CBM7021
Capacitive Touch Sensor Controller
Datasheet

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V0.2	2011-11-08	Updated product application	Touch Sensor Group
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V0.6	2012-3-8	Updated register list Updated Package outline	Touch Sensor Group

Contents

1. Introduction

CBM7021 is low-cost single chip solution for capacitive touch sensor controller. The chip is mainly used for mechanical buttons replacement in home appliances, consumer electronics, industrial areas. With robust sensing technology, it has high performance across a variety materials and thickness, high noise immunity, waterproof and dustproof.

CBM7021 is 8-bit RISC architecture microcontroller devices with I2C Host/Slave, UART interface. For function application, CBM7021 support Button information for customers. In operation mode, it can support protocol and I/O mode for customer. Developer can use I/O mode to get a valid button message and develop their system very easily, and no longer need to decode the communication package.

The capacitive touch sensor can be designed by placing a copper pad on the PCB directly, covered with a plastic or glass case. It provides auto-calibrate the parameter for a wide range of capacitance on the touch sensor(1pF ~ 40pF). The system controller converts finger data to button presses, depending on finger location and human interface context.

CBM7021 robust sense solutions leverage our flexible programmable system-on-chip architecture, which accelerate time-to-market, integrates critical system functions and reduced BOM costs. CBM7021 supports multi-package for various application.

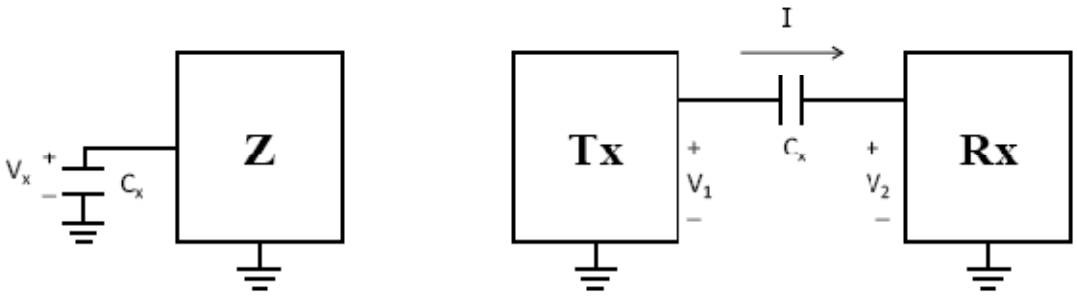
2. fundamental

Chipsbank Sensor Controller use changes in capacitance to detect the presence of a finger or near a touch surface, as shown in Figure 2-1. This capacitive sensor example illustrates a touch sensor replacement for a mechanical button.

Figure 2-1. Illustration of a Capacitance Sensor Application

2.1. Capacitive Sensing Methods

Capacitance can be measured between two points using either self capacitance or mutual capacitance.



Self Capacitance Mutual Capacitance

Figure 2-1-1. Self-Capacitance and Mutual-Capacitance Methods

2.1.1. Self Capacitance

Self capacitance uses a single pin and measures the capacitance between that pin and ground. A self-capacitance sensing system operates by driving current on a pin connected to a sensor and measuring the voltage. When a finger is placed on the sensor it increases the measured capacitance. The self-capacitance effect is best suited for single-touch sensors, such as buttons and sliders. Chipsbank Sensor solutions use self-capacitance sensing.

2.1.2. Mutual Capacitance

Mutual capacitance uses a pair of pins and measures the capacitance between those pins. A mutual-capacitance system operates by driving a current on a transmit pin and measuring the charge on a receive pin. When a finger is placed between the transmit and receive pins it decreases the measured capacitance. The mutual-capacitance effect is best suited to multitouch systems, such as touch screens.

2.2. Self-Capacitance Equivalent Model

In CBM7021 self-capacitance system, the sensor capacitance measured by the controller is named C_X. Figure 2-2-1 shows field lines only around the sensor pad, the actual electric field is more complicated. When a finger is not on the sensor, C_X equals the parasitic capacitance of the system. This parasitic capacitance, C_P, is a simplification of the distributed capacitance that includes the effects of the sensor pad, the overlay, the trace between the Sensor Controller pin and the sensor pad, the vias through the circuit board, and the pin capacitance of the Sensor Controller. C_P is related to the electric field around the sensor pad. Although Figure 2-2-1 shows field lines only around the sensor pad, the actual electric field is more complicated.

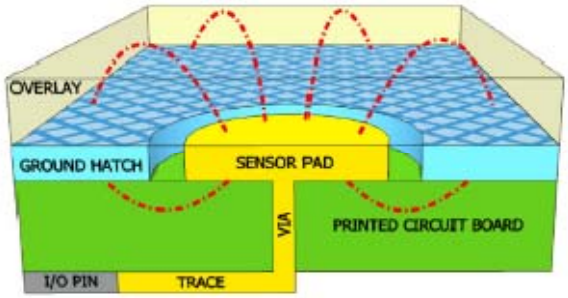


Figure. 2-2-1. C_P and Electric Field

When a finger touches the sensor surface, it forms a simple parallel plate capacitor with the sensor pad through the overlay. The result is called finger capacitance, C_F, and is defined:

$$C_F = \frac{\varepsilon_0 \varepsilon_r A}{D}$$

Where

ε_0 = Free space permittivity；

ε_r = Dielectric constant of overlay；

A = Area of finger and sensor pad overlap；

D = Overlay thickness

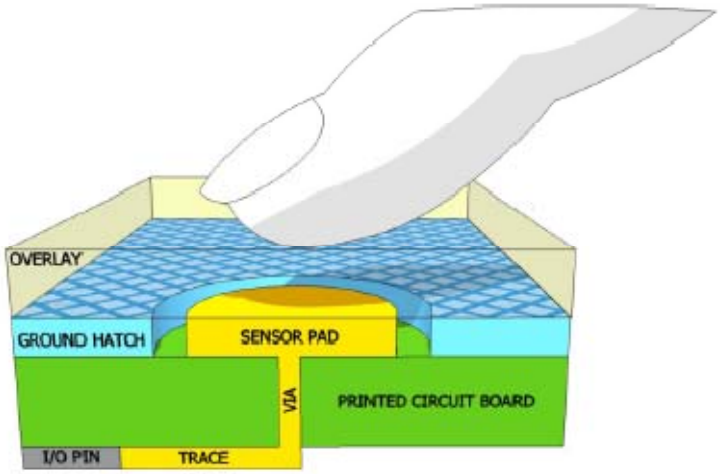


Figure 2-2-2. Sensor System Equivalent Model

With a finger on the sensor surface, C_X equals the sum of C_P and C_F.

$C_X = C_P + C_F$

2.3. Capacitance Conversion

CBM7021 algorithm converts the sensor capacitance into a digital count, called raw count. The raw count is interpreted as either a TOUCH or NO TOUCH state for the sensor. The numerical value of the raw count is the digital representation of the sensor capacitance, and increases as the capacitance increases.

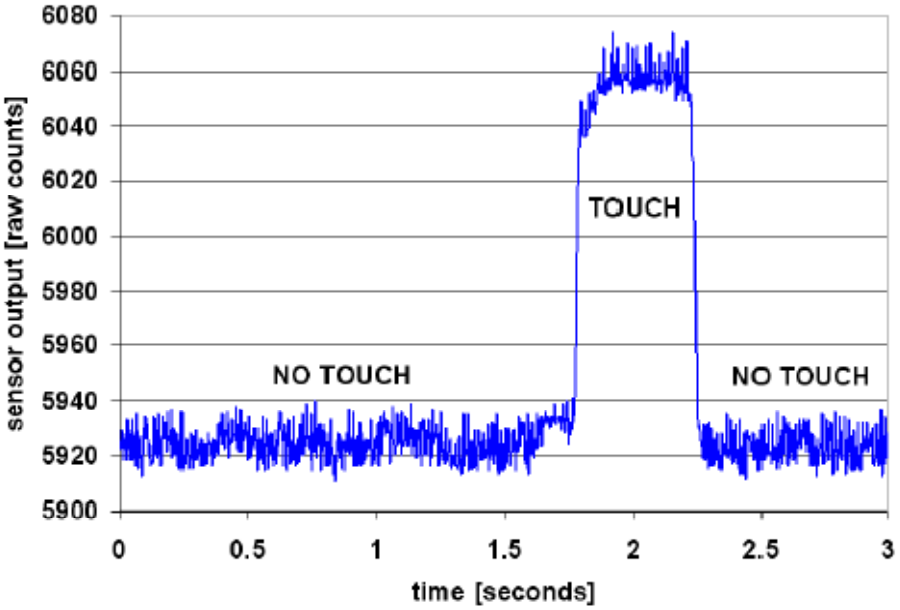


Figure 2-3-1. Output of Sensing Algorithm

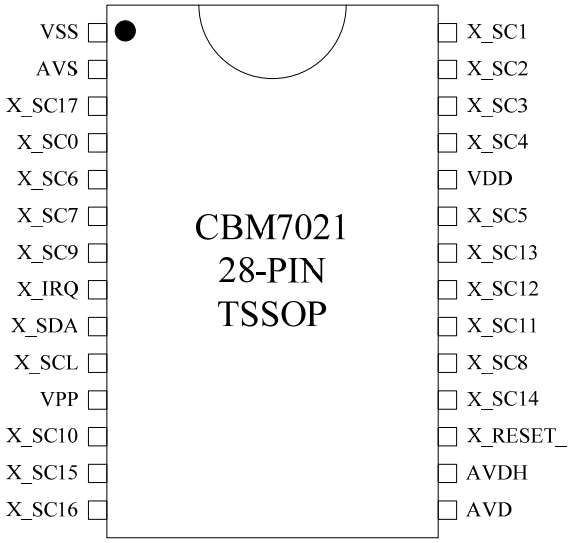
3. Features

- Support in-system programming and external reset control
- Powerful 8-bit RISC architecture processor
  - ✧ Speed running up to 32MHz
  - ✧ 24 x 8 multiply & divide, 32 bit accumulate
  - ✧ Support normal and idle operating mode
  - ✧ Operating voltage: 2.7V to 5.5V
  - ✧ Industrial temperature range: -40 °C to + 85 °C
- Robust sensing Technology
  - ✧ Up to 18 sensor channel analog-to-digital converters (ADC)
  - ✧ Flexible configuration for button, slider and wheel
  - ✧ Work normally covered by complete water film
  - ✧ Temperature, humidity adaptive adjustment
  - ✧ Low and high frequency interference immunity
- 24-bit timers, counters, and pulse width modulators (PWM)
- 8KB multi-time programmable device for user code and parameter, support code upgrading
- Cyclical redundancy check (CRC) modules for MTP data check
- Support Full-duplex UART, I2C slave/master interface
- 2KB user SRAM data storage
- Support up to 20 GPIOs
- Precision, programmable clocking
  - ✧ Internal 28MHz main oscillator
  - ✧ internal 32KHz oscillator for watch dog

4. Packaging

4.1. Package type

- **TSSOP28:**



4.2. PIN Description

NUM.	PIN NAME	ATTR.	DESCRIPTION
1	VSS	PWR	Ground
2	AVS	PWR	Ground
3	X_SC17	I/O	General purpose I/O 17 Sensor channel 17
4	X_SC0	I/O	General purpose I/O 0 Sensor channel 0 PWM output
5	X_SC6	I/O	General purpose I/O 6 Sensor channel 6
6	X_SC7	I/O	General purpose I/O 7 Sensor channel 7 External crystal input (XTALin)
7	X_SC9	I/O	General purpose I/O 9 Sensor channel 9 External crystal output (XTALout)
8	X_IRQ	I/O	General purpose I/O 18 Interrupt request output External pull-up resistor needed
9	X_SDA	I/O	General purpose I/O 20 I2C SDA UART RXD External pull-up resistor needed

10	X_SCL	I/O	General purpose I/O 19 I2C SCL UART TXD External pull-up resistor needed
11	VPP	PWR	6.5V power supply for MTP programming
12	X_SC10	I/O	General purpose I/O 10 Sensor channel 10
13	X_SC15	I/O	General purpose I/O 15 Sensor channel 15
14	X_SC16	I/O	General purpose I/O 16 Sensor channel 16
15	AVD	PWR	Power supply
16	AVDH	PWR	Power supply
17	X_RESET_	I	External reset signal, active low
18	X_SC14	I/O	General purpose I/O 14 Sensor channel 14
19	X_SC8	I/O	General purpose I/O 8 Sensor channel 8
20	X_SC11	I/O	Sensor channel 11
21	X_SC12	I/O	Sensor channel 12
22	X_SC13	I/O	Sensor channel 13
23	X_SC5	I/O	General purpose I/O 5 Sensor channel 5
24	VDD	PWR	Power supply
25	X_SC4	I/O	General purpose I/O 4 Sensor channel 4
26	X_SC3	I/O	General purpose I/O 3 Sensor channel 3
27	X_SC2	I/O	General purpose I/O 2 Sensor channel 2
28	X_SC1	I/O	General purpose I/O 1 Sensor channel 1

Note **I:** Input signal

O: Output signal

I/O: Bi-direction signal

PWR: Power signal

NC： Not Connection

5. Communication Interface

CBM7021 supports I2C slave/master，UART communication interface.

- I2C slave clk: 100KHz ~ 400KHz；
- I2C master clk: 100KHz ~ 400KHz (4 clock frequency available)；
- I2C slave address: 0x22 (Redefined available)；
- UART Baud Rate: 9600/19200/38400/57600bps

5.1. I2C Slave Interface

All address packets are 9 bits long, consisting of 7 address bits, one READ/WRITE control bit and an acknowledge bit. When the touch pad controller recognizes that it is being addressed, it will acknowledge by pulling SDA low in the ninth SCL (ACK) cycle. All data packets are 9 bits long, consisting of one data byte and an acknowledge bit. An acknowledge (ACK) is signaled by the Receiver pulling the SDA line low during the ninth SCL cycle. If the Receiver leaves the SDA line high, a NACK is signaled. Each write or read cycle must end with a STOP condition.

Figure 5-1-1 and 5-1-2 show bit level waveform of I2C master Write/Read data to/from I2C slave device with 7 bit addressing mode. When R/~W bit is set to 0, I2C master can write data to I2C slave that only slave address is verified. On the contrary, when R/~W bit is set to 1, I2C master can read data from I2C slave if slave address is verified. If slave address verify is error, I2C slave will not work.

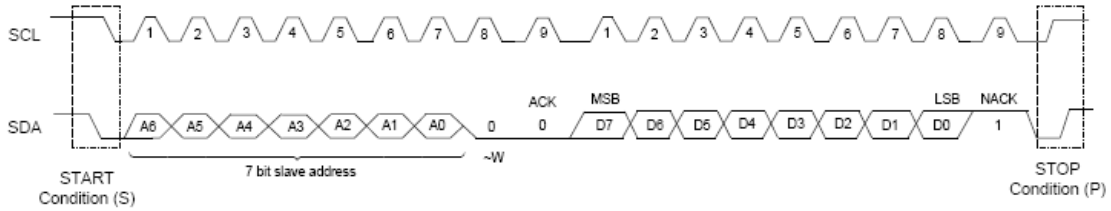


Figure 5-1-1. Bit Level waveform of I2C master write data to I2C slave (~W=0)

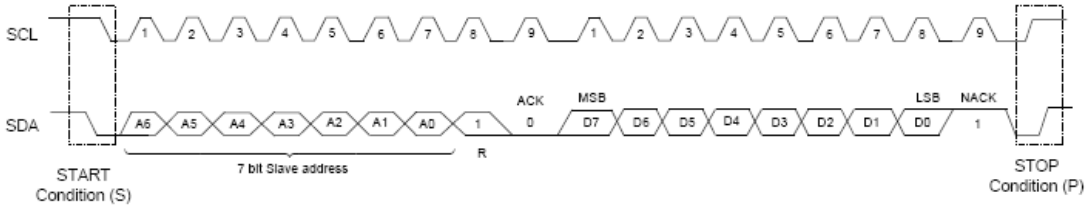


Figure 5-1-2. Bit Level waveform of I2C master read data from I2C slave (R=1)

The I2C bit level waveform of figure 5-1-1 and figure 5-1-2 are supported by CBM7021. The CBM7021 touch sensor controller is defined as a slave device of I2C and host is defined as a master. The device address of touch pad controller is designed as 7-bits address format. The controller address default is 0x22. If CBM7021 and other device setting have same I2C salve address, the developer can change I2C slave address content of CBM7021 by writing I2C Address Register. I2C slave address setting content range is 0x00~0x7F.

Figure 5-1-3 shows the system block diagram including I2C slave interface. The CBM7021 detects the object on the touch sensor and sends the information including button state to host. In I2C slave interface, the SCL and SDA signals should be pulled high with 5.1k resistors at the end of the host. The host processor has to provide the I2C serial clock signal (SCL) to CBM7021.

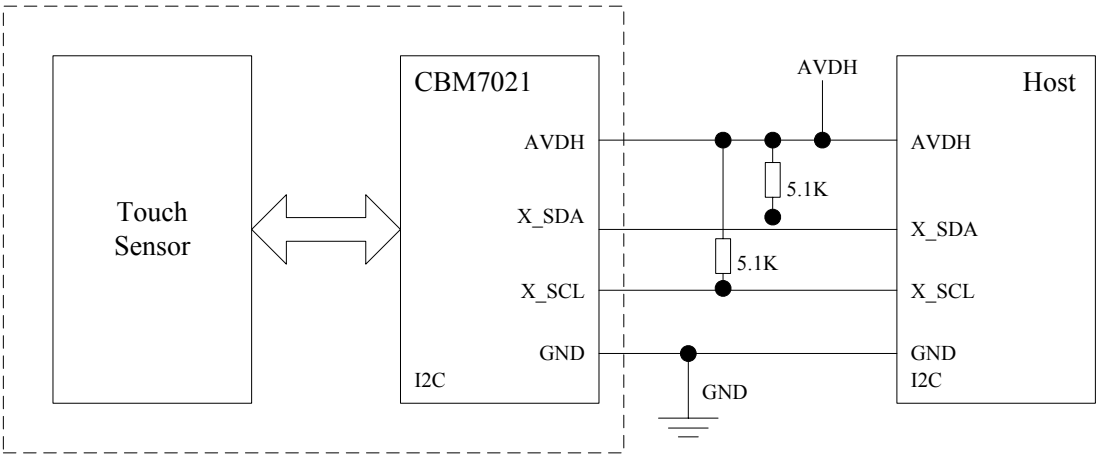
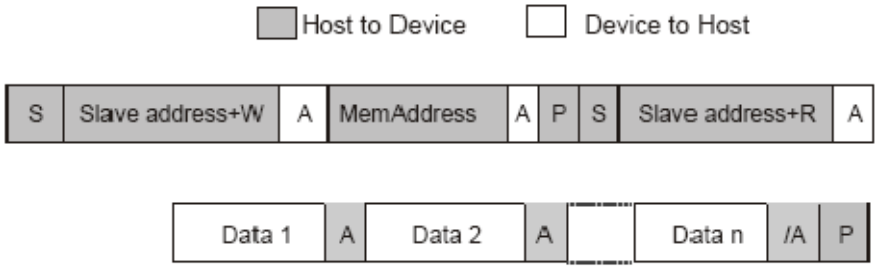


Figure 5-1-3. System block diagram with I2C interface

An address packet consisting of a slave address and a READ or a WRITE bit is called Slave address+R or Slave address+W, respectively. The sequence of events required to write data to the touchpad controller is shown next.

S	Start condition
Slave address+W	Slave address plus write bit
A	Acknowledge bit
Mem Address	Target memory address within CBM7021
Data	Data to be written
P	Stop condition

The sequence of events required to read data from the touch sensor controller is shown next.



S	Start condition
Slave address+W	Slave address plus write bit
A	Acknowledge bit
Mem Address	Target memory address within CBM7021

Data	Data from CBM7021
P	Stop condition
SLA+R	Slave address plus read bit
/A	Not Acknowledge bit/indicates last byte transmission

Figure 5-1-4 below shows the timing condition and characteristics of the I2C interface. In CBM7021, the touch pad adopts a bit rate of up to 400k bit/sec.

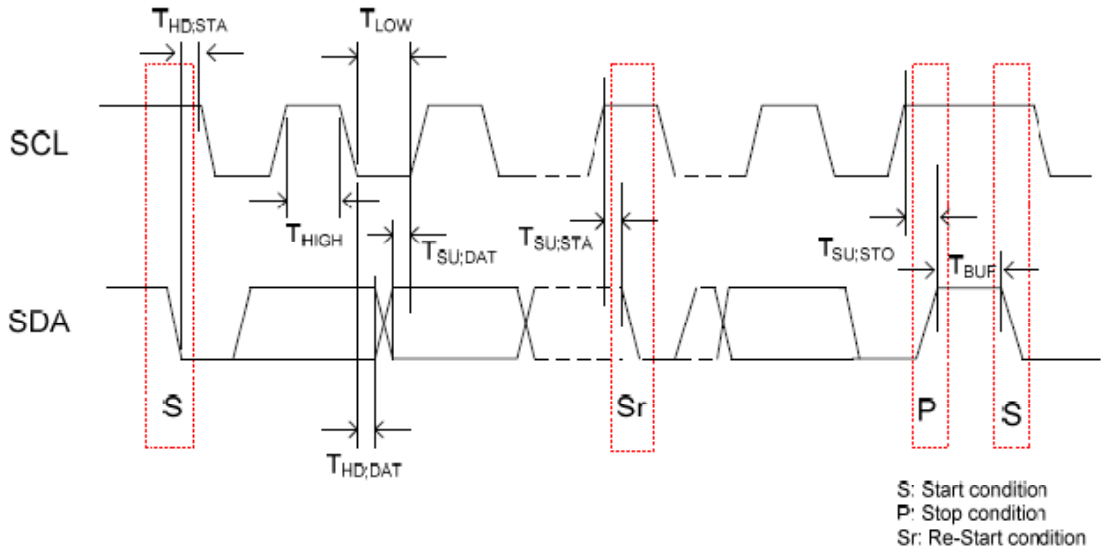


Figure 5-1-4. The Timing of I2C interface

Table1: Characteristics of the I2C SDA and SCL Pins

Symbol	Description	Standard Mode		Fast Mode		Units
		Min	Max	Min	Max	
F_{SCL}	SCL clock frequency	0	100	0	400	KHz
$T_{HD;STA}$	Hold time (repeated) START condition	4.0	-	0.6	-	μs
T_{LOW}	LOW period of the SCL clock	4.7	-	1.3	-	μs
T_{HIGH}	High period of the SCL clock	4.0	-	0.6	-	μs
TSU;STA	Setup time for a repeated START condition	4.7	-	0.6	-	μs
$T_{HD;DAT}$	Data hold time	0	-	0	-	μs
$T_{SU;DAT}$	Data setup time	250	-	100	-	ns
$T_{SU;STO}$	Setup time for STOP condition	4.0	-	0.6	-	μs
T_{BUF}	Bus free time between a STOP and START condition	4.7	-	1.3	-	μs

6. Timing Description

6.1. Power-on Reset

After the touch system is powered on, this controller will do initialization. The initialization includes MCU and analog parameter initialization. During the initial process, CBM7021 is not acknowledged any command. When Host gets CBM7021 device ID, the touch sensor is ready to work. Host must be release bus during touch sensor getting interface configuration to make sure touch sensor getting interface correctly. The release time (Tr) is 10 ms. Figure 6-1-1 shows the process after power up. Touch sensor power-on time is 300ms.

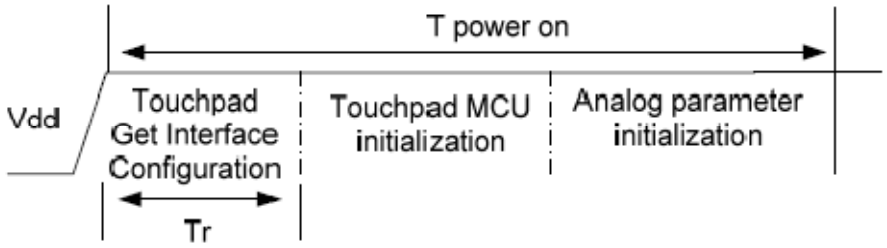


Figure 6-1-1. Power up process

6.2. IDLE MODE Timing

The one of key feature of CBM7021 microcontroller is its ability to provide an IDLE mode to save the power consumption. There are three main aspects to the design that contribute to the overall power consumption: clock source, clock frequency, and time spent out of a idle mode.

The CBM7021 series of microcontrollers include an integrated 28-MHz digitally controlled oscillator (DCO) as well as a very-low-power oscillator (VLO). The DCO is a high precision oscillator that can support wide range of frequency settings. Calibrated settings for the DCO include 28, 24, 20, 16, 12 and 1 MHz. In addition, the clock module allows the input frequency to be divided by 1, 2, 3, or 8. By adjusting these values, you can achieve various period lengths which directly relate to the length of time allocated for measuring each capacitive sensor and, thus, allow for greater sensitivity. On the other hand, a longer period means more time spent out of idle modes, which causes an increase in power consumption.

In idle mode, the DCO is closed and only idle timer module is working with VLO clock. Power consumption can be greatly reduced by altering how long the device spends in a idle mode. Figure 6-2-1 shows a example of IDLE mode application.

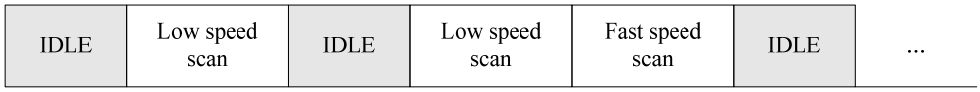


Figure 6-2-1. A example of IDLE mode application

The Controller starts a cycle by setting up the appropriate modules, then it enters IDLE mode and waits for the number of cycles defined in the IDLE time register. After the target number of cycles is reached, the controller wakes up and scans the sensors channel in a low speed. If a touch event is occurred, it switch to a fast speed clock to scan the sensors and determine the touch event properly.

After that, the controller returns to the IDLE mode again.

Table 2: Operation Current under different oscillator frequency

OSC Frequency	CISC Clock Divider	Operation current
28MHz	1	22.3mA
28MHz	2	19.2mA
28MHz	3	18.1mA
28MHz	8	16.7mA
24MHz	1	20.9mA
24MHz	2	18.3mA
24MHz	3	17.4mA
24MHz	8	16.3mA
20MHz	1	20.2mA
20MHz	2	17.8mA
20MHz	3	17.1mA
20MHz	8	16.9mA
16MHz	1	19.2mA
16MHz	2	17.3mA
16MHz	3	16.6mA
16MHz	8	16.4mA
12MHz	1	18.2mA
12MHz	2	16.6mA
12MHz	3	16.1mA
12MHz	8	16.0mA

Note:
Sensor Channel： 11
Scan cycles： 38

7. Register List

Register Name	Description	Conditions
CONFIG_R0	System configuration register	RW
CONFIG_R1	System configuration register	RW
TIMER	24bit Timer	RW
PIO_IN	GPIO Input register	R
PIO_OUT	GPIO output register	RW
PIO_CTL	GPIO output enable register	RW
SENSOR_CTL	Sensor channel enable register	RW
SER_REG	UART receive data register	R
SOFT_FLAG	Firmware state register	RW
COUNTER_I	16bit counter	RW
COUNTER_J	16bit counter	RW
COUNTER_K	16bit counter	RW
ADC_REG	ADC RAW count output register	R
CRC_REG	CRC setting register	RW
SENSOR_ACT	Touch state register	RW

OSC_REG	Oscillator setting register	RW
I2C_DATA	I2C read/write data register	RW
I2C_ADDR	I2C address register	RW
I2C_MEMADDR	I2C memory address register	RW
PWM_LOW	32bit PWM output low configuration register	RW
PWM_HIGH	32bit PWM output low configuration register	RW
WATCH_DOG	24bit watch dog register	RW
RESET_PC	Watch dog/Soft Reset setting register	RW

8. Electrical Characteristics

8.1. Absolute Maximum Ratings

Item	Rating
Temperature under bias	-40℃ to + 85℃
Storage temperature	-55℃ to +125℃
Input voltage	Vss-0.3V to Vdd+0.5V
Output voltage	Vss-0.3V to Vdd+0.5V

8.2. DC Electrical Characteristics

Parameter	Description	Min	Typ	Max	Units	Condition
DVDD	Power supply voltage	2.7		5	V	
IDDR	Normal operating current			20	mA	AVDH = 5V OSC = 20MHz
IDDS	Idle operating current		1		mA	AVDH = 5V
VIL	Input low voltage			0.3AVDH	V	2.7V < AVDH <5.5V
VHL	Input High voltage	0.7AVDH			V	2.7V < AVDH <5.5V
VOL	Output low voltage			0.3AVDH	V	
VOH	Output high voltage	0.7AVDH			V	

8.3. AC Electrical Characteristics

Parameter	Description	Min	Typ	Max	Units	Notes
T_{CLK}	Internal oscillator	26.6	28	32.6	MHz	AVDH = 5V
T_{VLCLK}	Internal oscillator	36.1	38	41.2	KHz	AVDH = 5V

8.4. Timing Specification

Parameter	Description	Min	Typ	Max	Units	Notes

T_{EXTRST}	External reset time		200		us	
T_{POR}	Power on to normal operation time		300		ms	

8.5. EMI/EMC Specification

Parameter	Description	Min	Typ	Max	Units	Notes
EFT				4.5	KV	
ESD				8	KV	

9. Package Outline