cleared

APPLICATION NOTE: The PWM frequency is determined based on the selected LED behavior, the programmed breathe period, and the programmed min and max duty cycles. For the Direct behavior mode, the PWM frequency is calculated based on the programmed Rise and Fall times. If these are set at 0, then the maximum PWM frequency will be used based on the programmed duty cycle settings.

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6.32 LED Pulse 1 Period Register

TABLE 6-53: LED PULSE 1 PERIOD REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
84h	R/W	LED Pulse 1 Period	ST_ TRIG	P1_ PER6	P1_ PER5	P1_ PER4	P1_ PER3	P1_ PER2	P1_ PER1	P1_ PER0	20h

The LED Pulse Period 1 register determines the overall period of a pulse operation as determined by the LED_CTL registers (see Table 6-52 - setting 01b). The LSB represents 32ms so that a setting of 18h (24d) would represent a period of 768ms (24 x 32ms = 768ms). The total range is from 32ms to 4.064 seconds as shown in Table 6-54 with the default being 1024ms.

APPLICATION NOTE: Due to constraints on the LED Drive PWM operation, any Breathe Period less than 160ms (05h) may not be achievable. The device will breathe at the minimum period possible as determined by the period and min / max duty cycle settings.

Bit 7 - ST_TRIG - Determines the start trigger for the LED Pulse behavior.

- '0' (default) - The LED will Pulse when a touch is detected or the drive bit is set.
- '1' - The LED will Pulse when a release is detected or the drive bit is cleared.

The Pulse 1 operation is shown in Figure 6-1 when the LED output is configured for non-inverted polarity (LEDx_POL = 1) and in Figure 6-2 for inverted polarity (LEDx_POL = 0).

FIGURE 6-1: *Pulse 1 Behavior with Non-Inverted Polarity*

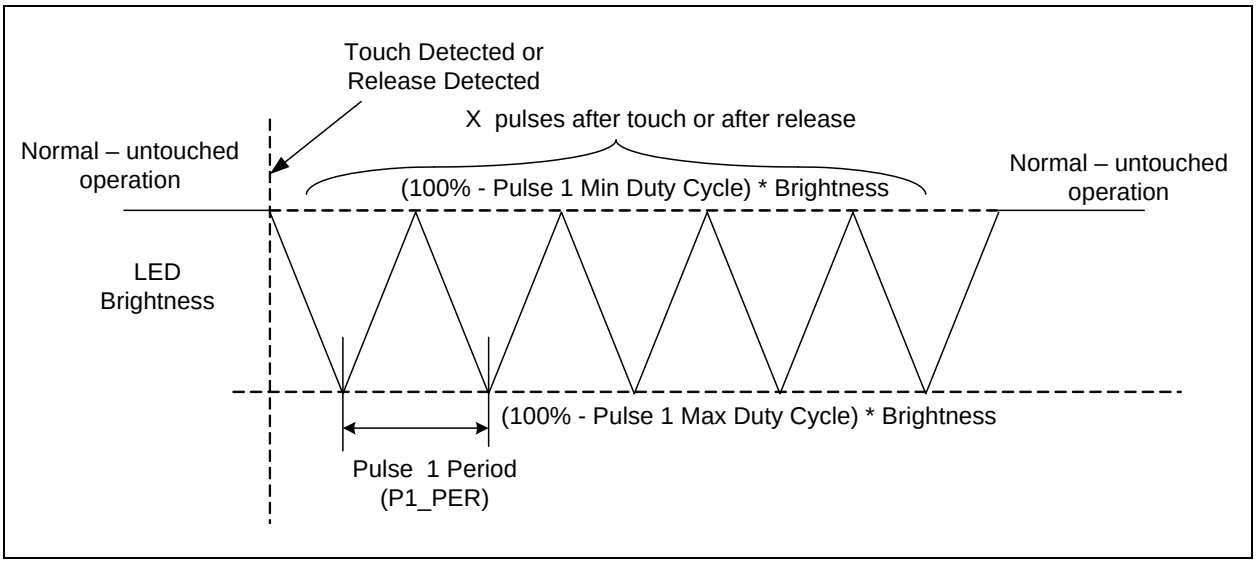


FIGURE 6-2: *Pulse 1 Behavior with Inverted Polarity*

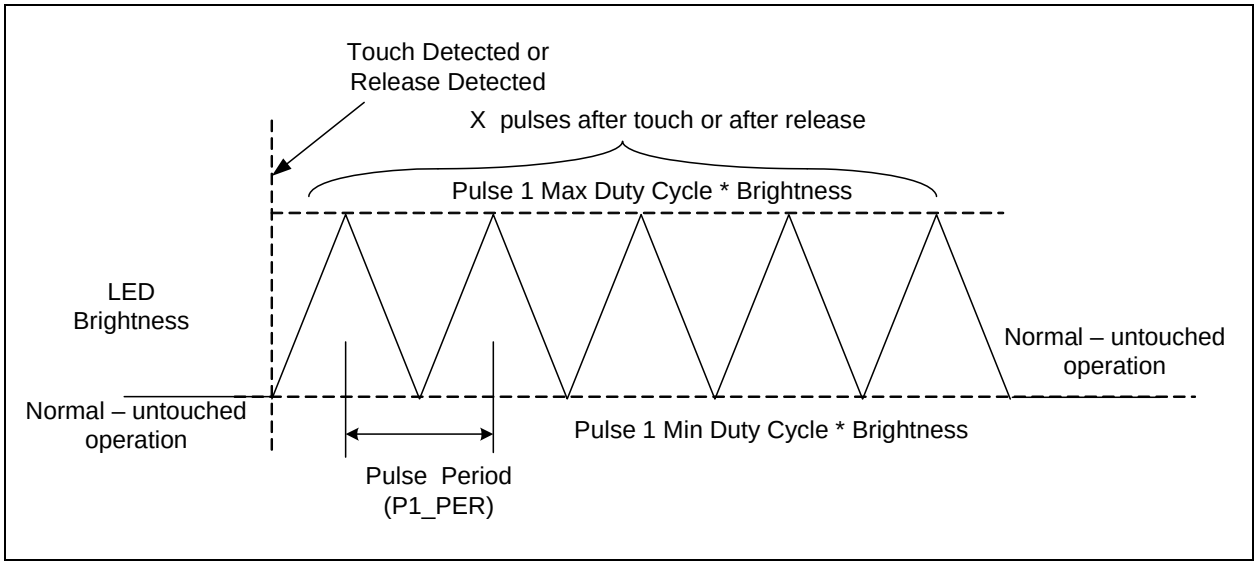


TABLE 6-54: LED PULSE / BREATHE PERIOD EXAMPLE

Setting (HEX)	Setting (Decimal)	Total Breathe / Pulse Period (MS)
00h	0	32
01h	1	32
02h	2	64
03h	3	96
. . .	. . .	. . .
7Dh	125	4000
7Eh	126	4032
7Fh	127	4064

6.33 LED Pulse 2 Period Register

TABLE 6-55: LED PULSE 2 PERIOD REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
85h	R/W	LED Pulse 2 Period	-	P2_ PER6	P2_ PER5	P2_ PER4	P2_ PER3	P2_ PER2	P2_ PER1	P2_ PER0	14h

The LED Pulse 2 Period register determines the overall period of a pulse operation as determined by the LED_CTL registers (see Table 6-52 - setting 10b). The LSB represents 32ms so that a setting of 18h (24d) would represent a period of 768ms. The total range is from 32ms to 4.064 seconds (see Table 6-54) with a default of 640ms.

APPLICATION NOTE: Due to constraints on the LED Drive PWM operation, any Breathe Period less than 160ms (05h) may not be achievable. The device will breathe at the minimum period possible as determined by the period and min / max duty cycle settings.

The Pulse 2 Behavior is shown in Figure 6-3 for non-inverted polarity (LEDx_POL = 1) and in Figure 6-4 for inverted polarity (LEDx_POL = 0).

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FIGURE 6-3: *Pulse 2 Behavior with Non-Inverted Polarity*

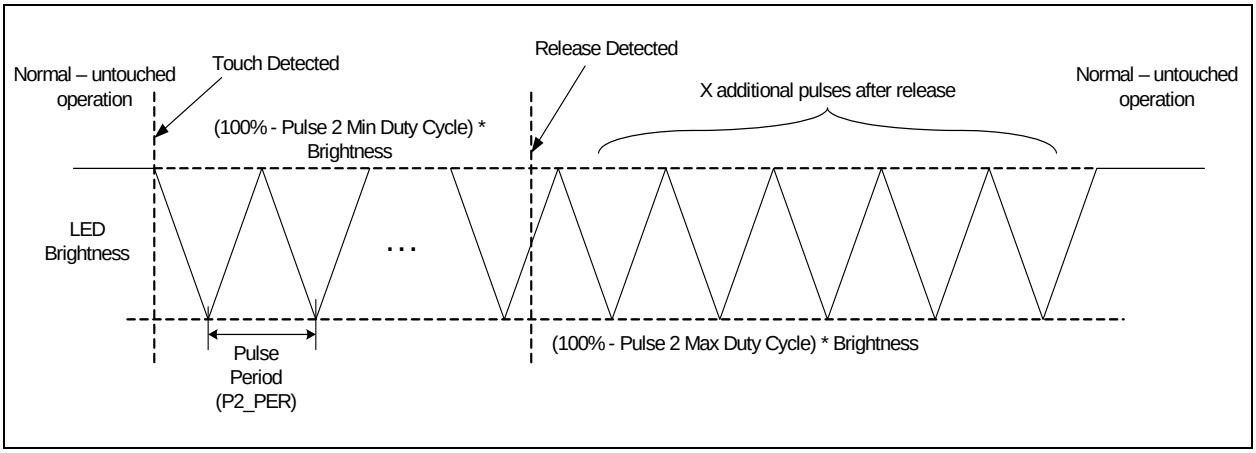
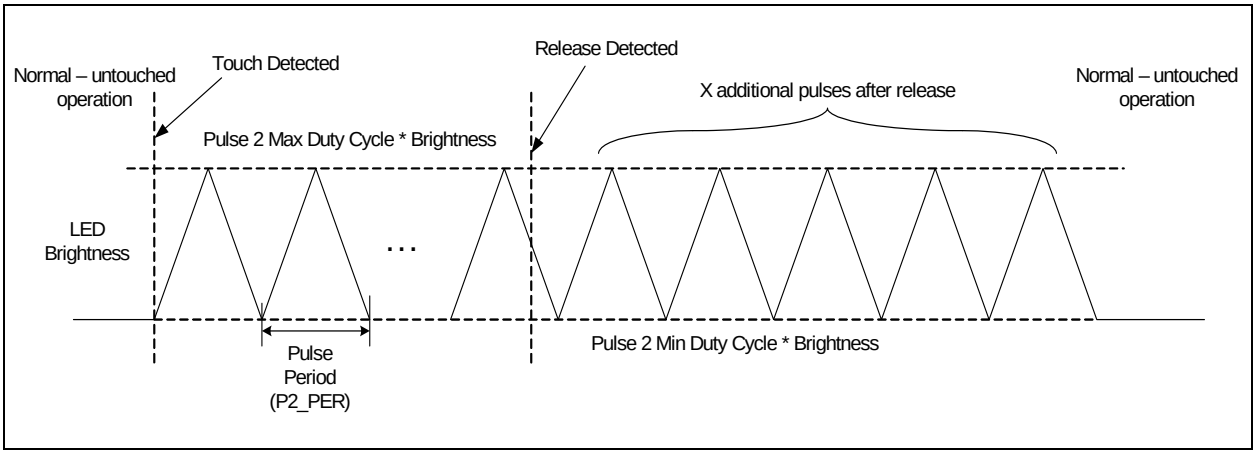


FIGURE 6-4: *Pulse 2 Behavior with Inverted Polarity*



6.34 LED Breathe Period Register

TABLE 6-56: LED BREATHE PERIOD REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
86h	R/W	LED Breathe Period	-	BR_ PER6	BR_ PER5	BR_ PER4	BR_ PER3	BR_ PER2	BR_ PER1	BR_ PER0	5Dh

The LED Breathe Period register determines the overall period of a breathe operation as determined by the LED_CTL registers (see Table 6-52 - setting 11b). The LSB represents 32ms so that a setting of 18h (24d) would represent a period of 768ms. The total range is from 32ms to 4.064 seconds (see Table 6-54) with a default of 2976ms.

APPLICATION NOTE: Due to constraints on the LED Drive PWM operation, any Breathe Period less than 160ms (05h) may not be achievable. The device will breathe at the minimum period possible as determined by the period and min / max duty cycle settings.

6.35 LED Configuration Register

TABLE 6-57: LED CONFIGURATION REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
88h	R/W	LED Config	-	RAMP_ ALERT	PULSE2_CNT[2:0]			PULSE1_CNT[2:0]			04h

The LED Configuration register controls general LED behavior as well as the number of pulses that are sent for the PULSE LED output behavior.

Bit 6 - RAMP_ALERT - Determines whether the device will assert the ALERT# pin when LEDs actuated by the LED Output Control register bits have finished their respective behaviors. Interrupts will only be generated if the LED activity is generated by writing the LED Output Control registers. Any LED activity associated with touch detection will not cause an interrupt to be generated when the LED behavior has been finished.

- '0' (default) - The ALERT# pin will not be asserted when LEDs actuated by the LED Output Control register have finished their programmed behaviors.
- '1' - The ALERT# pin will be asserted whenever any LED that is actuated by the LED Output Control register has finished its programmed behavior.

Bits 5 - 3 - PULSE2_CNT[2:0] - Determines the number of pulses used for the Pulse 2 behavior as shown in Table 6-58.

Bits 2 - 0 - PULSE1_CNT[2:0] - Determines the number of pulses used for the Pulse 1 behavior as shown in Table 6-58.

TABLE 6-58: PULSEX_CNT DECODE

PULSEX_CNT[2:0]			Number of Breaths
2	1	0	
0	0	0	1 (default - Pulse 2)
0	0	1	2
0	1	0	3
0	1	1	4
1	0	0	5 (default - Pulse 1)
1	0	1	6
1	1	0	7
1	1	1	8

6.36 LED Duty Cycle Registers

TABLE 6-59: LED DUTY CYCLE REGISTERS

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
90h	R/W	LED Pulse 1 Duty Cycle	P1_MAX_DUTY[3:0]				P1_MIN_DUTY[3:0]				F0h
91h	R/W	LED Pulse 2 Duty Cycle	P2_MAX_DUTY[3:0]				P2_MIN_DUTY[3:0]				F0h
92h	R/W	LED Breathe Duty Cycle	BR_MAX_DUTY[3:0]				BR_MIN_DUTY[3:0]				F0h
93h	R/W	Direct Duty Cycle	DR_MAX_DUTY[3:0]				DR_MIN_DUTY[3:0]				F0h

The LED Duty Cycle registers determine the minimum and maximum duty cycle settings used for the LED for each LED behavior. These settings affect the brightness of the LED when it is fully off and fully on.

The LED driver duty cycle will ramp up from the minimum duty cycle to the maximum duty cycle and back down again.

APPLICATION NOTE: When operating in Direct behavior mode, changes to the Duty Cycle settings will be applied immediately. When operating in Breathe, Pulse 1, or Pulse 2 modes, the LED must be unactuated and then re-actuated before changes to behavior are processed.

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Bits 7 - 4 - X_MAX_DUTY[3:0] - Determines the maximum PWM duty cycle for the LED drivers as shown in Table 6-60.

Bits 3 - 0 - X_MIN_DUTY[3:0] - Determines the minimum PWM duty cycle for the LED drivers as shown in Table 6-60.

TABLE 6-60: LED DUTY CYCLE DECODE

x_MAX/MIN_Duty [3:0]				Maximum Duty Cycle	Minimum Duty Cycle
3	2	1	0		
0	0	0	0	7%	0%
0	0	0	1	9%	7%
0	0	1	0	11%	9%
0	0	1	1	14%	11%
0	1	0	0	17%	14%
0	1	0	1	20%	17%
0	1	1	0	23%	20%
0	1	1	1	26%	23%
1	0	0	0	30%	26%
1	0	0	1	35%	30%
1	0	1	0	40%	35%
1	0	1	1	46%	40%
1	1	0	0	53%	46%
1	1	0	1	63%	53%
1	1	1	0	77%	63%
1	1	1	1	100%	77%

6.37 LED Direct Ramp Rates Register

TABLE 6-61: LED DIRECT RAMP RATES REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
94h	R/W	LED Direct Ramp Rates	-	-	RISE_RATE[2:0]			FALL_RATE[2:0]			00h

The LED Direct Ramp Rates register control the rising and falling edge time of an LED that is configured to operate in Direct behavior mode. The rising edge time corresponds to the amount of time the LED takes to transition from its minimum duty cycle to its maximum duty cycle. Conversely, the falling edge time corresponds to the amount of time that the LED takes to transition from its maximum duty cycle to its minimum duty cycle.

Bits 5 - 3 - RISE_RATE[2:0] - Determines the rising edge time of an LED when it transitions from its minimum drive state to its maximum drive state as shown in Table 6-62.

Bits 2 - 0 - FALL_RATE[2:0] - Determines the falling edge time of an LED when it transitions from its maximum drive state to its minimum drive state as shown in Table 6-62.

TABLE 6-62: RISE / FALL RATE DECODE

RISE_RATE/ FALL_RATE/ Bit Decode			Rise / Fall Time (T_{RISE} / T_{FALL})
2	1	0	
0	0	0	0
0	0	1	250ms
0	1	0	500ms
0	1	1	750ms
1	0	0	1s
1	0	1	1.25s

TABLE 6-62: RISE / FALL RATE DECODE (CONTINUED)

RISE_RATE/ FALL_RATE/ Bit Decode			Rise / Fall Time (T_{RISE} / T_{FALL})
2	1	0	
1	1	0	1.5s
1	1	1	2s

6.38 LED Off Delay Register

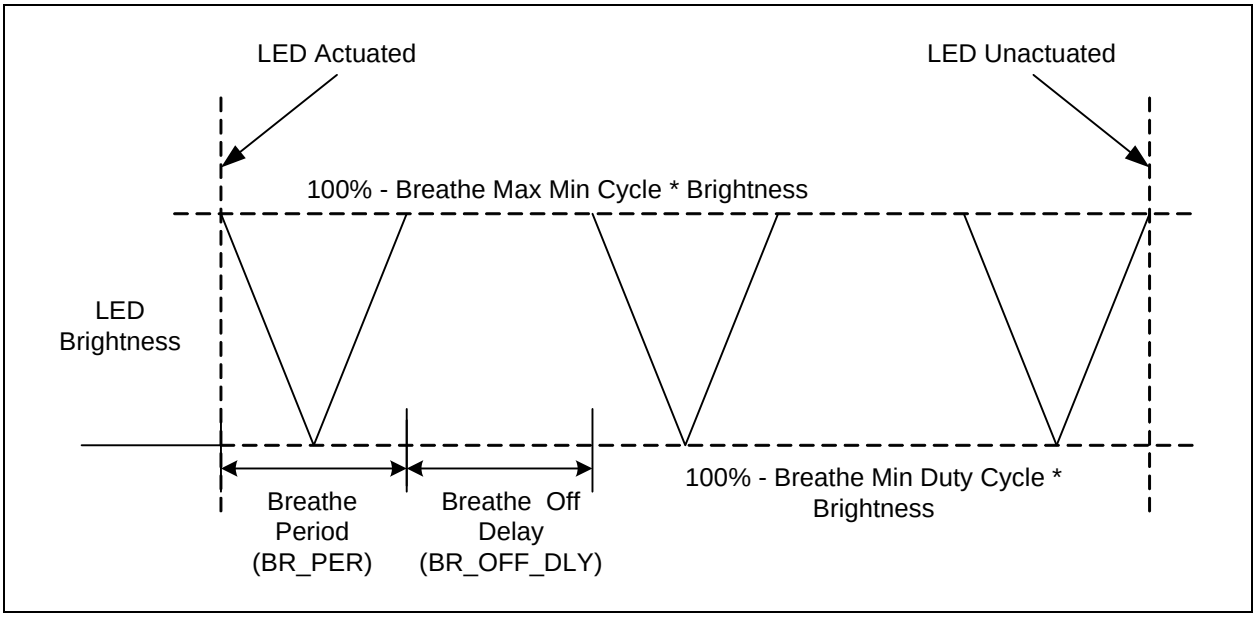
TABLE 6-63: LED OFF DELAY REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
95h	R/W	LED Off Delay Register	-	BR_OFF_DLY[2:0]			DIR_OFF_DLY[3:0]				00h

The LED Off Delay register determines the amount of time that an LED remains at its maximum duty cycle (or minimum as determined by the polarity controls) before it starts to ramp down. If the LED is operating in Breathe mode, this delay is applied at the top of each “breath”. If the LED is operating in the Direct mode, this delay is applied when the LED is unactuated.

Bits 6 - 4 - BR_OFF_DLY[2:0] - Determines the Breathe behavior mode off delay, which is the amount of time an LED in Breathe behavior mode remains inactive after it finishes a breathe pulse (ramp on and ramp off), as shown in Figure 6-5 (non-inverted polarity LEDx_POL = 1) and Figure 6-6 (inverted polarity LEDx_POL = 0). Available settings are shown in Table 6-64.

FIGURE 6-5: *Breathe Behavior with Non-Inverted Polarity*



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FIGURE 6-6: *Breathe Behavior with Inverted Polarity*

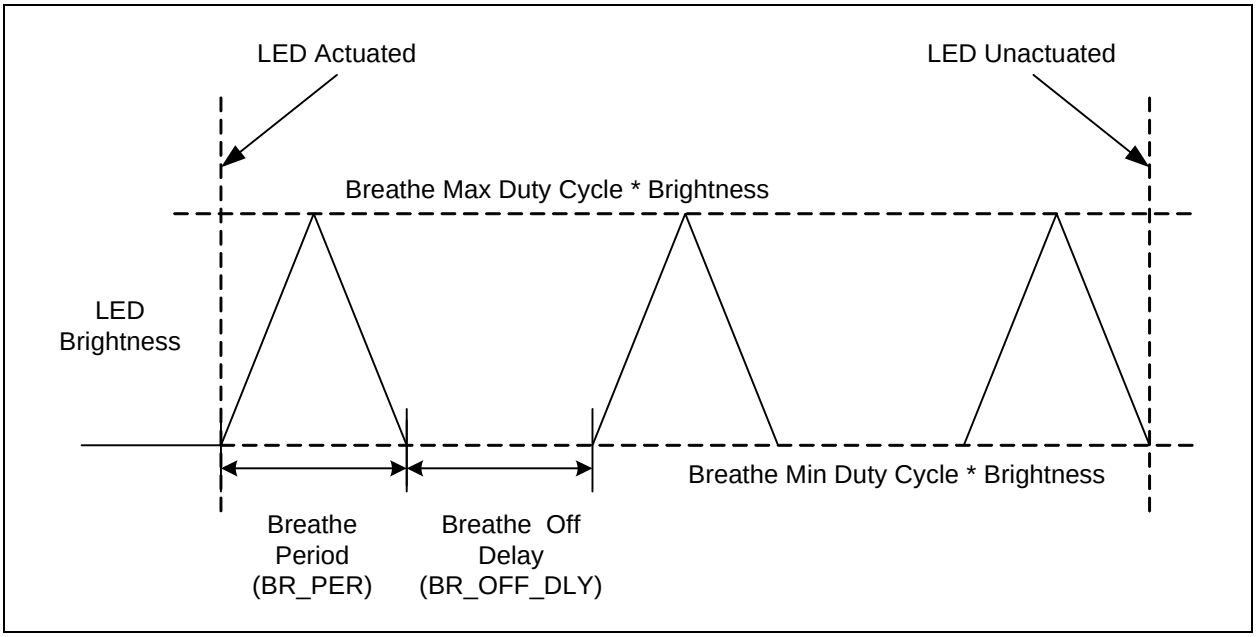


TABLE 6-64: BREATHE OFF DELAY SETTINGS

BR_OFF_DLY [2:0]			OFF Delay
2	**1**	**0**	
0	0	0	0 (default)
0	0	1	0.25s
0	1	0	0.5s
0	1	1	0.75s
1	0	0	1.0s
1	0	1	1.25s
1	1	0	1.5s
1	1	1	2.0s

Bits 3 - 0 - DIR_OFF_DLY[3:0] - Determines the turn-off delay, as shown in Table 6-65, for all LEDs that are configured to operate in Direct behavior mode.

The Direct behavior operation is determined by the combination of programmed Rise Time, Fall Time, Min and Max Duty cycles, Off Delay, and polarity. Figure 6-7 shows the behavior for non-inverted polarity (LEDx_POL = 1) while Figure 6-8 shows the behavior for inverted polarity (LEDx_POL = 0).

FIGURE 6-7: *Direct Behavior for Non-Inverted Polarity*

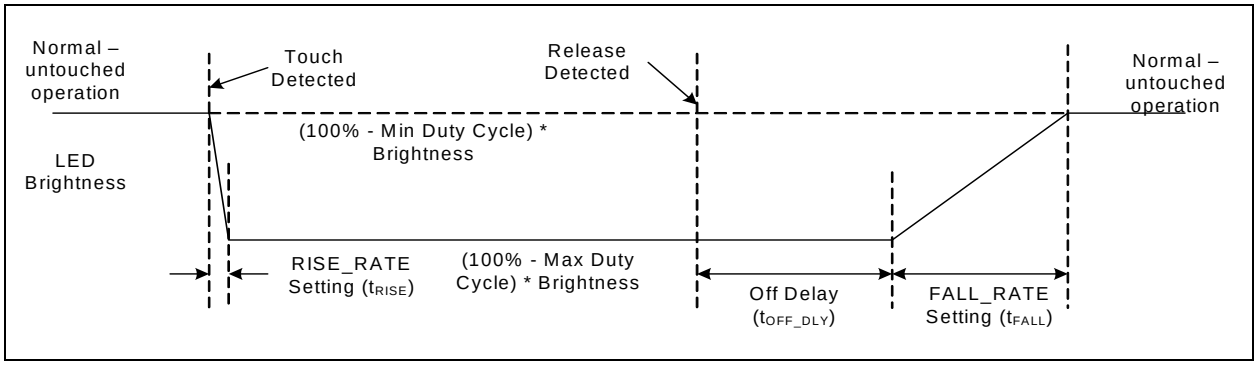


FIGURE 6-8: *Direct Behavior for Inverted Polarity*

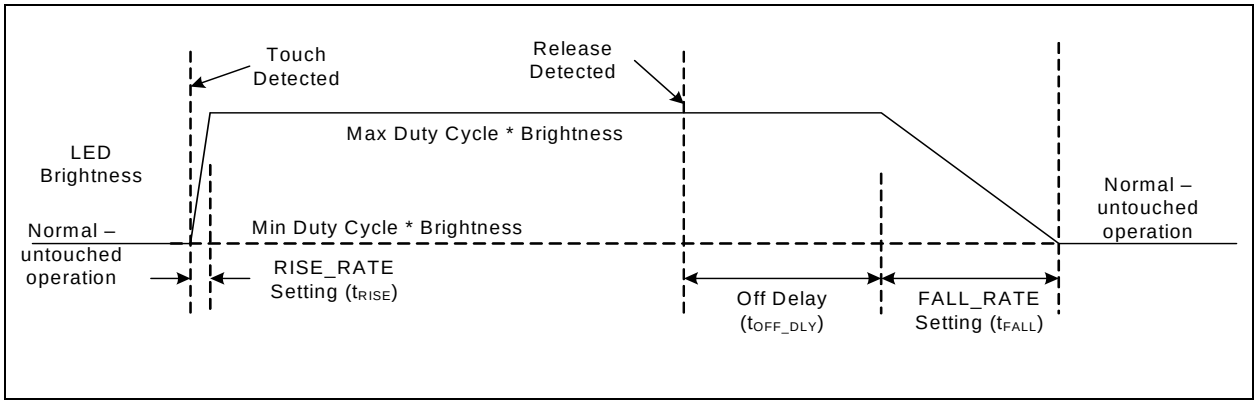


TABLE 6-65: OFF DELAY DECODE

OFF Delay[3:0] Bit Decode				OFF Delay (t_{OFF_DLY})
3	**2**	**1**	**0**	
0	0	0	0	0
0	0	0	1	250ms
0	0	1	0	500ms
0	0	1	1	750ms
0	1	0	0	1s
0	1	0	1	1.25s
0	1	1	0	1.5s
0	1	1	1	2s
1	0	0	0	2.5s
1	0	0	1	3.0s
1	0	1	0	3.5s
1	0	1	1	4.0s
1	1	0	0	4.5s
All others				5.0s

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6.39 Sensor Input Calibration Registers

TABLE 6-66: SENSOR INPUT CALIBRATION REGISTERS

ADDR	Register	R/W	B7	B6	B5	B4	B3	B2	B1	B0	Default
B1h	Sensor Input 1 Calibration	R	CAL1_9	CAL1_8	CAL1_7	CAL1_6	CAL1_5	CAL1_4	CAL1_3	CAL1_2	00h
B2h	Sensor Input 2 Calibration	R	CAL2_9	CAL2_8	CAL2_7	CAL2_6	CAL2_5	CAL2_4	CAL2_3	CAL2_2	00h
B3h	Sensor Input 3 Calibration	R	CAL3_9	CAL3_8	CAL3_7	CAL3_6	CAL3_5	CAL3_4	CAL3_3	CAL3_2	00h
B4h	Sensor Input 4 Calibration	R	CAL4_9	CAL4_8	CAL4_7	CAL4_6	CAL4_5	CAL4_4	CAL4_3	CAL4_2	00h
B5h	Sensor Input 5 Calibration	R	CAL5_9	CAL5_8	CAL5_7	CAL5_6	CAL5_5	CAL5_4	CAL5_3	CAL5_2	00h
B6h	Sensor Input 6 Calibration	R	CAL6_9	CAL6_8	CAL6_7	CAL6_6	CAL6_5	CAL6_4	CAL6_3	CAL6_2	00h
B7h	Sensor Input 7 Calibration	R	CAL7_9	CAL7_8	CAL7_7	CAL7_6	CAL7_5	CAL7_4	CAL7_3	CAL7_2	00h
B8h	Sensor Input 8 Calibration	R	CAL8_9	CAL8_8	CAL8_7	CAL8_6	CAL8_5	CAL8_4	CAL8_3	CAL8_2	00h
B9h	Sensor Input Calibration LSB 1	R	CAL4_1	CAL4_0	CAL3_1	CAL3_0	CAL2_1	CAL2_0	CAL1_1	CAL1_0	00h
BAh	Sensor Input Calibration LSB 2	R	CAL8_1	CAL8_0	CAL7_1	CAL7_0	CAL6_1	CAL6_0	CAL5_1	CAL5_0	00h

The Sensor Input Calibration registers hold the 10-bit value that represents the last calibration value.

6.40 Product ID Register

TABLE 6-67: PRODUCT ID REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
FDh	R	Product ID	0	1	0	1	0	0	1	0	52h

The Product ID register stores a unique 8-bit value that identifies the device.

6.41 Manufacturer ID Register

TABLE 6-68: VENDOR ID REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
FEh	R	Manufacturer ID	0	1	0	1	1	1	0	1	5Dh

The Vendor ID register stores an 8-bit value that represents Microchip.

6.42 Revision Register

TABLE 6-69: REVISION REGISTER

ADDR	R/W	Register	B7	B6	B5	B4	B3	B2	B1	B0	Default
FFh	R	Revision	1	0	0	0	0	0	1	1	83h

The Revision register stores an 8-bit value that represents the part revision.

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7.0 PACKAGE INFORMATION

Note:	For the most current package drawings, see the Microchip Packaging Specification at: http://www.microchip.com/packaging.

7.1 CAP1128 Package Drawings

FIGURE 7-1: *20-Pin QFN 4mm x 4mm Package Drawing*

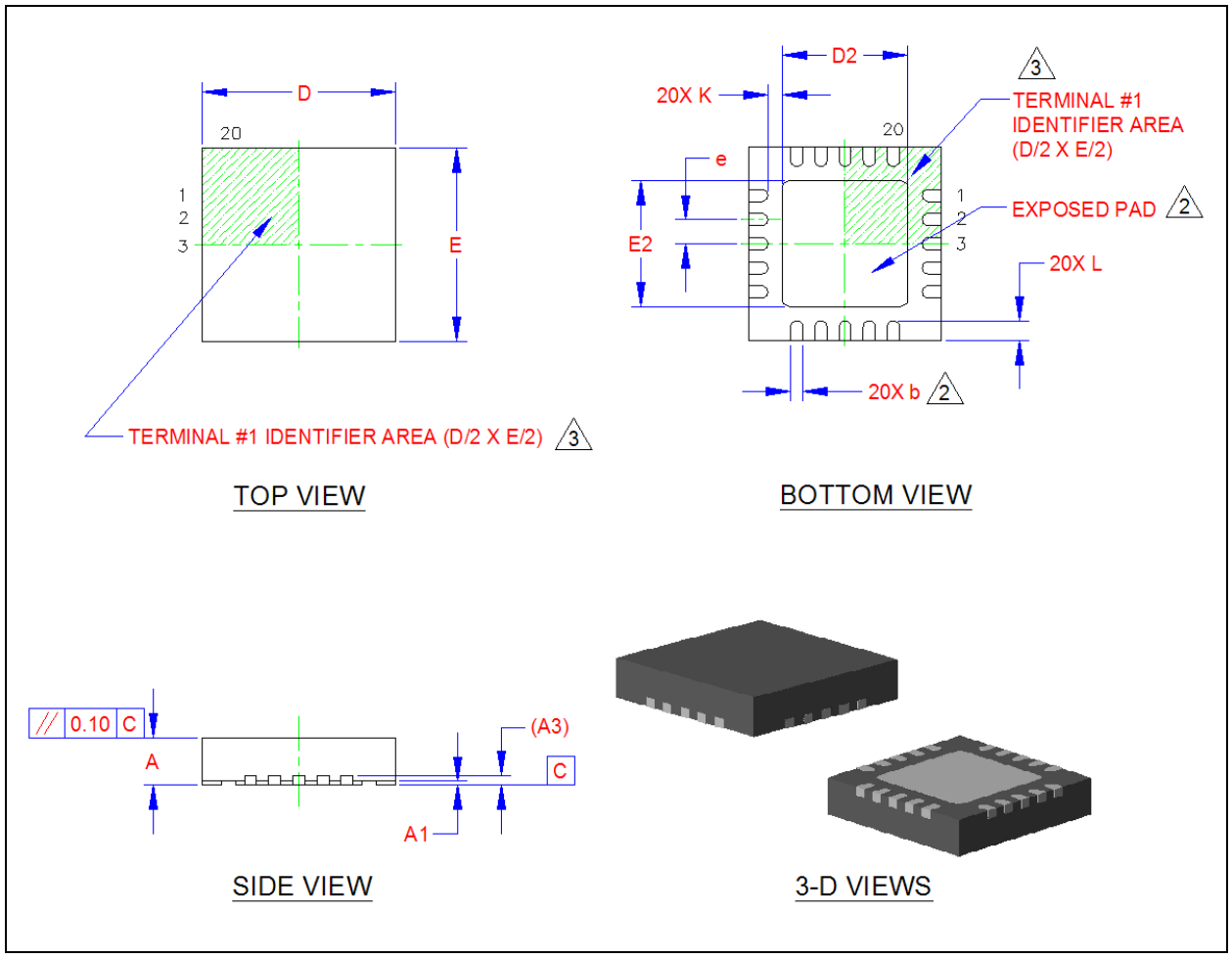
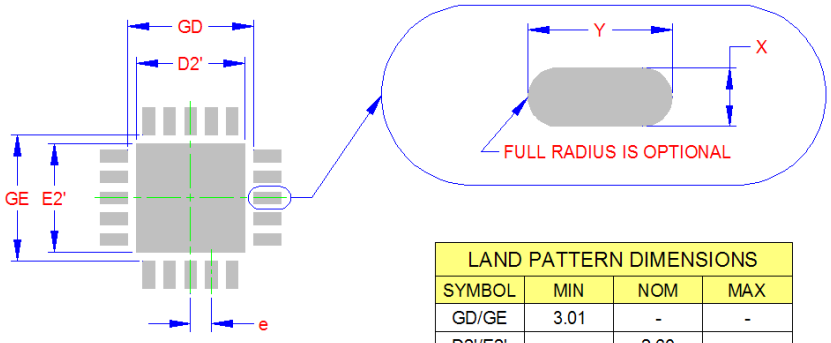


FIGURE 7-2: *20-Pin QFN 4mm x 4mm Package Dimensions*

COMMON DIMENSIONS					
SYMBOL	MIN	NOM	MAX	NOTE	REMARK
A	0.80	0.85	0.90	-	OVERALL PACKAGE HEIGHT
A1	0	0.02	0.05	-	STANDOFF
A3		0.20 REF		-	LEAD-FRAME THICKNESS
D/E	3.90	4.00	4.10	-	X/Y BODY SIZE
D2/E2	2.50	2.60	2.70	2	X/Y EXPOSED PAD SIZE
L	0.35	0.40	0.45	-	TERMINAL LENGTH
b	0.18	0.25	0.30	2	TERMINAL WIDTH
K	0.20	-	-	-	TERMINAL TO PAD DISTANCE
e		0.50 BSC		-	TERMINAL PITCH

NOTES:
1. ALL DIMENSIONS ARE IN MILLIMETERS.
2. POSITION TOLERANCE OF EACH TERMINAL AND EXPOSED PAD IS ± 0.05mm AT MAXIMUM MATERIAL CONDITION. DIMENSIONS "b" APPLIES TO PLATED TERMINALS AND IT IS MEASURED BETWEEN 0.15 AND 0.30 mm FROM THE TERMINAL TIP.
3. DETAILS OF TERMINAL #1 IDENTIFIER ARE OPTIONAL BUT MUST BE LOCATED WITHIN THE AREA INDICATED.

FIGURE 7-3: *20-Pin QFN 4mm x 4mm PCB Drawing*



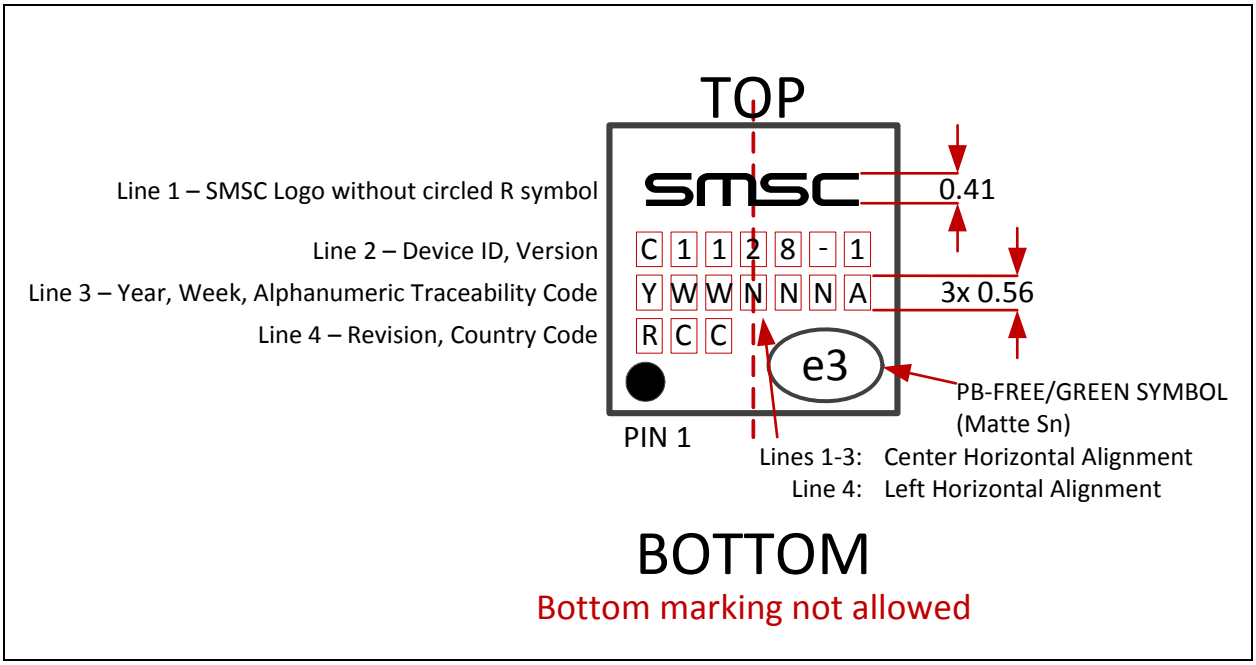
LAND PATTERN DIMENSIONS			
SYMBOL	MIN	NOM	MAX
GD/GE	3.01	-	-
D2'/E2'	-	2.60	-
X	-	-	0.28
Y	-	-	0.65
e		0.50	

RECOMMENDED PCB LAND PATTERN

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7.2 Package Marking

FIGURE 7-4: *CAP1128 Package Markings*



APPENDIX A: DEVICE DELTA

A.1 Delta from CAP1028 to CAP1128

1. Updated circuitry to improve power supply rejection.
2. Updated LED driver duty cycle decode values to have more distribution at lower values - closer to a logarithmic curve. See Table 6-60, "LED Duty Cycle Decode".
3. Updated bug that breathe periods were not correct above 2.6s. This includes rise / fall time decodes above 1.5s.
4. Added filtering on RESET pin to prevent errant resets.
5. Updated controls so that the RESET pin assertion places the device into the lowest power state available and causes an interrupt when released. See Section 5.2, "RESET Pin".
6. Added 1 bit to the LED Off Delay register (see Section 6.38, "LED Off Delay Register") to extend times from 2s to 5s in 0.5s intervals.
7. Breathe behavior modified. A breathe off delay control was added to the LED Off Delay Register (see Section 6.38, "LED Off Delay Register") so the LEDs can be configured to remain inactive between breathes.
8. Added controls for the LED transition effects when linking LEDs to capacitive sensor inputs. See Section 6.29, "Linked LED Transition Control Register".
9. Added controls to “mirror” the LED duty cycle outputs so that when polarity changes, the LED brightness levels look right. These bits are automatically set when polarity is set. Added control to break this auto-set behavior. See Section 6.30, "LED Mirror Control Register".
10. Added Multiple Touch Pattern detection circuitry. See Section 6.15, "Multiple Touch Pattern Configuration Register".
11. Added General Status register to flag Multiple touches, Multiple Touch Pattern issues and general touch detections. See Section 6.2, "Status Registers".
12. Added bits 6 and 5 to the Recalibration Configuration register (2Fh - see Section 6.17, "Recalibration Configuration Register"). These bits control whether the accumulation of intermediate data and the consecutive negative delta counts counter are cleared when the noise status bit is set.
13. Added Configuration 2 register for LED linking controls, noise detection controls, and control to interrupt on press but not on release. Added control to change alert pin polarity. See Section 6.6, "Configuration Registers".
14. Updated Deep Sleep behavior so that device does not clear DSLEEP bit on received communications but will wake to communicate.
15. Changed PWM frequency for LED drivers. The PWM frequency was derived from the programmed breathe period and duty cycle settings and it ranged from ~4Hz to ~8000 Hz. The PWM frequency has been updated to be a fixed value of ~2000Hz.
16. Register delta:

Table A.1 Register Delta From CAP1028 to CAP1128

Address	Register Delta	Delta	Default
00h Page 31	Changed - Main Status / Control	added bits 7-6 to control gain	00h
02h Page 32	New - General Status	new register to store MTP, MULT, LED, RESET, and general TOUCH bits	00h
44h Page 36	New - Configuration 2	new register to control alert polarity, LED touch linking behavior, LED output behavior, and noise detection, and interrupt on release	40h
24h Page 39	Changed - Averaging Control	updated register bits - moved SAMP_AVG[2:0] bits and added SAMP_TIME bit 1. Default changed	39h
2Bh Page 43	New - Multiple Touch Pattern Configuration	new register for Multiple Touch Pattern configuration - enable and threshold settings	80h

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Table A.1 Register Delta From CAP1028 to CAP1128 (continued)

Address	Register Delta	Delta	Default
2Dh Page 44	New - Multiple Touch Pattern Register	new register for Multiple Touch Pattern detection circuitry - pattern or number of sensor inputs	FFh
2Fh Page 44	Changed - Recalibration Configuration	updated register - updated CAL_CFG bit decode to add a 128 averages setting and removed highest time setting. Default changed. Added bit 6 NO_CLR_INTD and bit 5 NO_CLR_NEG.	8Ah
38h Page 46	Changed - Sensor Input Noise Threshold	updated register bits - removed bits 7 - 3 and consolidated all controls into bits 1 - 0. These bits will set the noise threshold for all channels. Default changed	01h
39h	Removed - Noise Threshold Register 2	removed register	n/a
41h Page 47	Changed - Standby Configuration	updated register bits - moved STBY_AVG[2:0] bits and added STBY_TIME bit 1. Default changed	39h
77h Page 52	New - Linked LED Transition Control	new register to control transition effect when LED linked to sensor inputs	00h
79h Page 53	New - LED Mirror Control	new register to control LED output mirroring for brightness control when polarity changed	00h
90h Page 58	Changed - LED Pulse 1 Duty Cycle	changed bit decode to be more logarithmic	F0h
91h Page 58	Changed - LED Pulse 2 Duty Cycle	changed bit decode to be more logarithmic	F0h
92h Page 58	Changed - LED Breathe Duty Cycle	changed bit decode to be more logarithmic	F0h
93h Page 58	Changed - LED Direct Duty Cycle	changed bit decode to be more logarithmic	F0h
95h	Added controls - LED Off Delay	Added bits 6-4 BR_OFF_DLY[2:0] Added bit 3 DIR_OFF_DLY[3]	00h
FDh Page 63	Changed - Product ID	Changed bit decode for CAP1128	52h

APPENDIX B: DATA SHEET REVISION HISTORY

Revision	Section/Figure/Entry	Correction
DS00001622B (02-09-15)	Features, Table 2-1, Table 2-2, "Pin Types", Section 5.0, "General Description"	References to BC-Link Interface, BC_DATA, BC_-CLK, BC-IRQ#, BC-Link bus have been removed
	Application Note under Table 2-6	[BC-Link] hidden in data sheet
	Table 3-2, "Electrical Specifications"	BC-Link Timing Section hidden in data sheet
	Table 4-1	Protocol Used for 68K Pull Down Resistor changed from “BC-Link Communications” to “Reserved”
	Section 4.2.2, "SMBus Address and RD / WR Bit"	Replaced “client address” with “slave address” in this section.
	Section 4.2.4, SMBus ACK and NACK Bits, Section 4.2.5, SMBus Stop Bit,Section 4.2.7, SMBus and I2C Compatibility	Replaced “client” with “slave” in these sections.
	Table 4-4, "Read Byte Protocol"	Heading changed from “Client Address” to “Slave Address”
	Table 6-1	Register Name for Register Address 77h changed from “LED Linked Transition Control” to “Linked LED Transition Control”
	Section 6.30	changed CS2 to LED2
	Section 7.7 Package Marking	Updated package drawing
	Appendix A: Device Delta	changed 2Dh to 2Fh in item #12
	Product Identification System	Removed BC-Link references
REV A	REV A replaces previous SMSC version Rev. 1.32 (01-05-12)	
Rev. 1.32 (01-05-12)	Table 3-2, "Electrical Specifications"	Added conditions for $t_{HD:DAT}$.
	Section 4.2.7, "SMBus and I2C Compatibility"	Renamed from “SMBus and I2C Compliance.” First paragraph, added last sentence: “For information on using the CAP1188 in an I^2C system, refer to SMSC AN 14.0 SMSC Dedicated Slave Devices in I^2C Systems.” Added: CAP1188 supports I^2C fast mode at 400kHz. This covers the SMBus max time of 100kHz.
	Section 6.4, "Sensor Input Delta Count Registers"	Changed negative value cap from FFh to 80h.
Rev. 1.31 (08-18-11)	Section 4.3.3, "SMBus Send Byte"	Added an application note: The Send Byte protocol is not functional in Deep Sleep (i.e., DSLEEP bit is set).
	Section 4.3.4, "SMBus Receive Byte"	Added an application note: The Receive Byte protocol is not functional in Deep Sleep (i.e., DSLEEP bit is set).
Rev. 1.3 (05-18-11)	Section 6.42, "Revision Register"	Updated revision ID from 82h to 83h.
Rev. 1.2 (02-10-11)	Section A.8, "Delta from Rev B (Mask B0) to Rev C (Mask B1)"	Added.
	Table 2-1, "Pin Description for CAP1128"	Changed value in “Unused Connection” column for the ADDR_COMM pin from “Connect to Ground” to “n/a“.

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Revision	Section/Figure/Entry	Correction
	Table 3-2, "Electrical Specifications"	PSR improvements made in functional revision B. Changed PSR spec from ±100 typ and ±200 max counts / V to ±3 and ±10 counts / V. Conditions updated.
	Section 5.5.2, "Recalibrating Sensor Inputs"	Added more detail with subheadings for each type of recalibration.
	Section 6.6, "Configuration Registers"	Added bit 5 BLK_PWR_CTRL to the Configuration 2 Register 44h. The TIMEOUT bit is set to '1' by default for functional revision B and is set to '0' by default for functional revision C.
	Section 6.42, "Revision Register"	Updated revision ID in register FFh from 81h to 82h.
Rev. 1.1 (11-17-10)	Document	Updated for functional revision B. See Section A.7, "Delta from Rev A (Mask A0) to Rev B (Mask B0)".
	Cover	Added to General Description: "includes circuitry and support for enhanced sensor proximity detection." Added the following Features: Calibrates for Parasitic Capacitance Analog Filtering for System Noise Sources Press and Hold feature for Volume-like Applications
	Table 3-2, "Electrical Specifications"	Conditions for Power Supply Rejection modified adding the following: Sampling time = 2.56ms Averaging = 1 Negative Delta Counts = Disabled All other parameters default
	Section 6.11, "Calibration Activate Register"	Updated register description to indicate which re-calibration routine is used.
	Section 6.14, "Multiple Touch Configuration Register"	Updated register description to indicate what will happen.
	Table 6-34, "CSx_BN_TH Bit Decode"	Table heading changed from "Threshold Divide Setting" to "Percent Threshold Setting".
Rev. 1.0 (06-14-10)	Initial release	

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PART NO.	[X]	-	1	-	XXX	-	[X](1)
Device	Temperature Range				Package		Tape and Reel Option

Device:	CAP1128
Temperature Range:	Blank = 0°C to +85°C (Extended Commercial)
Package:	BP = QFN
Tape and Reel Option:	TR = Tape and Reel(1)

Example:

CAP1128-1-BP-TR
20-pin QFN 4mm x 4mm (RoHS compliant)
Eight capacitive touch sensor inputs, Two LED drivers, Dedicated Wake, Reset, SMBus / BC-Link / SPI interfaces
Reel size is 4,000 pieces

Note 1: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

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