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CAP1114

Multiple Channel Capacitive Touch Sensor and LED Driver

PRODUCT FEATURES

Datasheet

General Description

The CAP1114, which incorporates SMSC's RightTouch™[1] technology, is a multiple channel Capacitive Touch sensor and LED Driver.

The CAP1114 contains up to fourteen (14) individual Capacitive Touch sensor inputs with programmable sensitivity for use in touch button and slider switch applications. Each sensor also contains automatic recalibration with programmable time delays.

The CAP1114 also includes internal circuitry to compensate for design and parasitic variance in un-touched capacitance on sensors.

The CAP1114 also contains eleven (11) low side LED drivers that offer full-on / off, variable rate blinking, dimness controls, and breathing. Capacitive buttons can be linked to LED outputs.

Applications

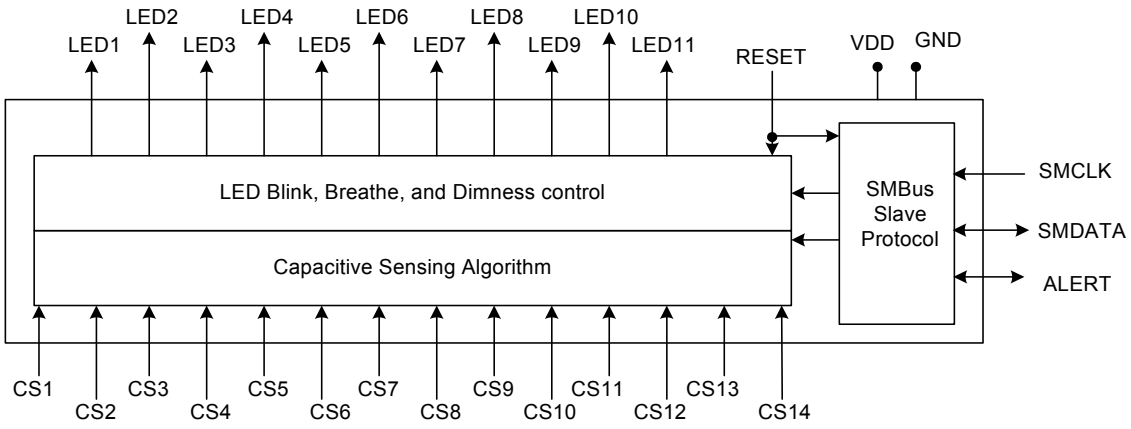
- Consumer Electronics
- Desktop and Notebook PCs
- LCD Monitors

1. SMSC and the SMSC logo are registered trademarks and SMSC RightTouch and the RightTouch logo are trademarks of Standard Microsystems Corporation ("SMSC").

Features

- Fourteen (14) capacitive touch sensor inputs
  - Compensates for variable sensor capacitance
  - Programmable sensitivity
  - High SNR allows for easy tuning
  - Automatic recalibration
  - Slider acceleration detection
  - Slider positional detection
  - Proximity detection
- Lid closure detection
- Low power operation
  - 4.5uA quiescent current in Deep Sleep
  - 200uA quiescent current in Sleep while monitoring 1 button
- Alert to signal touch to host processor
- User controlled reset
- Low external component count
- SMBus 2.0 compliant interface to change operating parameters to work in a wide variety of systems
  - Block Read and Write function for quick tasking
- Eleven (11) LED driver outputs
  - Programmable blink, breathe, and dimness controls
  - 8 configurable as GPIOs
  - Buttons can be linked to LED responses
- Development boards and software available
- Available in 32-pin 5mm x 5mm QFN Lead-free RoHS Compliant package

Block Diagram



ORDER NUMBER(S):

ORDERING NUMBER	PACKAGE	FEATURES
CAP1114-1-EZK-TR	32-pin QFN 5mm x 5mm (Lead Free RoHS compliant)	Fourteen Capacitive Touch Sensors. Eleven LED drivers. SMBus communications.

REEL SIZE IS 4,000 PIECES

This product meets the halogen maximum concentration values per IEC61249-2-21

For RoHS compliance and environmental information, please visit www.smsc.com/rohs

Please contact your SMSC sales representative for additional documentation related to this product such as application notes, anomaly sheets, and design guidelines.

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Chapter 1 Delta from CAP1014 to CAP1114

1.1 Summary

1. Updated circuitry to reduce sensitivity to power supply stepping.
2. Updated LED Pulse 1 behavior. This function may be triggered on button press or on release. See Section 6.49.
3. Updated Product ID to 3Ah.
4. Updated LED behavior for host control during direct mode when not linked. The LED Output register will now be able to be written to emulate a touch or release. Enables all behaviors while in host mode. See Section 6.43 and Section .
5. Updated recalibration controls to add negative delta count. See Section 6.27.
6. Removed ACAL_RT bits.
7. Added digital controls to disable the slider functionality but still detect basic touches essentially bypassing the slider algorithms entirely. See Section 6.33.
8. Added controls to enable individual buttons in the slider. See Section 6.34.
9. Updated button interrupt schemes to allow interrupt on press only, not on release. Retained previous behavior as default. See Figure 5.2, Figure 5.3, and Section 5.7.1. Retained previous behavior as default. See Section 6.27.
10. Updated Noise Threshold default settings to ~25%. See Section 6.29.
11. Added control bit and status registers to enable interrupt when LEDs finish their directed behavior in the same fashion. See Section 6.52 and Section 6.39.
12. Updated LED driver duty cycle decode values to have more distribution at lower values - closer to a logarithmic curve. See Section 6.53.
13. Renamed D_DSP[3:0] and C_DSP[3:0] to DELTA_SENSE[2:0] and BASE_SHIFT[3:0]. D_DSP[3] did nothing so removed references. See Section 6.13.
14. Added filtering on RESET pin to prevent errant resets. The RESET pin must be high or low for longer than 10ms before it will be detected by the device. See Section 8.6.
15. Added proximity to CS1 channel.
16. Updated Deep Sleep to wake on communications. See Section 5.1.
17. Updated controls so that the RESET pin assertion places the device into the lowest power state available. See Section 5.2 and Section 5.1.
18. Added LED transition controls that affect the LED behavior when a Capacitive Touch Sensor is linked to an LED channel to remove bouncing. See Section 6.45.
19. Added controls to “mirror” the LED duty cycle outputs so that when polarity changed, the LED brightness levels look right. See Section 6.46.
20. Added register to force digital recalibration of all sensors. See Section 6.32.
21. Added register to enable oversampling on specific sensors. See Section 6.35 and Section 6.37.
22. 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.

1.2 Register Delta

Table 1.1 Register Delta

ADDRESS	REGISTER DELTA	DELTA	DEFAULT
05h	Changed - Build Revision	Reset build revision to 10h	10h
20h	Changed - Configuration	Changed functionality of RPT_EN_B bit. Changed default	29h
2Fh	Changed - Recalibration Configuration	Removed ACAL_RT[1:0] bits and replaced with NEG_CNT[1:0] bits. These bits control recalibration when negative counts are received.	93h
38h	Changed - Button Noise Threshold 1	Changed default	AAh
39h	Changed - Button Noise Threshold 2	Changed default	AAh
3Fh	New - Digital Recalibration	New register to force digital recalibration on all sensors	00h
40h	New - Configuration 2	New register to control LED touch linking behavior, LED output behavior, and noise detection, and interrupt on release	00h
41h	New - Grouped Channel Sensor Enable	New register to enable individual sensors within the grouped sensors	7Fh
42h	New - Proximity Control	New register to enable / configure proximity settings on CS1	02h
46h	New - Group Button Calibration Activate	New register to force calibration on individual grouped sensors	00h
4Eh	New - Sampling Channel Select	New register to select which channels can be controlled via the Sampling Configuration register	00h
60h	New - LED Status 1	New register to store status for LEDs that have finished their programmed behavior	00h
61h	New - LED Status 2	New register to store status for LEDs that have finished their programmed behavior	00h
77h	New - Linked LED Transition Control 1	New register to control transition effect when LED linked to CS sensor	00h
78h	New - Linked LED Transition Control 2	New register to control transition effect when LED linked to CS sensor	00h
79h	New - LED Mirror Control 1	New register to control LED output mirroring for brightness control when polarity changed	00h
7Ah	New - LED Mirror Control 2	New register to control LED output mirroring for brightness control when polarity changed	00h

Table 1.1 Register Delta (continued)

ADDRESS	REGISTER DELTA	DELTA	DEFAULT
90h	Changed - LED Pulse 1 Duty Cycle	Changed bit decode to be more logarithmic	F0h
91h	Changed - LED Pulse 2 Duty Cycle	Changed bit decode to be more logarithmic	F0h
92h	Changed - LED Breathe Duty Cycle	Changed bit decode to be more logarithmic	F0h
93h	Changed - LED Direct Duty Cycle	Changed bit decode to be more logarithmic	F0h
FDh	Changed - Product ID	Changed bit decode for CAP1114	3Ah
FEh	Added - Manufacturer ID	Added - this register mirrors the Vendor ID	5Dh

Chapter 2 Pin Description

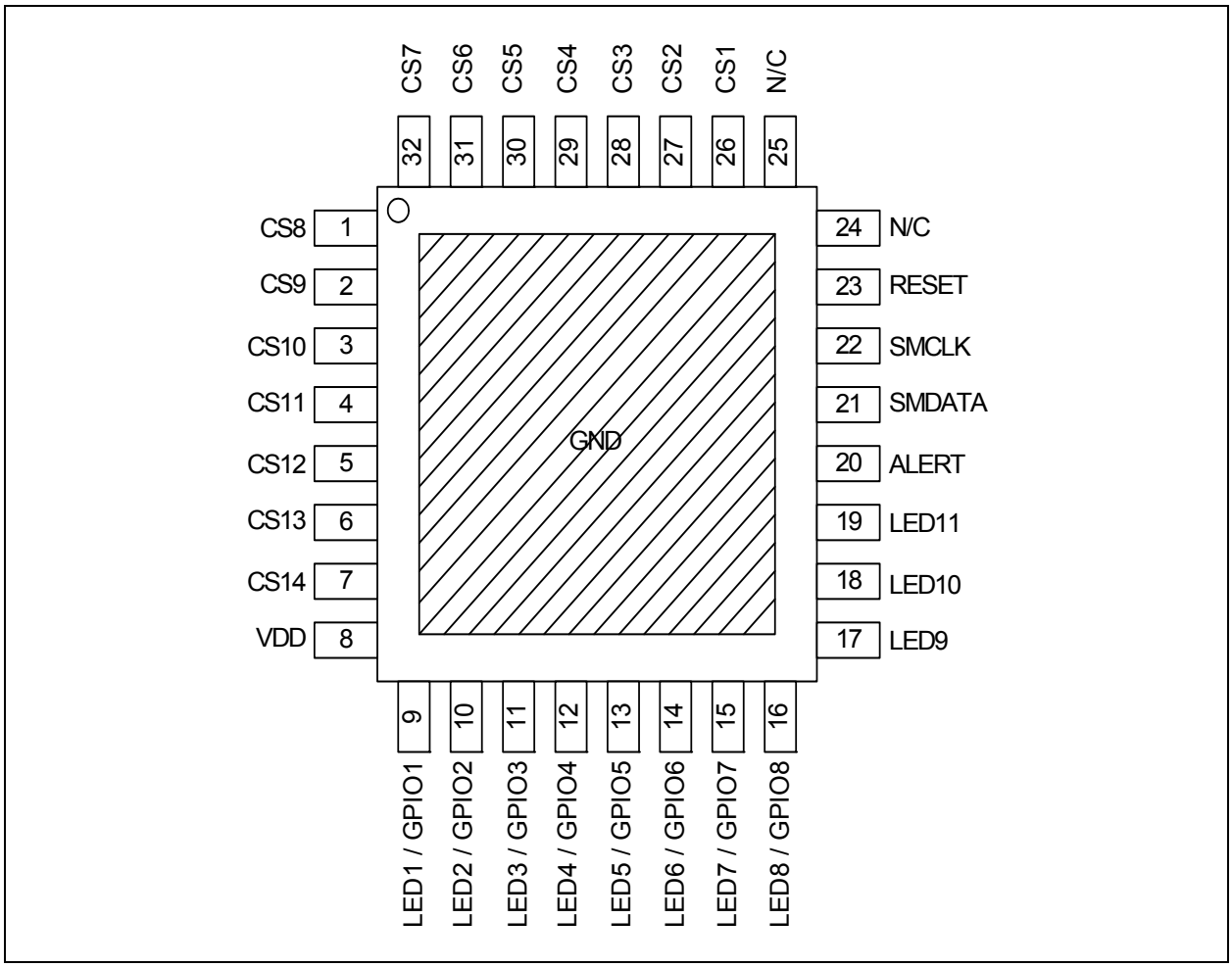

Figure 2.1 CAP1114 Pin Diagram (32-Pin QFN)

Table 2.1 Pin Description for CAP1114

PIN NUMBER	PIN NAME	PIN FUNCTION	PIN TYPE
1	CS8	Capacitive Touch Sensor 8	AIO
2	CS9	Capacitive Touch Sensor 9	AIO
3	CS10	Capacitive Touch Sensor 10	AIO
4	CS11	Capacitive Touch Sensor 11	AIO
5	CS12	Capacitive Touch Sensor 12	AIO
6	CS13	Capacitive Touch Sensor 13	AIO
7	CS14	Capacitive Touch Sensor 14	AIO

Table 2.1 Pin Description for CAP1114 (continued)

PIN NUMBER	PIN NAME	PIN FUNCTION	PIN TYPE
8	VDD	Positive Power supply	Power
9	LED1 / GPIO1	LED1 - Open drain LED driver (default)	OD (5V)
		GPI1 - GPIO 1 Input	DI (5V)
		GPO1 - GPIO 1 push-pull output	DO
10	LED2 / GPIO 2	LED2 - Open drain LED driver (default)	OD (5V)
		GPI2 - GPIO 2 Input	DI (5V)
		GPO2 - GPIO 2 push-pull output	DO
11	LED3 / GPIO3	LED3 - Open drain LED driver (default)	OD (5V)
		GPI3 - GPIO 3 Input	DI (5V)
		GPO3 - GPIO 3 push-pull output	DO
12	LED4 / GPIO4	LED4 - Open drain LED driver (default)	OD (5V)
		GPI4 - GPIO 4 Input	DI (5V)
		GPO4 - GPIO 4 push-pull output	DO
13	LED5 / GPIO5	LED5 - Open drain LED driver (default)	OD (5V)
		GPI5 - GPIO 5 Input	DI (5V)
		GPO5 - GPIO 5 push-pull output	DO
14	LED6 / GPIO6	LED6 - Open drain LED driver (default)	OD (5V)
		GPI6 - GPIO 6 Input	DI (5V)
		GPO6 - GPIO 6 push-pull output	DO
15	LED7 / GPIO7	LED7 - Open drain LED driver (default)	OD (5V)
		GPI7 - GPIO 7 Input	DI (5V)
		GPO7 - GPIO 7 push-pull output	DO
16	LED8 / GPIO8	LED8 - Open drain LED driver (default)	OD (5V)
		GPI8 - GPIO 8 Input	DI (5V)
		GPO8 - GPIO 8 push-pull output	DO
17	LED9	LED9 - Open drain LED driver	OD (5V)
18	LED10	LED10 - Open drain LED driver	OD (5V)
19	LED11	LED11 - Open drain LED driver	OD (5V)
20	ALERT	Active High Interrupt / Wake Up Input	DIO
21	SMDATA	Bi-directional SMBus data - requires a pull-up resistor	DIOD (5V)
22	SMCLK	SMBus clock input - requires a pull-up resistor	DI (5V)
23	RESET	Soft reset for system - resets all registers to default values	DI (5V)

Table 2.1 Pin Description for CAP1114 (continued)

PIN NUMBER	PIN NAME	PIN FUNCTION	PIN TYPE
24	N/C	Not Connected - connect to gnd	N/A
25	N/C	Not Connected - connect to gnd	N/A
26	CS1	Capacitive Touch Sensor 1	AIO
27	CS2	Capacitive Touch Sensor 2	AIO
28	CS3	Capacitive Touch Sensor 3	AIO
29	CS4	Capacitive Touch Sensor 4	AIO
30	CS5	Capacitive Touch Sensor 5	AIO
31	CS6	Capacitive Touch Sensor 6	AIO
32	CS7	Capacitive Touch Sensor 7	AIO
Bottom Plate	GND	Power Ground	Power

The pin types are described in Table 2.2, "Pin Types". All pins labeled with (5V) are 5V tolerant.

Note: For all 5V tolerant pins that require a pull-up resistor, the voltage difference between VDD and the pull-up voltage must never exceed 3.6V.

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.
DIO	Digital Input Output - this pin is used as a digital input / output.
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 an 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.

Chapter 3 Electrical Specifications

Table 3.1 Absolute Maximum Ratings

Voltage on VDD pin	-0.3 to 4	V
Voltage on 5V tolerant pins (V_{5VT_PIN})	-0.3 to 5.5	V
Voltage on 5V tolerant pins ($\|V_{5VT\_PIN} - V_{DD}\|$) (see Note 3.1)	0 to 3.6	V
Voltage on any other pin to GND	-0.3 to VDD + 0.3	V
Package Power Dissipation up to T_A = 85°C (see Note 3.2)	1	W
Junction to Ambient (θ_{JA}) (see Note 3.3)	48	°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: 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 3.1 For the 5V tolerant pins that have a pull-up resistor, the pull-up voltage must not exceed 3.6V when the device is unpowered.

Note 3.2 The Package Power Dissipation specification assumes a thermal via design with the thermal landing be soldered to the PCB ground plane with 0.3mm (12mil) diameter vias in a 4x4 matrix at 0.9mm (35.4mil) pitch.

Note 3.3 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.

Table 3.2 Electrical Specifications

V_{DD} = 3V to 3.6V, T_A = -40°C to 125°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_{DD}		0.55	1	mA	Average current Capacitive Sensing Active, LEDs enabled
	I_{SLEEP}		200	250	uA	Sleep state active, 1 sensor monitored; LED11 inactive T_A < 85°C
	I_{DSLEEP}		4.5	10	uA	Deep Sleep, LED 11 inactive T_A < 40°C
Time to Communications	t_{COMM}		15	20	ms	Time from power applied to communications active

Table 3.2 Electrical Specifications (continued)

V_{DD} = 3V to 3.6V, T_A = -40°C to 125°C, all Typical values at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNIT**	**CONDITIONS**
Time to First Conversion	t_{CONV}		400	500	ms	Time from power applied to first sensor sampled
Capacitive Touch Sensor						
Base Capacitance	C_{BASE}	5	15	50	pF	Pad untouched
Detectable Capacitive Shift	ΔC_{TOUCH}	0.1	0.4	2	pF	Pad touched
Sample Time	t_{TOUCH}		2.5		ms	
Update Time	Δt_{TOUCH}		35		ms	
Recalibration Interval	Δt_{CAL}		8		s	Automatic Recalibration active, no touch active, default settings
LED / GPIO Drivers (LED / GPIO 1 - 8)						
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
Input High Voltage	V_{IH}	2.0			V	LED / GPIO configured as input
Input Low Voltage	V_{IL}			0.8	V	LED / GPIO configured as input
LED Drivers (LED 9 - LED 10)						
Duty Cycle	$DUTY_{LED}$	0		100	%	Programmable
Drive Frequency	f_{LED}		2		kHz	
Sinking Current	I_{SINK}			24	mA	
Output Low Voltage	V_{OL}			0.4	V	I_{SINK} = 24mA
LED11 Driver						
Duty Cycle	$DUTY_{LED}$	0		100	%	Programmable
Drive Frequency	f_{LED}		2		kHz	
Sinking Current	I_{SINK}			48	mA	
Output Low Voltage	V_{OL}			0.4	V	I_{SINK} = 48mA
I/O Pins - SMDATA, SMCLK, and ALERT Pins						
Output Low Voltage	V_{OL}			0.4	V	I_{SINK_IO} = 8mA
Output High Voltage	V_{OH}	V_{DD} - 0.4			V	ALERT pin active high and asserted I_{SOURCE_IO} = 8mA
Input High Voltage	V_{IH}	2.0			V	

Table 3.2 Electrical Specifications (continued)

V_{DD} = 3V to 3.6V, T_A = -40°C to 125°C, all Typical values at T_A = 27°C unless otherwise noted.						
CHARACTERISTIC	**SYMBOL**	**MIN**	**TYP**	**MAX**	**UNIT**	**CONDITIONS**
Input Low Voltage	V_{IL}			0.8	V	
Leakage Current	I_{LEAK}			±5	uA	powered or unpowered TA < 85°C pull-up voltage ≤ 3.6V
RESET Pin						
Input High Voltage	V_{IH}	2.0			V	
Input Low Voltage	V_{IL}			0.8	V	
RESET Filter Time	t_{RST_FILT}	10			ms	
RESET Pin release to fully active operation	t_{RST_ON}		400	500	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 Start to Stop	t_{BUF}	1.3			us	
Setup Time: Start	$t_{SU:STA}$	0.6			us	
Setup Time: Stop	$t_{SU:STP}$	0.6			us	
Data Hold Time	$t_{HD:DAT}$	0.6		6	us	
Data Setup Time	$t_{SU:DAT}$	0.6		72	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

Chapter 4 Communications

The CAP1114 communicates via the SMBus or I^2C communications protocols.

APPLICATION NOTE: Upon power up, the CAP1114 will not respond to any SMBus communications for 10ms. After this time, full functionality is available.

4.1 System Management Bus Protocol

The CAP1114 communicates with a host controller, such as an SMSC 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 CAP1114 will not stretch the clock signal.

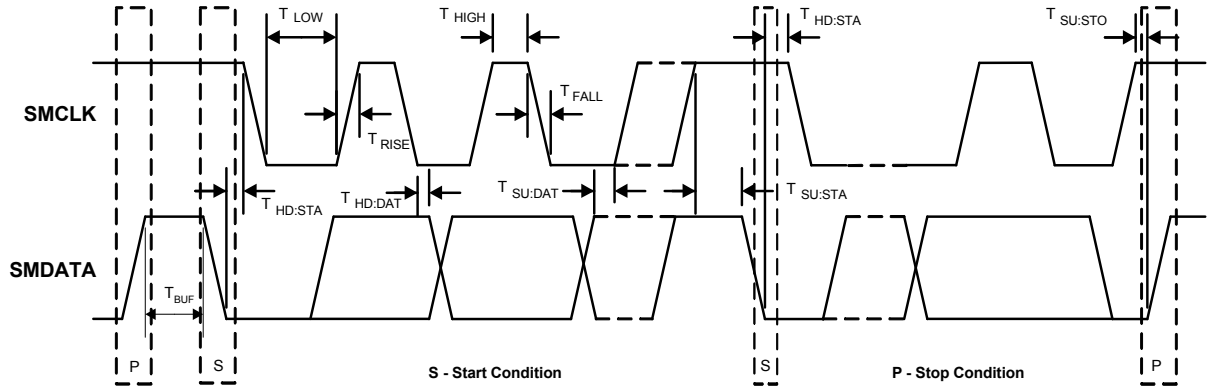

Figure 4.1 SMBus Timing Diagram

4.1.1 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.

4.1.2 SMBus Address and RD / $\overline{WR}$ Bit

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

The CAP1114 responds to the slave address 0101_000xb. Multiple addressing options are available. For more information contact SMSC.

4.1.3 SMBus Data Bytes

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

4.1.4 SMBus ACK and NACK Bits

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

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

4.1.5 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 CAP1114 detects an SMBus Stop bit, and it has been communicating with the SMBus protocol, it will reset its client interface and prepare to receive further communications.

4.1.6 SMBus Time-out

The CAP1114 includes an SMBus time-out feature. Following a 30ms period of inactivity on the SMBus where the SMCLK pin is held low, the device will time-out and reset the SMBus interface.

The time-out function defaults to disabled. It can be enabled by setting the TIMEOUT bit in the Configuration register (see Section 6.14).

4.1.7 SMBus and I^{2}C Compliance

The major difference between SMBus and I^{2}C devices is highlighted here. For complete compliance information, refer to the SMBus 2.0 specification.

1. Minimum frequency for SMBus communications is 10kHz.
2. The client protocol will reset if the clock is held low longer than 30ms.
3. Except when operating in Deep Sleep, the client protocol will reset if both the clock and the data line are high for longer than 150us (idle condition).
4. I^{2}C devices do not support the Alert Response Address functionality (which is optional for SMBus).

4.2 SMBus Protocols

The CAP1114 is SMBus 2.0 compatible and supports Send Byte, Read Byte, Block Read, Receive Byte as valid protocols as shown below. The CAP1114 also supports the I^{2}C block read and block write protocols.

All of the below protocols use the convention in Table 4.1.

Table 4.1 Protocol Format

DATA SENT TO DEVICE	DATA SENT TO THE HOST
Data sent	Data sent

4.2.1 SMBus Write Byte

The Write Byte is used to write one byte of data to a specific register as shown in Table 4.2.

Table 4.2 Write Byte Protocol

START	CLIENT ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	REGISTER DATA	ACK	STOP
1 ->0	0101_000	0	0	XXh	0	XXh	0	0 -> 1

4.2.2 Block Write

The Block Write is used to write multiple data bytes to a group of contiguous registers as shown in Table 4.3. It is an extension of the Write Byte Protocol.

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 4.3 Block Write Protocol

START	CLIENT ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	REGISTER DATA	ACK
1 ->0	0101_000	0	0	XXh	0	XXh	0
REGISTER DATA	**ACK**	**REGISTER DATA**	**ACK**	**. . .**	**REGISTER DATA**	**ACK**	**STOP**
XXh	0	XXh	0	. . .	XXh	0	0 -> 1

4.2.3 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	CLIENT ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	START	CLIENT ADDRESS	RD	ACK	REGISTER DATA	NACK	STOP
1->0	0101_000	0	0	XXh	0	1 ->0	0101_000	1	0	XXh	1	0 -> 1

4.2.4 Block Read

The Block Read is used to read multiple data bytes from a group of contiguous registers as shown in Table 4.5. It is an extension of the Read Byte Protocol.

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 4.5 Block Read Protocol

START	CLIENT ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	START	CLIENT ADDRESS	RD	ACK	REGISTER DATA
1->0	0101_000	0	0	XXh	0	1 ->0	0101_000	1	0	XXh
ACK	**REGISTER DATA**	**ACK**	**REGISTER DATA**	**ACK**	**REGISTER DATA**	**ACK**	**. . .**	**REGISTER DATA**	**NACK**	**STOP**
0	XXh	0	XXh	0	XXh	0	. . .	XXh	1	0 -> 1

4.2.5 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 4.6.

Table 4.6 Send Byte Protocol

START	CLIENT ADDRESS	WR	ACK	REGISTER ADDRESS	ACK	STOP
1 -> 0	0101_000	0	0	XXh	0	0 -> 1

4.2.6 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 4.7.

Table 4.7 Receive Byte Protocol

START	CLIENT ADDRESS	RD	ACK	REGISTER DATA	NACK	STOP
1 -> 0	0101_000	1	0	XXh	1	0 -> 1

Chapter 5 Product Description

The CAP1114 is a multiple channel Capacitive Touch sensor and LED Driver.

The CAP1114 contains up to 14 individual Capacitive Touch sensor inputs with programmable sensitivity for use in touch button and slider switch applications. Each sensor also contains automatic recalibration.

The CAP1114 also contains eleven (11) open drain LED drivers that offer full-on / off, variable rate breathing, and dimness controls. Eight (8) of these LEDs can double as GPIOs and support open-drain or push-pull operation. Capacitive buttons can be linked to LED outputs. Additionally, LEDs 1-7 may be optionally linked to Buttons 1-7 so that when a touch is detected, the LED is actuated.

The device communicates with a host controller using SMBus. 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 press is detected on any sensor.

Each sensor is polled by the device approximately every 35 ms. The host may also initiate a recalibration routine for one or more sensors or set up times and conditions so that the device automatically invokes the re-calibration routine.

The CAP1114 contains multiple power states including several low power operating states. In addition, it contains a user driven RESET pin to force the device to reset.

A typical system diagram is shown in Figure 5.1.

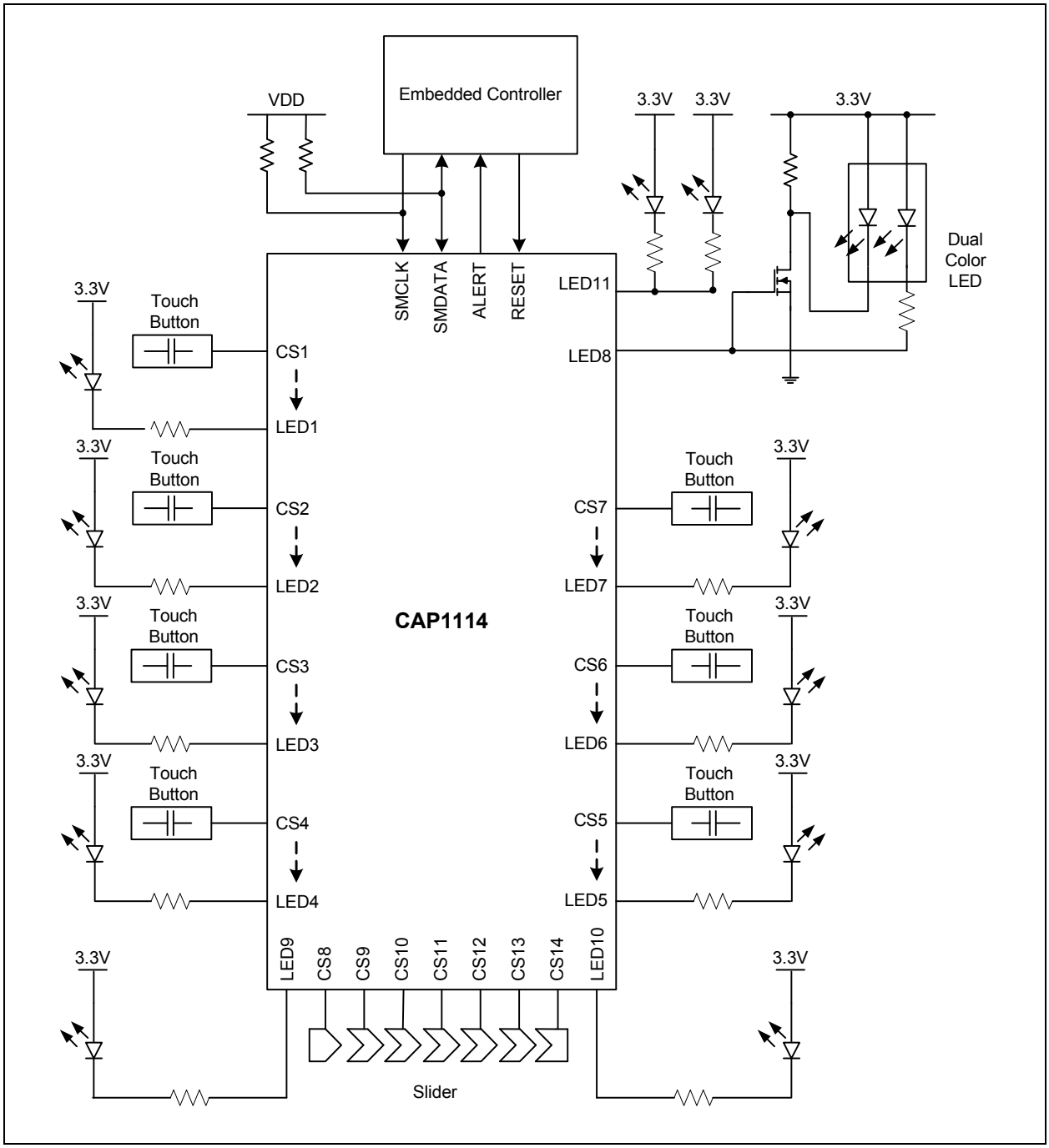

Figure 5.1 System Diagram for CAP1114

5.1 Power States

The CAP1114 has four operating states depending on the status of the SLEEP, DEACT, and DSLEEP bits (see Section 6.1). They are described below and summarized in Table 5.1. When the device transitions between power states, previously detected touches (for deactivated channels) are cleared and the status bits reset.

1. Fully Active - The device is fully active. It is monitoring all active Capacitive Sensor channels and driving all LED channels as defined.

2. Sleep - The device is in the Sleep state. It is monitoring a limited number of Capacitive Sensor channels (default 2). Interrupts will still be generated based on the active channels. The device will still respond to SMBus commands normally and can be returned to the Fully Active state by clearing the SLEEP bit. The LED11 channel is controlled via the PWR_LED control (see Section 6.1). All other LEDs will not be affected.
3. Deep Sleep - The device is in Deep Sleep state. It is not monitoring any Capacitive Sensor channels or the SMBus. The LED11 channel is controlled via the PWR_LED control (see Section 6.1). All other LEDs will be driven to their programmed non-actuated state and no PWM operations will be done.

   When the device enters the Deep Sleep state, it will release control to the ALERT pin and will change the direction of the ALERT pin (i.e. the device will monitor the ALERT pin instead of driving it).

   The device has two methods to exit the Deep Sleep state. They are:

   a. The ALERT pin is driven to its active state.
   b. Any SMBus communications are directed at the device.

   When the device leaves the Deep Sleep state, it automatically returns to its previously defined state and clears the DSLEEP bit.

Note: When the device enters the Deep Sleep state, the Slider Position / Volumetric Data Register (06h) is cleared.

4. Inactive - The device is inactive. It is not monitoring any Capacitive Sensor channels. The device will still respond to SMBus commands normally and can be returned to Fully Active state by clearing the DEACT bit. All LEDs will have PWM controls suspended so they should be disabled prior to entering this state. If these LEDs are not disabled, the system will show excess current draw from these LEDs.

Table 5.1 Power States

POWER STATE	DEACT	SLEEP	DSLEEP
Fully Active	0	0	0
Deep Sleep waking to Fully Active	0	0	1
Sleep	0	1	0
Deep Sleep waking to Sleep	0	1	1
Inactive	1	0	0
Deep Sleep waking to Inactive	1	0	1
Inactive	1	1	0
Deep Sleep waking to Inactive	1	1	1

The priority of power control signals is:

1. DSLEEP - when set, will override DEACT, disable all LEDs except LED11 then disable SMBus communications.
2. DEACT - when set, will override the SLEEP controls. It will disable sensor measurement and all LEDs.
3. SLEEP - when set, will enable Sleep state.

5.2 RESET Pin

The RESET pin is an active high reset that is driven from an external source. The pin contains an internal delay timer (t_{RST_FILT}) that will block errant glitches on the RESET pin. The RESET pin must be driven high or low longer than this time before the CAP1114 will react to the pin state.

While the RESET pin is held high, all the internal blocks will be held in reset including the SMBus. All configuration settings will be reset to default states and all readings will be cleared. Furthermore, the device will be held in Deep Sleep that can only be removed by driving the RESET pin low.

Once the RESET pin is pulled low, the CAP1114 will begin operation as if a power-on-reset had occurred. When this happens, the RESET bit will be set and an interrupt will be generated.

5.3 LED Drivers

The CAP1114 contains eleven (11) LED Drivers. Each LED Driver is controlled independently of the others and may be linked to the corresponding Capacitive Touch Sensor input. All LED drivers will operate in one of the following modes. LED drivers 1 - 8 can be configured to operate with either push-pull or open-drain drive and may also be configured to operate as GPIOs. LED drivers 9 - 11 will only operate as open-drain drivers.

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. Further, the LED can be configured to be actuated upon a touch detection or release detection (or based on user written control registers).
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 is released.
4. Breathe - The LED is configured to transition continuously ON-OFF-ON (i.e. to “Breathe”) with a programmable rate and min / max brightness.

In addition to these four behaviors, all LED drivers support user initiated ramps and have an option to assert the ALERT pin when the ramp has reached its maximum or minimum settings.

LED11 operates differently than the other LED outputs in three ways. First, it is configured to drive up to two external LED channels simultaneously. Second, it is not disabled during the Sleep or Deep Sleep states of operation (see Section 6.1). The third and final difference is it allows for different behaviors when the device is in Fully Active state versus when the device is in Sleep or Deep Sleep state.

5.3.1 Linking LEDs to Capacitive Touch Sensors

LEDs 1 - 7 can be optionally linked to Capacitive Touch Sensors 1-7 so that when the sensor detects a button press, the corresponding LED will be actuated at one of the programmed responses.

LEDs 9 and 10 may be optionally linked to the Grouped Sensors to indicate a slide / tap / press and hold in the “Up” or “Down” directions.

5.4 Capacitive Touch Sensing

The CAP1114 contains 14 independent Capacitive Touch Sensor inputs. Each sensor has dynamic range to detect a change of capacitance due to a touch. Additionally, each sensor can be configured to be automatically and routinely re-calibrated.