Version 2.2
Sept. 2007

SW6888 Single Chip Fingerprint Sensor Datasheet

General Description

The **SW6888** is a low cost swipe-type field-switch fingerprint sensor, with built-in image processing. The sensor uses state-of-art biometric technology to capture, and transmit fingerprint from human finger to other devices, with up to 256-contrast levels.

It has resolution of 500dpi, and operates with 2.5-3.6V power supply with low power consumption. It supports ultra low power sleep mode, as well as ultra low power fingerprint navigation. It is suitable for battery-powered operation.

The **SW6888** has built-in image processing, such as still motion detection, and binarization, to reduce the complexity of implementation for certain applications. It is integrated with standard computer interfaces, such as SPI, Parallel Interface and Flash Interface.

The surface of the sensor is protected by ultra hard coating with Mohs Hardness rating of 7+. Such film protects the sensor surface from scratch and erosion.

The sensor meets **IEC**61000-4-2 ESD standard for air discharge of no less than 15K volt.

Applications

- **USB Flash Drive**
- **Cell phone/PDA**
- **Personal Media Player (PMP)**
- **Portable MPEG4 Player**
- **Lock**
- **ATM**
- **ID Management**
- **PC & Laptop security and encryption for online transaction**
- **Automobile**

Features

- **500dpi Resolution**
- **2.5-3.6V single power supply**
- **Built in 8 bit ADC**
- **Standard computer interface: SPI, Parallel and Flash interface**
- **On chip power management with normal operation less than 8mA.**
- **Ultra low power in sleep/standby mode.**
- **Automatic finger detecting**
- **Still motion detection**
- **768 Bytes internal memory**
- **On chip binarization algorithm**
- **Full fingerprint navigation**
- **Low BOM Cost**
- **High ESD standard of 15KV**
- **Ultra hard coating protection**
- **Integrated Crystal Oscillator**
- **True parallel scan with enhanced image quality**
- **Thin package**

SW6888 Single Chip Fingerprint Sensor Datasheet

Version 2.2

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INTRODUCTION

The SW6888 is a silicon-based swipe type fingerprint reader. The SW6888 Product Manual version 2.0 is the hardware design manual. It describes in details the configuration and the operation of the SW6888.

Functional Summary

The SW6888 swipe sensor is comprised of a sensing matrix, analog-to-digital converters, and computer interfaces. A two dimensional matrix of 16x192 sensor units have been integrated with resolution of 500dpi. The sensing area has dimension of 0.8mm x 9.8mm. The sensor is capable of sensing electrical signal differences between the ridges and the valleys on human finger. The reading is further digitized into digital value and then transmitted.

The sensor scans in the true parallel mode. It captures 16 readings at the same time from 16 vertically aligned pixels. 16 analog-to-digital converters (ADC) with 8-bit resolution have been integrated on chip to allow the analog readings been processed simultaneously. Such arrangement allows the SW6888 to be able to capture more details of the finger image, especially at relatively high swipe speed.

SW6888 has built-in power management circuitry to prevent large current caused by physical damage, as well as to support ultra-low power standby mode, with less than 3mA current consumption. The internal Finger detecting circuit is capable of detecting finger presence, and automatically wakes up the sensor. In the normal scan mode, the sensor consumes as little as 8mA current.

SW6888 also supports finger navigation for mouse pad function. Power consumption is much lower than the normal scan operation.

SW6888 is further integrated with a 768-byte memory, and supports several standard computer interfaces, such as such as SPI, Parallel Interface, and Flash Interface. The integrated Binarization image processing can reduce the data rate and increase the buffering significantly.

The sensor area is exposed, and protected by a special extra-hard ceramic coating, with Mohs Hardness of 7+. Such coating protects the sensor surface from scratch and erosion. The sensor also meets IEC61000-4-2 ESD standard for air discharge of no less than 15K volt.

SW6888 is packaged into ultra-thin BGA package. Such design allows the end user to easily apply the sensor onto the surface of the products.

In case of any damage to the chip, usually such event will create large current. SW6888 is integrated with large current detection circuit, and can be disabled and isolated by external control, to prevent it from further draining the current from the system.

Operation Summary

The SW6888 is a swipe-type field-switch fingerprint reader. It supports different operation modes, standby mode, scan mode, and navigation mode.

The sensor is normally in standby mode with ultra-low power consumption. When human finger is present, the integrated finger detecting mechanism automatically wakes up the sensor. As the finger is rolling down, the sensor matrix is actively sensing and capturing the electrical signal differences between the ridges and the valleys on human finger, until the finger is removed from the surface of the sensor. The maximum swipe speed supported by the SW6888 is 37cm/s at internal clock of 12MHz.

In the scan mode, the digitized data is transferred in real time through selected interface, including flash interface, parallel interface and serial peripheral interface (SPI). The maximum output data rate is 12Mbps, and 1.5Mbps with on-chip Binarization at internal clock of 12MHz.

SW6888 also supports finger navigation. In this particular operation, the sensor can be set to reduce the capture window, and accuracy in order to further reduce the power consumption.

Functional Features

Here is a high-level feature list for the SW6888 fingerprint sensor:

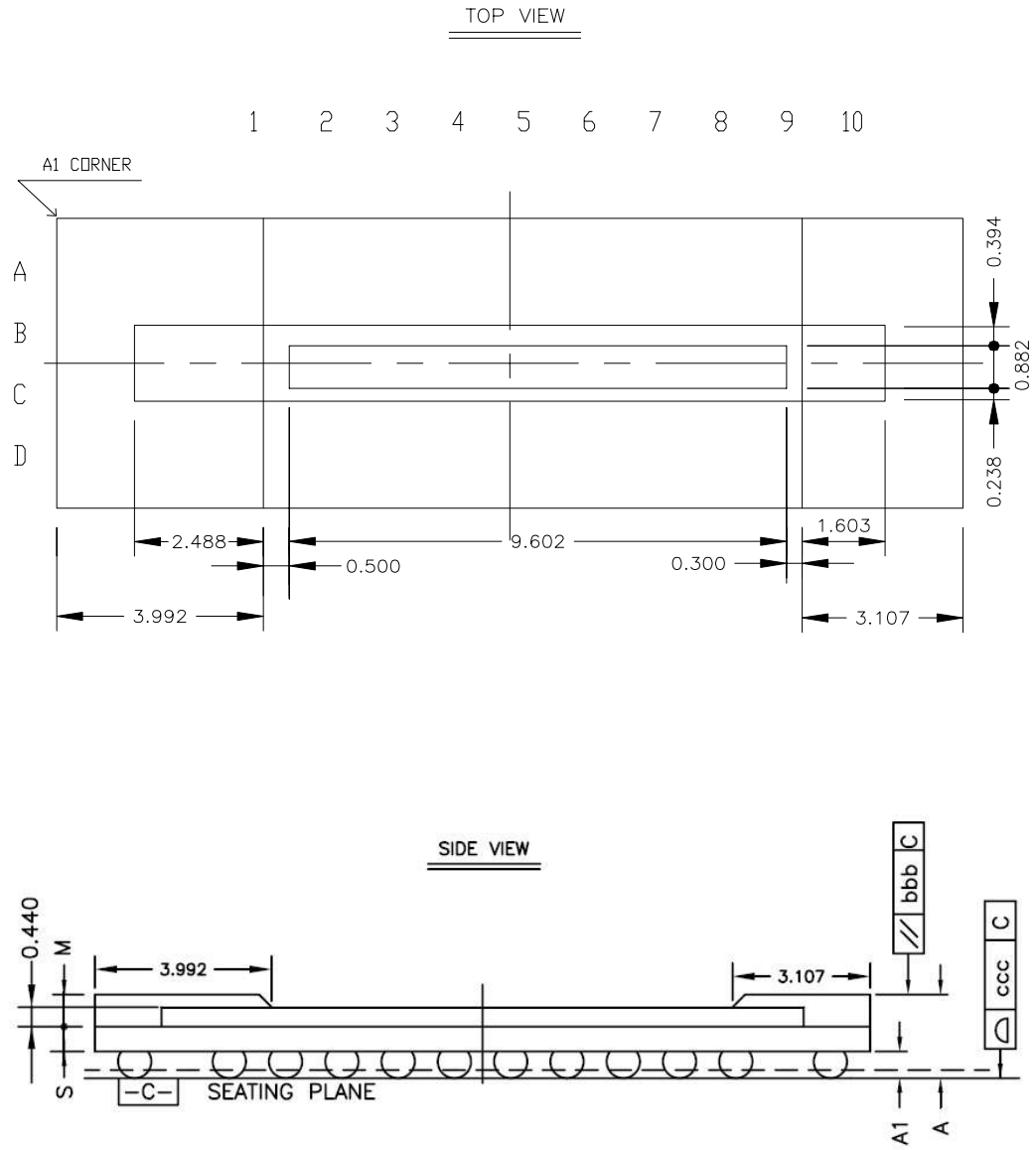
- Programmable scan rate
- 2.5V – 3.6V single power supply
- Adjustable electrical stimulus signal amplitude
- Low power consumption
- Ultra low power navigation mode
- Automatic transition to scan mode after detecting finger
- Programmable finger detecting threshold
- Support different digital interfaces, SPI, Parallel, and Flash
- Data encryption
- On-chip binarization
- On-chip still motion measurement and image reduction

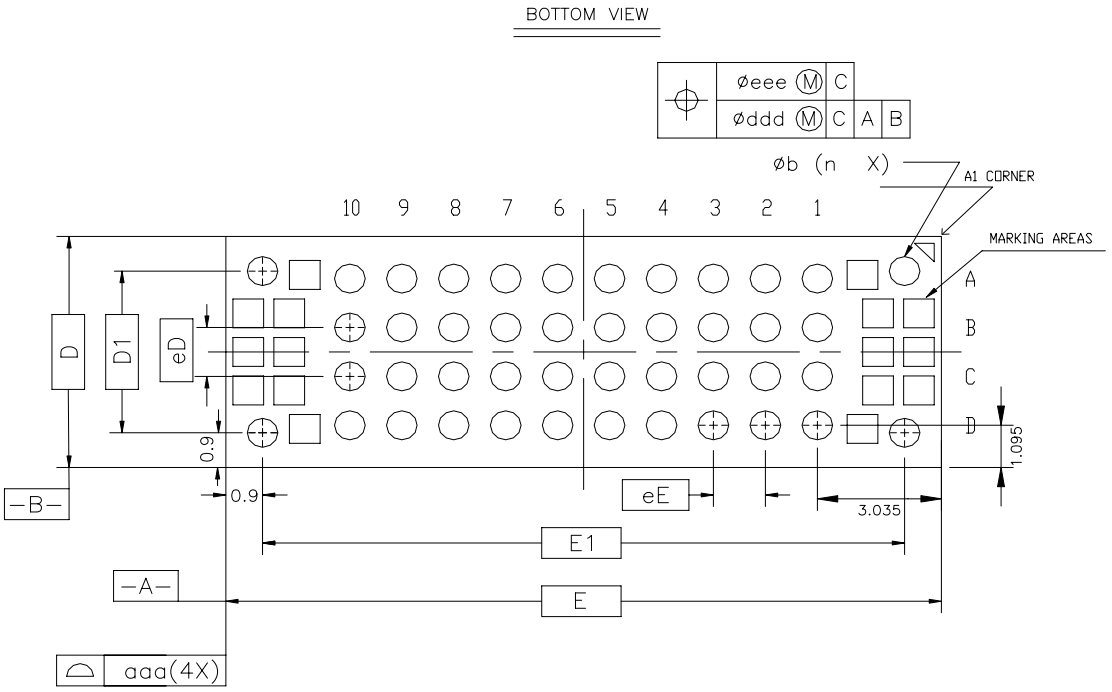
HARDWARE DESCRIPTION

Form Factor

The SW6888 sensor is packaged in a specially designed 40-pin BGA package. The package has dimension of 17.5mm x 6mm x 1.93mm. The details are shown in the following:

Note: Unless otherwise specified, the unit for all dimensions is mm.

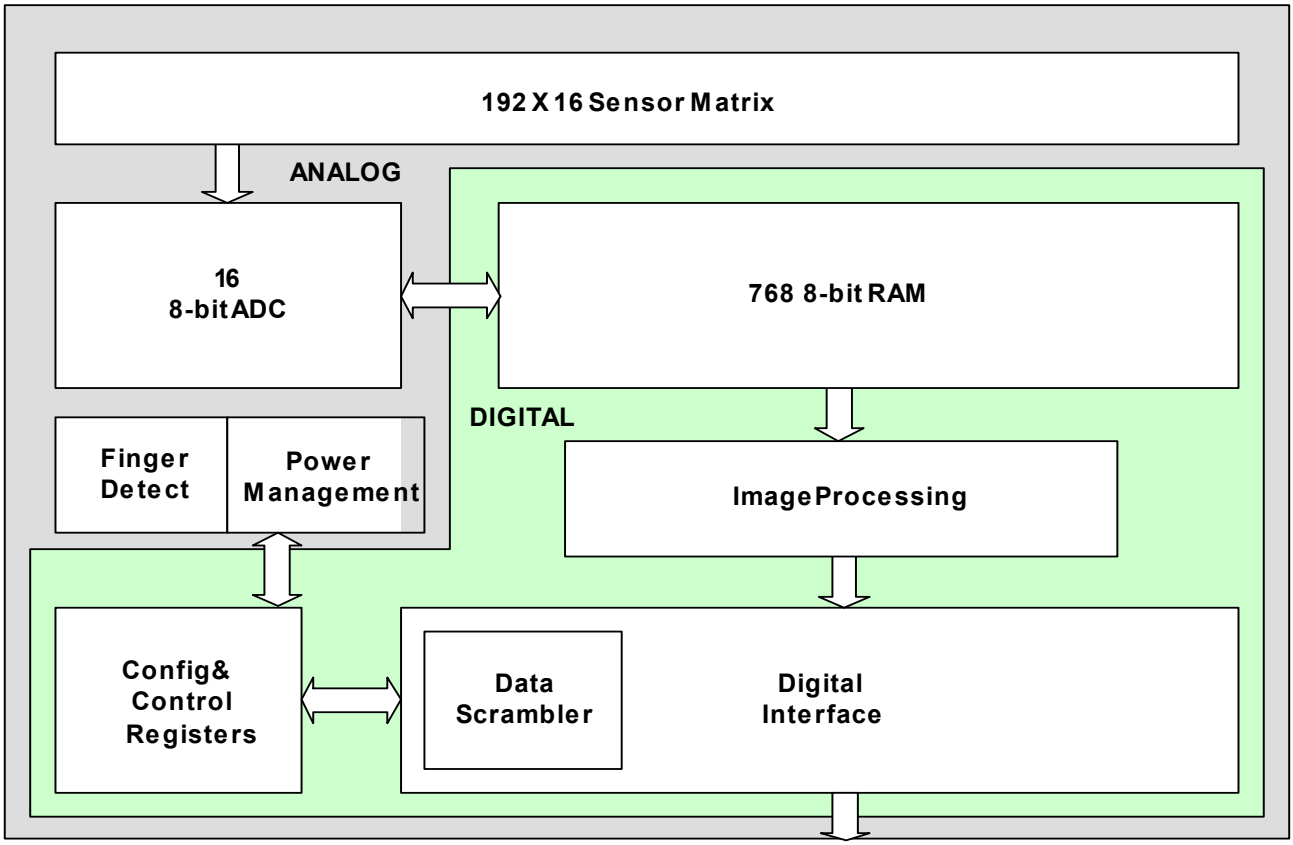




		Symbol	Common Dimensions
Package :			FPS BGA
Body Size:	X	E	17.500
	Y	D	6.000
Ball Pitch :	X	eE	1.270
	Y	eD	1.270
Total Thickness :		A	1.880 +/-0.100
Mold Thickness :		M	0.720 Ref.
Substrate Thickness :		S	0.560 Ref.
Ball Diameter :			0.750
Stand Off :		A1	0.500 ~ 0.700
Ball Width :		b	0.600 ~ 0.900
Package Edge Tolerance :		aaa	0.200
Mold Flatness :		bbb	0.350
Coplanarity:		ccc	0.200
Ball Offset (Package) :		ddd	0.250
Ball Offset (Ball) :		eee	0.100
Ball Count :		n	44
Edge Ball Center to Center :	X	E1	15.700
	Y	D1	4.200

Block Diagram

SW6888 is comprised of analog and digital portion. The analog portion includes 192 x 16 sensor matrix, Analog-to-Digital convertor (ADC), finger detecting, and power management circuit, while the digital portion includes memory, image processing, controller and digital interface. The following is a block diagram of the SW6888:



Device Level Definition

Pin Definition

Power Supply

Name	Pin	Description
DVDD	B6	3.3V Digital Power Supply
DVSS	C6, D2	Digital Ground
AVDD1	B9	3.3V Analog Power Supply
AVSS1	C9	Analog Ground
AVDD2	B10	3.3V Analog Power Supply
AVSS2	C10	Analog Ground

Analog Interface

Name	Pin	IO	Type	Description
FNG_DET	A9	O	CMOS	High when finger is present, intend to wake up sensor matrix.
PCLK	A8	O	CMOS	Scan clock signal output
IREF	D8	O	Analog	Analog reference,
XTALIN	B7	I	Analog	Crystal input, recommended 12MHz
XTALOUT	C7	O	Analog	Crystal Output

System Interface

Name	Pin	IO	Type	Description
CEN	C8	I	CMOS	Active low chip select

Digital Interface

Pin Name	Pin	I/O	Description		
			Flash mode	Parallel mode	SPI mode
RSTB	C4	I	Active-low asynchronous reset		
READY	C2	O	New image ready / FIFO not empty		
IO [7:0]	B1, B2, A7, A6, A5, A4, A3, A2	I/O	Parallel data		N/A
CLE	D5	I	Command latch enable	Register address latch	SDI
ALE	D6	I/O	Address latch enable	FIFO read enable	SDO
CEB	C3	I	Active-low interface enable		SSB
REB	C1	I	Active-low read enable	Active-low register read	
WEB	D7	I	Active-low write enable	Active-low register write	Pixel-rate interface clock
IFSEL [1:0]	B3, C5	I	Select interface mode: 00: Flash mode 01: Parallel mode 10: N/A 11: SPI mode		
CLK_DIV[1:0]	D4, D3	I	Input 00		
ICLK	B4	I	Active high enable clock-divider-4		
N.C.	A1, A10, B8, D1, D10		No connection.		

Electrical Specification

Maximum ratings

Parameter		Maximum	Unit
Supply Voltage	Vdd	3.6	V
Input Voltage	Vi	Vdd+0.5	V
Output Voltage	Vo	Vdd+0.5	V
Operating Room Temperature	To	70	°C
Non-operating (Storage) Temperature	Tn	130	°C
Lead Temperature	Tl	250	°C

Operating Conditions

Parameter		Condition	Min	Typ	Max	Unit
3.3V Supply Voltage	Vdd		2.5	3.3	3.6	V
3.3V Supply current (cut off)	Idd	Damaging event		100		mA
Power-up time	Tpu			1		ms
Standby Current	Ist	Terminated crystal oscillator		39		µA
Power Consumption	Pd	Normal scan		26		mW
	Pdn	Navigation (16x16 window)		10		mW
Operating Temperature	Top		-20		70	C

Electrical Characteristics

Digital I/O

Parameter		Condition	Min	Typ	Max	Unit
High-level input voltage	Vih		2.0			V
Low-level input voltage	Vil				0.8	V
Output current	Iol			-2		mA
Output current	Ioh			4		mA
High-level output voltage	Voh		2.8			V
Low-level output voltage	Vol				0.4	V
Leakage output current	Ioz	All digital I/O			2	µA
I/O Speed	CKi	3.3V supply			30	MHz
		2.5V supply			15	MHz
Rising time	Tr			TBA		nS
Falling time	Tf			TBA		nS

Module-Level Description

SW6888 is comprised of analog and digital portion. The analog portion includes 192 x 16 sensor matrix, Analog-to-Digital (ADC) converters, finger detecting, and power management circuit, while the digital portion includes memory, image processing, controller and digital interface. The following is a brief description of individual blocks.

Digital portion

The digital portion of SW6888 is comprised of the controller, *binarization* module, 768 bytes FIFO, still motion detection and digital interfaces. The controller provides the controlling for clock frequency and the different scan modes. The *binarization* module is designed to convert the 8-bit level sensor reading into binary format. The data rate can be reduced by a factor of 8, when operating at the *binary* mode.

Controller and Clock Frequency

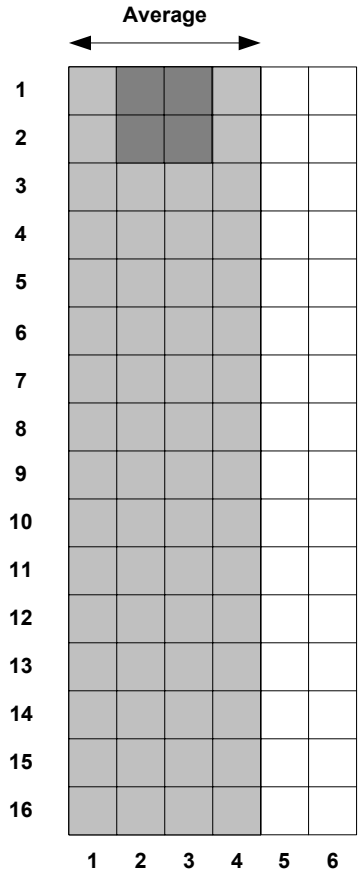
The controller provides the controlling for clock frequency and different scan modes through internal registers. The detailed description of all registers is listed in the *Register Map* section of this specification.

The SW6888 has built-in crystal oscillator, supporting crystal frequency from 6MHz up to 24MHz. Internal main clock is generated from the crystal oscillator.

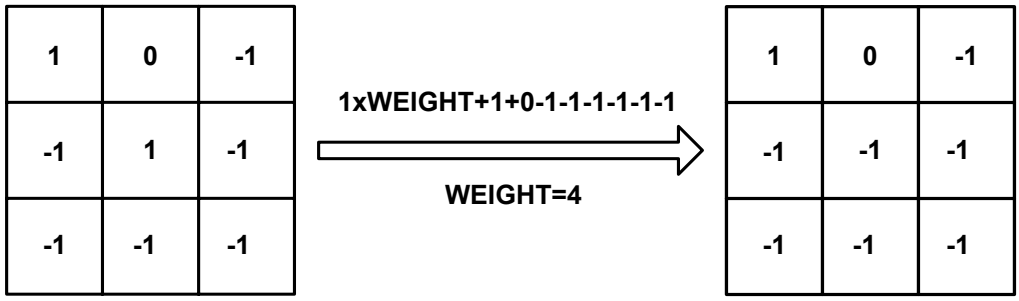
In the case, crystal frequency is 12MHz; internal clock is running at 12MHz while pin ICLK=0 and running at 3MHz while pin ICLK=1. Pin ICLK active high enables the internal clock divide by 4. The parallel scan is at 12MHz/(8x16)=93.75KHz per line while the internal clock running at 12MHz. The vertically aligned 16 pixels are captured simultaneously, and further *quantified* by 16 parallel Analog-to-Digital Converters (ADC). Thus the scan frame rate can be calculated: *FrameRate* = 12MHz/(8x16x192) = 488 frame/s.

Binarization

On-chip *binarization*, or binary scan mode, can reduce the amount of data for the fingerprint image transmission and storage. Instead of storing and transmitting 8 bits per pixel, the chip will output only “0” or “1” in binary format to represent the ridge or the valley of finger. This mode can be activated by setting register **BIN_MOD**. The SW6888 takes local reference approach for *binarization* processing. Two plates are calculated by averaging small portion of pixel matrix. The top plate is the average of 1 pixel or 2x2 pixels, set by registers **PXL_SEL**. The bottom plate is the average of 16x4 pixels plus an offset defined by register **OFFSET_SEL**. By subtracting the two plates, binary value will be obtained. The following is a diagram illustrating the *binarization* algorithm with 2x2 pixel for the top plate:



The module further goes through a *clean up* logic operation, to reduce the effect of the average value of the two plates are equal. The current design takes the center pixel value, and times a **WEIGHT**, set by register, and compares against the 8 surrounding pixel values. The following diagram shows the *clean up* process for binarization process.



FIFO

The First-In-First-Out (FIFO) memory is realized by implementing a dual port synchronous SRAM. 768 bytes memory has been integrated on-chip. It can buffer up to 1/4 frame of data in normal scan mode, or 2 frames of data in binary mode. The FIFO write is operating at internal clock, while the FIFO read is operating at external **REB** clock from different digital interface, such as SPI, Parallel, and Flash. When FIFO is filled over 1/8 of the capacity, the FIFO module will send out **Ready** signal to notice host computer for data transmission.

Preventing memory overflow:

If the 1[7] register **HOLD_SCAN_EN** = 0, the scanned fingerprint data must be transferred to host computer or other storage devices in time, otherwise, the FIFO will overflow. When overflow occurs, the host computer will not be able to process the data. The memory overflow can be checked by reading register **RAM_FUL**.

Assuming a 12MHz chip clock, the buffering time from the **Ready** signal being sent to memory overflow is in the following:

	Normal Scan	Binary Scan	Navigation Scan					
			16 x 16 pixel		16 x 32 pixel		16 x 64 pixel	
			Normal	Binary	Normal	Binary	Normal	Binary
Buffering Time (mS)	0.448	3.58	10.75	42.5	5.375	21.25	2.69	10.63

Note: for details of different scan modes, please follow "*Operation*" for reference.
The buffering time for different clock speed can be calculated proportionally.

Hold scan operation:

If the 1[7] register **HOLD_SCAN_EN** = 1, which only available in SW6888 BC version, the sensor scan operation is held once the FIFO overflow. The data flow can pause and the scan operation will continue after the FIFO is available for writing new data. In this way, the data overflow will never be a problem.

Still Motion Detection

Still motion detection is designed to reduce the mount of fingerprint image data being transferred. At the beginning of each scan, in case finger is not moving, without still motion detection, the sensor will output the same frame image over and over again. For certain application with limited system memory, this feature will reduce the requirement for system memory, as well as the load to host CPU tremendously.

For each new scan, the captured frame image is calculated against the previous one. Only when certain threshold is exceeded, which is set by register **THRESHOLD**, SW6888 will begin to transmit. The calculated value can be checked by reading register **DIFF_ACCUM**. The still motion can be disabled by setting register **THRESHOLD** to 0.

Analog Portion

The analog portion of the SW6888 is comprised of bandgap voltage reference, sensor pixel/VGA, 16-channel 8-bit analog-to-digital converters (ADC), and finger detecting circuit. Each block is described in the following:

Bandgap Voltage Reference
The SW6888 is integrated with internal voltage and current reference. The current reference is derived from the voltage reference. For more accurate current setting, a 62K ohm resistor needs to be inserted between pin **IREF** and ground. If the user leaves pin **IREF** floating, the internal current reference is designed within $\pm$10% accuracy.

Sensor Pixel/VGA
The sensor matrix is comprised of 16x192 sensing units. The physical size of the sensing area is 0.81mm x 9.75mm. Each sensing unit is designed to meet **IEC**61000-4-2 ESD standard for human interaction of no less than 15K volt.

The sensing unit also has integrated Variable Grain Amplifier (VGA). The gain can be programmed by setting register **VGA[1:0]**. This feature allows to user to adjust the gain in different environment to achieve maximum sensitivity.

ADC
The SW6888 is integrated with 16-channel 8-bit ADC. It captures 16 analog signals at the same time from 16 vertically aligned pixels. The 16 analog-to-digital converters (ADC) convert the analog signals to digital readings simultaneously. Such arrangement allows the SW6888 to be able to capture more details of the finger image, especially at relatively high swipe speed.

Finger Detecting Circuit
The Finger detecting circuit is designed to detect human finger. When human finger is detected, the Finger detecting circuit sets pin **FNG_DET**. This circuit operates in all operational mode, including standby mode, scan mode, and navigation mode.

Large Current Detection
In case the sensor suffers physical damage, usually such damage causes large short current between power supply and ground. The SW6888 is integrated with a large current detection circuit. The threshold is set around 100mA. During normal operation, **ErrB** will be set high. When large current is detected, this circuit will set pin **ErrB** to 0. Thus the host computer can take further action to isolate the SW6888 from the system to prevent it from further draining power. For detailed description please refer to " *Operation* ".

Interface Description

The SW6888 supports four digital interfaces, Flash Interface, Parallel Interface, and Serial Peripheral Interface (SPI). Each interface can be selected by setting **IFSEL [1:0]** to different value. The maximum data rate through serial interface is 12Mbps, while parallel interfaces support fast data rate.
For each mode, there are four basic functions that are accommodated:

1. Interrupt (new data ready / FIFO not empty)
2. Register read
3. Register write
4. FIFO read

For all modes, the first function is enabled with the **READY** signal, which signifies that a new detection is available, and/or that the FIFO is not empty (there is data in the FIFO ready to be read). Register access and FIFO read operations are handled separately for each mode:

Pin Name	Width	I/O	Description		
			Flash mode	Parallel mode	SPI mode
RSTB	1	I	Active-low asynchronous reset		
READY	1	O	New image ready / FIFO not empty		
IO	8	I/O	Parallel data		N/A
CLE	1	I	Command latch enable	Register address latch	SDI
ALE	1	I/O	Address latch enable	FIFO read enable	SDO
CEB	1	I	Active-low chip enable		SSB
REB	1	I	Active-low read enable		N/A
WEB	1	I	Active-low write enable		Read/Write Clock
IFSEL	2	I	Select interface mode: 0: Flash mode 1: Parallel mode 2: N/A 3: SPI mode		

Flash interface mode
In Flash interface compatibility mode, the fingerprint sensor acts like a standard flash-memory device. Reads and writes are set up with commands, and addresses are latched to target either the FIFO data or the control and configuration registers.

Parallel interface mode
In GPIO parallel interface mode, the fingerprint sensor operates in the fastest, most efficient mode. For register access, two cycles are necessary, one to set up the register address, one to send the data. For FIFO reads, only one cycle is necessary, which allows the FIFO data to be read out very quickly.

SPI mode
Serial peripheral interface mode provides serial access to the fingerprint sensor. When SSB (slave-select bar) is low, data is shifted into the sensor on SDI (serial data in) and out on SDO (serial data out). When SSB is high, SDO is tri-stated. The first eight bits received on SDI after SSB goes low are the address and read/write bit.

The timing for each digital interface is illustrated in "*Interface Details*".

Register Map

SW6888 has total of 10 registers. Each register is 8 bits long. Registers can be used to control different settings as well as to read back values for analysis purpose. The following is a register map of SW6888:

Address	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0	NAV_WDW		NAV_MOD	FNG_CNTL [1:0]		FNG_DET _FORCE	FNG_DET	PWR_DN
1	HOLD_SCA N_EN	RESERVED		RAM_FUL	DRV_AMP		VGA	
2	RESERVED	OFFSET_SEL [1:0]		TEST_MEM	WEIGHT		PXL_SEL	BIN_MOD
3	DIFF_ACCUM [7:0]							
4	DIFF_ACCUM [15:8]							
5	RESERVED			FLAG	DIFF_ACCUM [19:16]			
6	RESERVED -- SM THRESHOLD [7:0]							
7	RESERVED -- SM THRESHOLD [15:8]							
8	RESERVED				RESERVED -- SM THRESHOLD [19:16]			
9	FLASH COMMAND							

The following is the detailed description of each register:

NAME	ADDRESS	Read/Write	Default	Function
PWD_DN	0[0]	R	0	Active high power down digital to analog
FNG_DET	0[1]	R	0	High when finger is detected
FNG_DET_FORCE	0[2]	R/W	0	Active high force scan 64 frames
FNG_CNTL [1:0]	0[4:3]	R/W	00	Control setting for finger detecting: 00 High sensitivity 01 Lower sensitivity 10 High sensitivity 11 Fng_detect=1
NAV_MOD	0[5]	R/W	0	Active high set navigation mode
NAV_WDW [1:0]	0[7:6]	R/W	11	Navigation scan window: 00 16 pixels 01 32 pixels 10 64 pixels 11 192 pixels
VGA [1:0]	1[1:0]	R/W	00	Sensor VGA control: 00 1 01 2 10 4 11 1/2
DRV_AMP [1:0]	1[3:2]	R/W	00	Internal electrical signal amplitude adjustment 00 1.4 01 VDD 10 0.8 11 0.4

RAM_FUL	1[4]	R	0	RAM full indicator
HOLD_SCAN_EN	1[7]	W/R	0	Hold Scan Enable if RAM_FUL=1, Only available in SW6888 Rev. BC
BIN_MOD	2[0]	R/W	0	Active high set binary mode
PXL_SEL	2[1]	R/W	0	Top plate pixel array for binary mode 0: 1 1: 2x2
WEIGHT	2[3:2]	R/W	00	Binarization weight: 00 0 01 1 10 2 11 4
TEST_MEM	2[4]	R/W	0	Whether to test memory
OFFSET_SEL	2[6:5]	R/W	00	Binarization offset selection: 00: 0; 01: 8; 10: 16; 11: 32;
DIFF_ ACCUM [7:0]	3[7:0]	R	00000000	Difference accumulate value
DIFF_ ACCUM [15:8]	4[7:0]	R	00000000	Difference accumulate value
DIFF_ ACCUM [19:16]	5[3:0]	R	0000	Difference accumulate value
FLAG	5[4]	R	0	Active high set send flag, indication of exceed threshold Reset to 0
THRESHOLD [7:0]	6[7:0]	R/W	00000000	Threshold
THRESHOLD [15:8]	7[7:0]	R/W	00000000	Threshold
THRESHOLD [19:16]	8[3:0]	R/W	0000	Threshold
FLASH COMMAND	9[7:0]	R	00000000	Flash interface query command

The entire register map can be accessed at once through different interfaces. The detailed operation is illustrated in the "*Interface Details*".

The recommended settings for the register for gray-scale mode is shown below:

Register	0	1	2	3	4	5	6	7	8	9
Value	**D0**	**88**	**00**	**00**	**00**	**00**	**00**	**00**	**00**	**00**

The recommended settings for the register for binary mode is shown below:

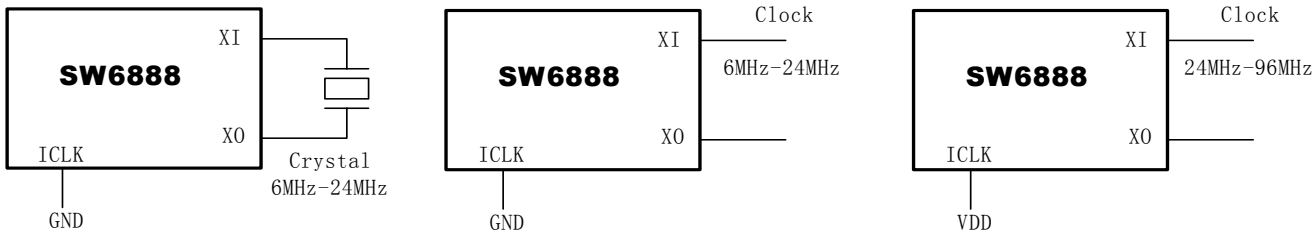
Register	0	1	2	3	4	5	6	7	8	9
Value	**D0**	**88**	**23**	**00**	**00**	**00**	**00**	**00**	**00**	**00**

INTERFACE DETAIL

Clock Generation

SW6888 is integrated with crystal oscillator. The recommended crystal frequency is 6MHz to 24MHz. The higher the crystal is chosen, the faster the scanning rate is. The host controller must be able to receive all the scanned data in time under a chosen crystal frequency.

The host controller can also send a controlled clock to pin "**XI**" instead. Such configuration is also required for ultra low power standby mode. The following are the configuration diagram of clock generation for SW6888:



Interface Description

SW6888 supports parallel interface, flash interface, and SPI. The following is a detailed description for each interface.

Parallel Interface

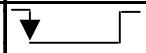
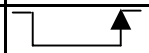
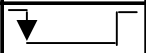
SW6888 supports industrial standard parallel interface. The data rate on the parallel interface is 1/8 of the chip clock on average. The host computer can stream scanned fingerprint data out, as well as access internal registers. The following illustrates the operation and timing requirement of parallel interface:

Digital I/O supporting parallel interface

Pin Name	Width	I/O	Parallel Interface
RSTB	1	I	Active-low asynchronous reset
READY	1	O	New image ready / FIFO not empty
IO [7:0]	8	I/O	Parallel data
CLE	1	I	Register address latch
ALE	1	I	FIFO read enable

Pin Name	Width	I/O	Parallel Interface
CEB	1	I	Active-low chip enable
REB	1	I	Active-low read
WEB	1	I	Active-low write
IFSEL [1:0]	2	I	Set to 01

Mode select for parallel interface:

		Ready	CLE	ALE	CEB	WEB	REB	I/O[7:0]
Read Status Mode		L	X	L	L	H		Status (10clock)
Write Status Mode	Load Address	L	H	L	L		H	1st Address Byte
Write Status Mode	Load Status	L	L	L	L		H	Output Status sequential
Read FIFO Mode		H	L	H	L	H		Output data sequential

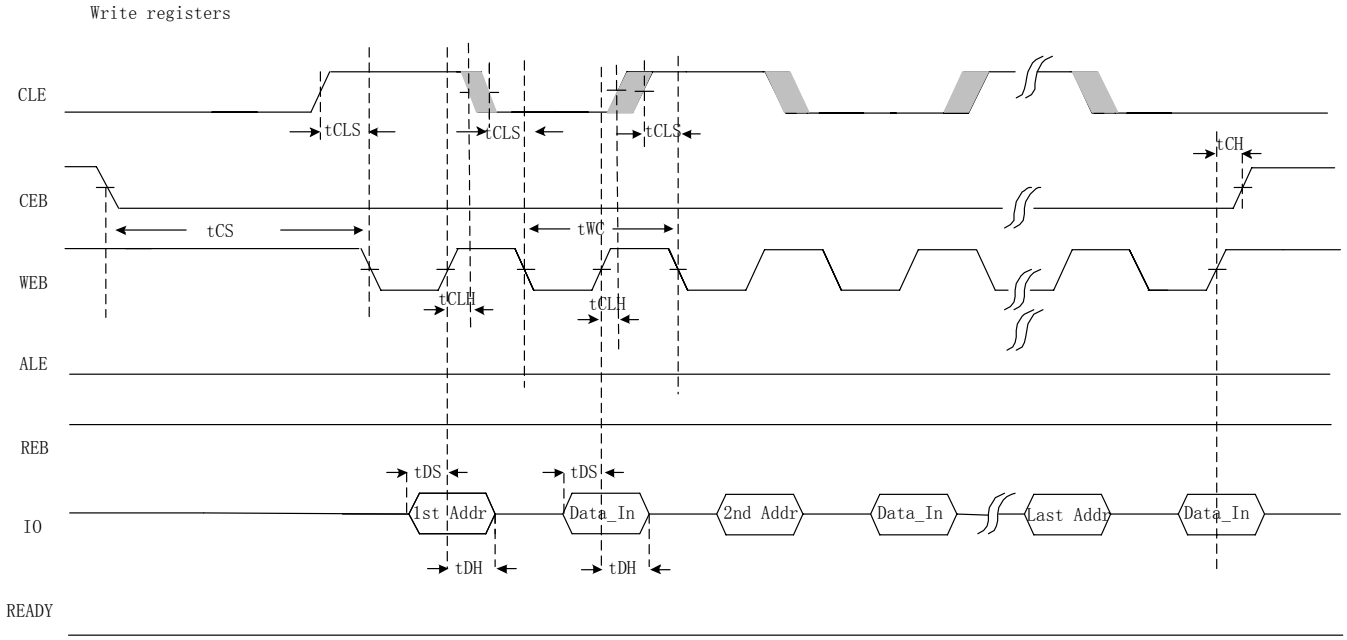
Parallel interface timing specification:

Timing diagram for parallel interface:

Parameter	Symbol	Min. (ns)	Typ. (ns)	Max. (ns)
CLE Set-up Time	t_{CLS}	1		
CLE Hold Time	t_{CLH}	5		
CEB Setup Time	t_{CS}	6		
CEB Hold Time	t_{CH}	1		
WEB Pulse Width	t_{WP}	25		
Data Setup Time	t_{DS}	20		
Data Hold Time	t_{DH}	10		
Write Cycle Time	t_{WC}	60		
WEB High Hold Time	t_{WH}	15		
ALE to RE Delay (Read cycle)	t_{AR}	5		

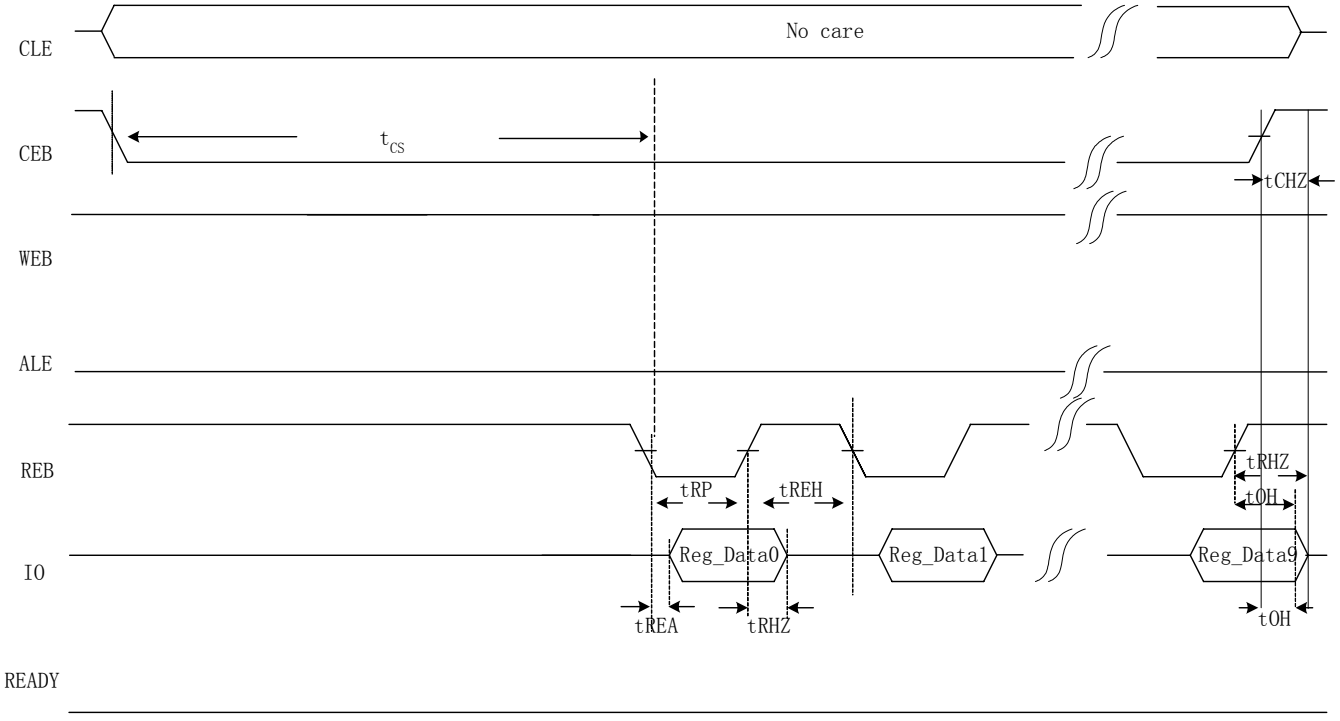
REB Pulse Width	t_{RP}	25		
Read Cycle Time	t_{RC}	50		
REB Access Time	t_{REA}			15
REB High to Output Hi-Z	t_{RHZ}		7	30
CEB High to Output Hi-Z	t_{CHZ}			20
REB or CE High to Output hold	t_{OH}	15		
REB High Hold Time	t_{REH}	15		
Ready to RE Low	t_{RR}	20		

Register write through parallel interface:
User can write individual register by applying selected address prior to register value. **ALE** must be set low during this operation. **CLE** is the select for register address/data.



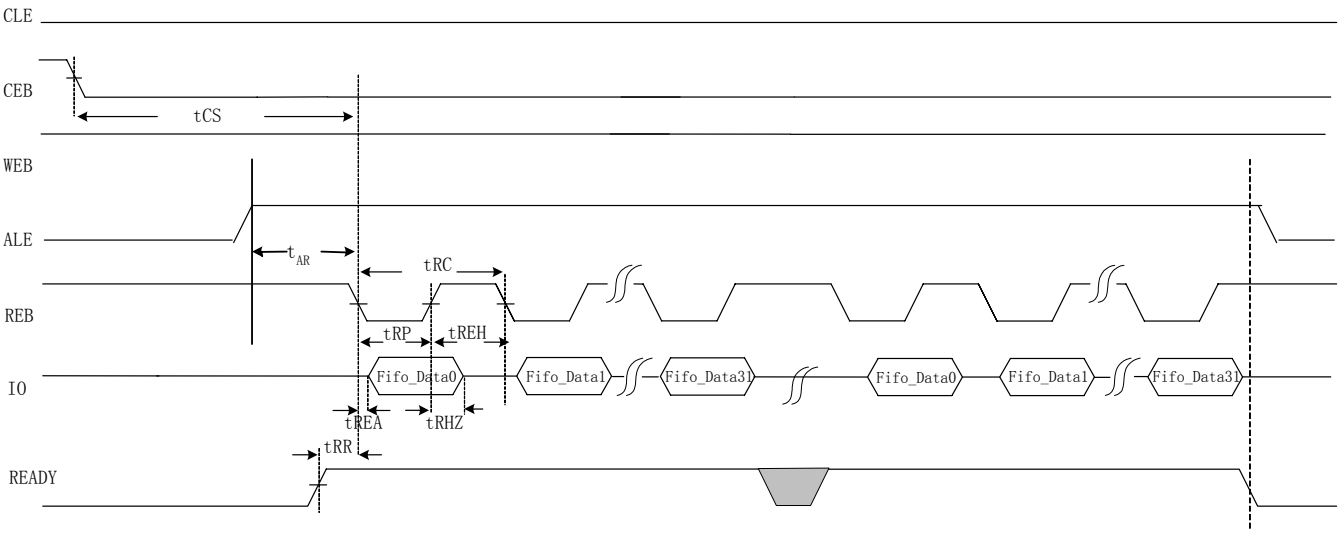
Register read through parallel interface:

During this operation, **ALE** must be set to 0, **WEB** to 1,



FIFO read through parallel interface:

In order to receive scanned fingerprint data from SW6888, set **CLE** low, **WEB** and **ALE** high, apply **REB**, when **READY** is set. Do not apply **REB** when **READY** is low.



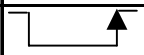
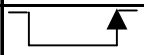
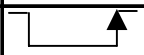
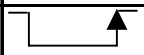
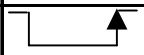
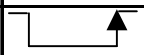
Flash Interface

SW6888 supports standard flash interface. The manufacture ID for SW6888 is set to be **EAH** and the product ID is **67H**.The data rate on the flash interface is 1/8 of the chip clock on average. The host computer can stream scanned fingerprint data out, as well as access internal registers through flash interface. The last flash interface commend can also be checked through reading registers. The following illustrates the operation and timing requirement for flash interface:

Digital I/O supporting flash interface

Pin Name	Width	I/O	Flash Interface
RSTB	1	I	Active-low asynchronous reset
READY	1	O	New image ready / FIFO not empty
IO [7:0]	8	I/O	Parallel data
CLE	1	I	Command latch enable
ALE	1	I	Address latch enable
CEB	1	I	Active-low chip enable
REB	1	I	Active-low read enable
WEB	1	I	Active-low write enable
IFSEL [1:0]	2	I	Set to 00

Mode select for flash interface:

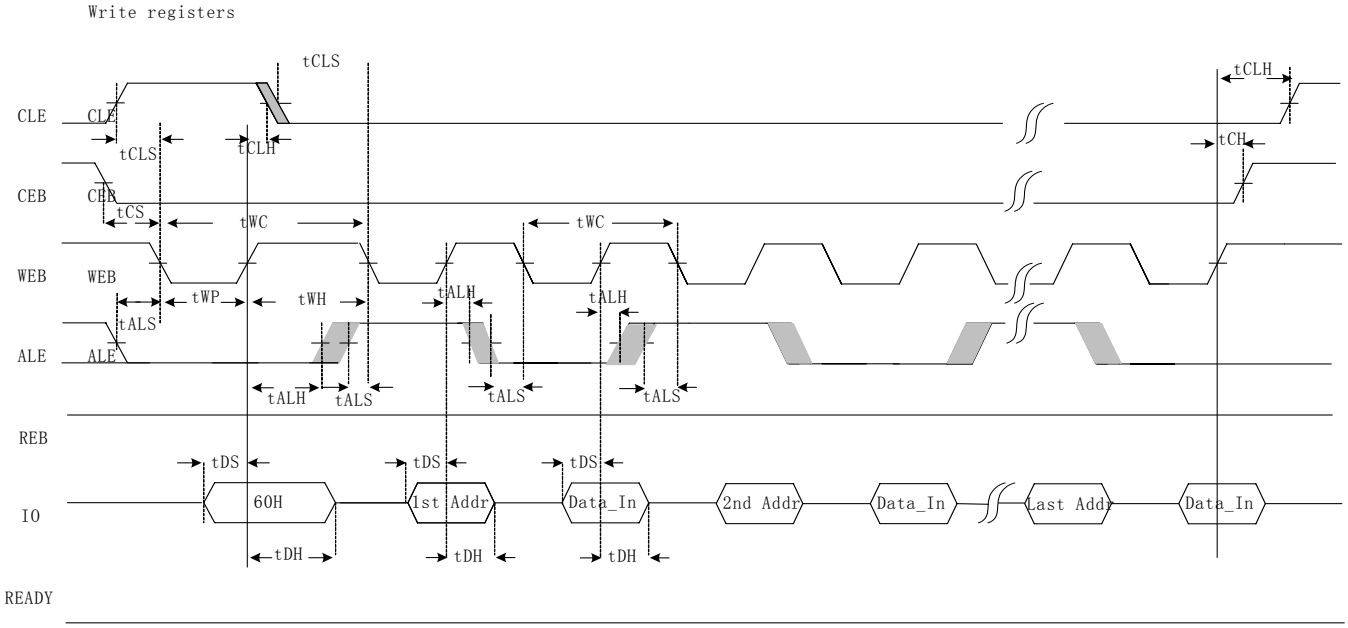
		Ready	CLE	ALE	CEB	WEB	REB	I/O[7:0]
Read Status Mode	Command Load	L	H	L	L		H	Input Command Byte(70h)
Read Status Mode	Address Load	L	L	H	L		H	Input 1st Address Byte
Read Status Mode	Read Status Register	L	L	L	L	H		Output Status (10clock)
Write Status Mode	Input Command	L	H	L	L		H	Input Command Input Byte(60h)
Write Status Mode	Address Load	L	L	H	L		H	Input Signed Address Byte
Write Status Mode	Status Load	L	L	L	L		H	Input Status after each Address
Read FIFO Mode	Load Command	L	H	L	L		H	Input Command Byte(01h)

Flash interface timing specification:

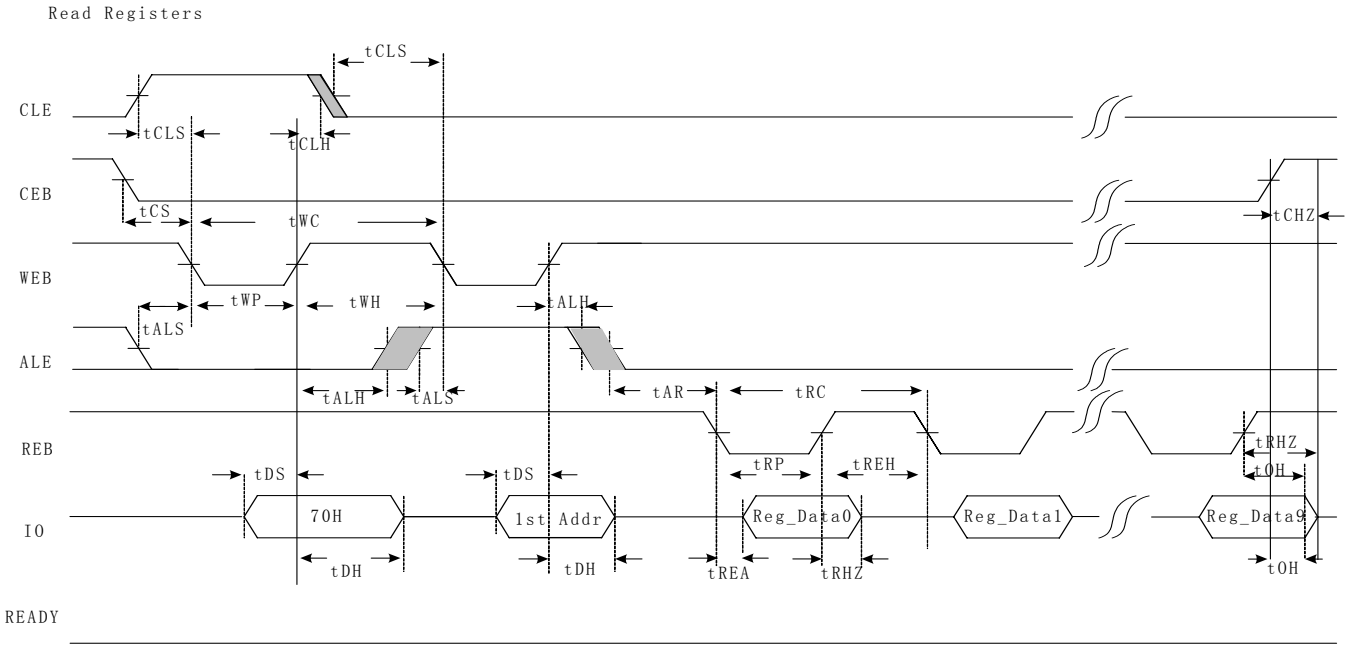
Parameter	Symbol	Min. (nS)	Typ. (nS)	Max. (nS)
CLE Set-up Time	t_{CLS}	1		
CLE Hold Time	t_{CLH}	5		
CE Setup Time	t_{CS}	5		
CE Hold Time	t_{CH}	1		
WE Pulse Width	t_{WP}	5		
ALE Setup Time	t_{ALS}	1		
ALE Hold Time	t_{ALH}	5		
Data Setup Time	t_{DS}	5		
Data Hold Time	t_{DH}	10		
Write Cycle Time	t_{WC}	60		
WE High Hold Time	t_{WH}	15		
RE Pulse Width	t_{RP}	25		
Read Cycle Time	t_{RC}	50		
RE Access Time	t_{REA}		7	15
RE High to Output Hi-Z	t_{RHZ}			27
RE High to Output hold	t_{OH}	15		
RE High Hold Time	t_{REH}	15		

Timing diagram for flash interface:

Register write through flash interface:
User can write to individual registers by applying the selected address prior to the register value. The register write sequence started with a command **60H**, while **CLE** is set.

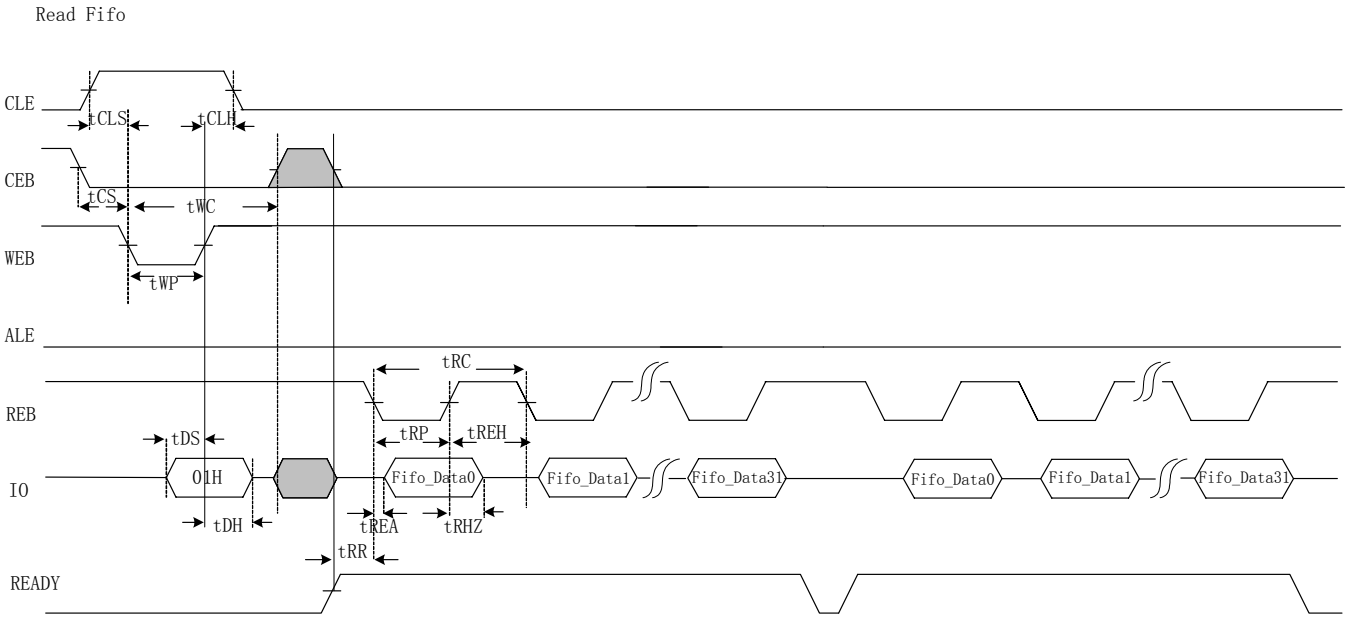


Register read through flash interface:
When the user reads the register value, a command **70H** must be sent, with **CLE** set. Unlike register writes, the SW6888 will automatically output 10 register values without selecting the register address. 10 **REB** pulses must be applied after sending command **70H**.



FIFO read through flash interface:

To receive fingerprint data from the SW6888, the command **01H** must be sent prior to the **READY** signal. When **READY** is set, the host computer should send **REB** and read out **IO** values. **REB** should not be applied when **READY** is low.



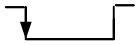
Serial Peripheral Interface (SPI)

SW6888 is compliant with the standard slave-mode Serial Peripheral Interface (SPI). The data rate on the SPI interface is the same as the chip clock on average. The host computer can stream scanned fingerprint data out, as well as access internal registers through the SPI interface. The following illustrates the operation and timing requirements for SPI interface:

Digital I/O supporting SPI:

Pin Name	Width	I/O	SPI
RSTB	1	I	Active-low asynchronous reset
READY	1	O	New image ready / FIFO not empty
CLE	1	I	SDI: Serial Receive Data
ALE	1	I/O	SDO: Serial Transmit Data
CEB	1	I	SSB: Frame Sync.
WEB	1	I	Read/Write Clock
IFSEL [1:0]	2	I	Set to 11

Mode select for SPI

		Ready	CLE	ALE	CEB	WEB	REB	I/O[7:0]
Read Status Mode	Command Load (aah)	L	Command Bit	X	L		X	X
Read Status Mode	Read Status	L	Output Data Bit	X	L		X	X
Write Status Mode	Command Load (55h)	L	Command Bit	X	L		X	X
Write Status Mode	Write Status	L	Input Data Bit	X	L		X	X
Read FIFO Data		H	X	Output Data Bit	L		X	X

SPI interface timing specification:

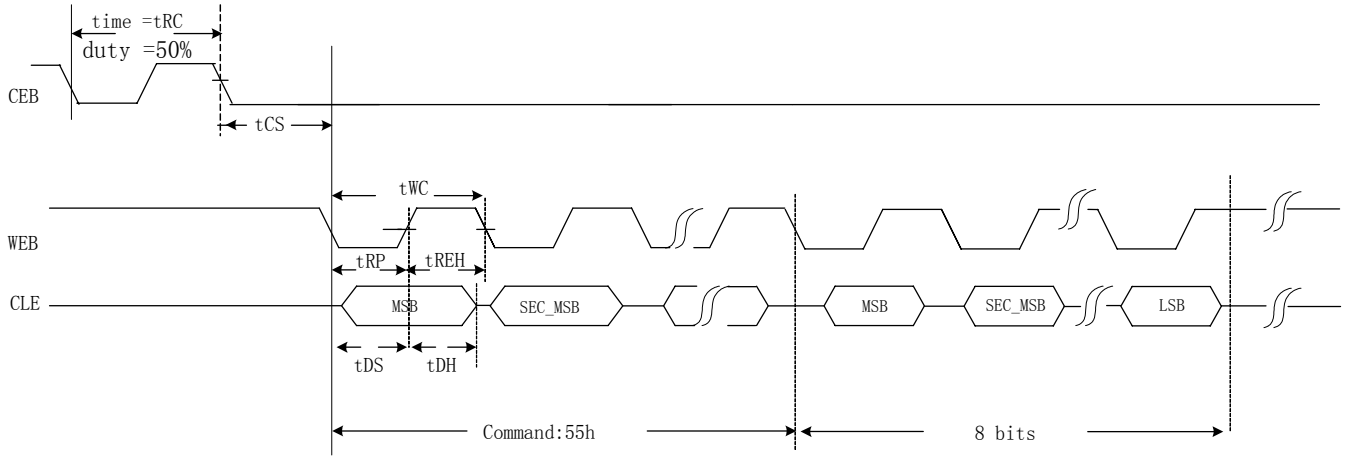
Parameter	Symbol	Min. (nS)	Typ. (nS)	Max. (nS)
CE Setup Time	t_{CS}	10		
WE Pulse Width	t_{WP}	10		
Data Setup Time	t_{DS}	20		
Data Hold Time	t_{DH}	5		

Write Cycle Time	t_{WC}	35		
WE High Hold Time	t_{WH}	10		
RE Pulse Width	t_{RP}	20		
Read Cycle Time	t_{RC}	30		
RE Access Time	t_{REA}			
RE High to Output Hi-Z	t_{RHZ}			15
CEB High to Output Hi-Z	t_{CHZ}			15
RE or CE High to Output hold	t_{OH}	15		35
RE High Hold Time	t_{REH}	10		15
Ready to RE Low	t_{RR}	20		

Timing diagram for SPI:

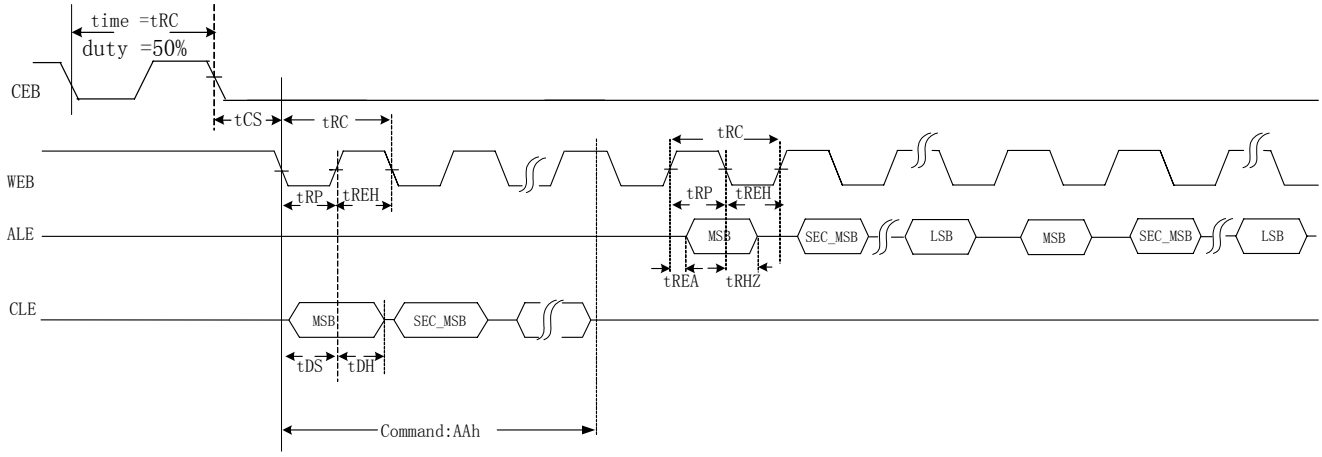
Register write through SPI:

In order to access registers for write operations, a commend **55H** must be applied on the first 8 clock cycles after setting **CEB** low, serially through **CLE**. The first-bit-in is the MSB of the command. It is followed by 10 8-bit write data values into the registers. The first-bit-in is the MSB in any 8-bit sequence. No addresses need to be transmitted. **CEB** should be set to "1" after write all the data.



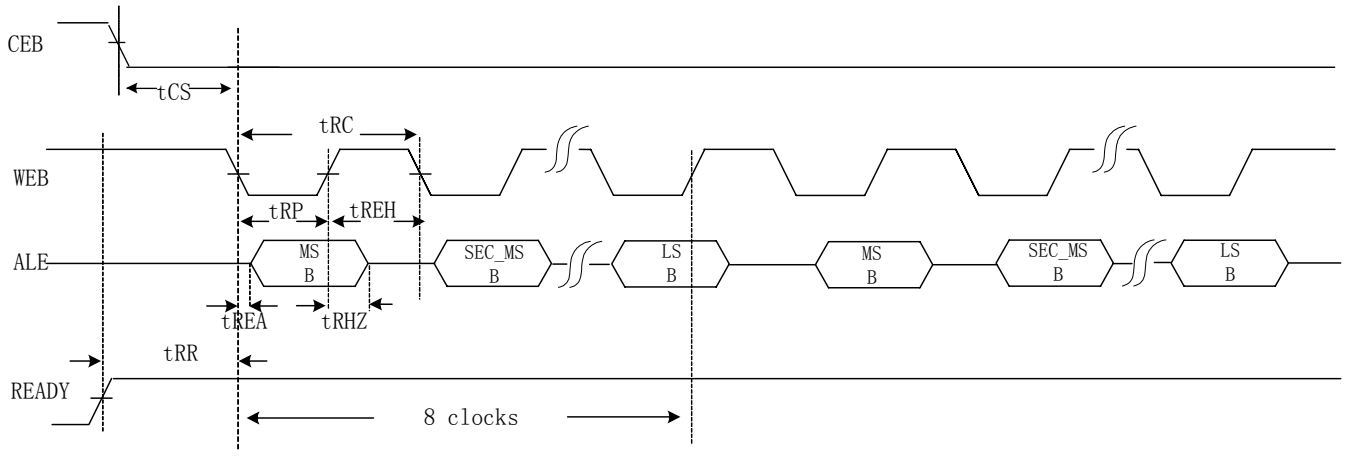
Register read through SPI:

To read out register, set **CEB** to 0, write commend "**AAH**" on the rising edge of **WEB** through **ALE**, and then switch **ALE** to read mode. The register data is valid at the falling edge of **WEB**. The value of all 10 8-bit registers is transmitted out sequentially through pin **CLE**. The MSB of each register is transmitted first. **CEB** should be set to "1" after read all the data.



FIFO read through SPI:

In order to receive the fingerprint data from SW6888, set **CEB** to 0, while **READY** is set, and apply **WEB**. The first-bit-out is the MSB of the FIFO 8-bit data. Do not apply **WEB** when **READY** is 0. **CEB** should be set to "1" after read all the data.

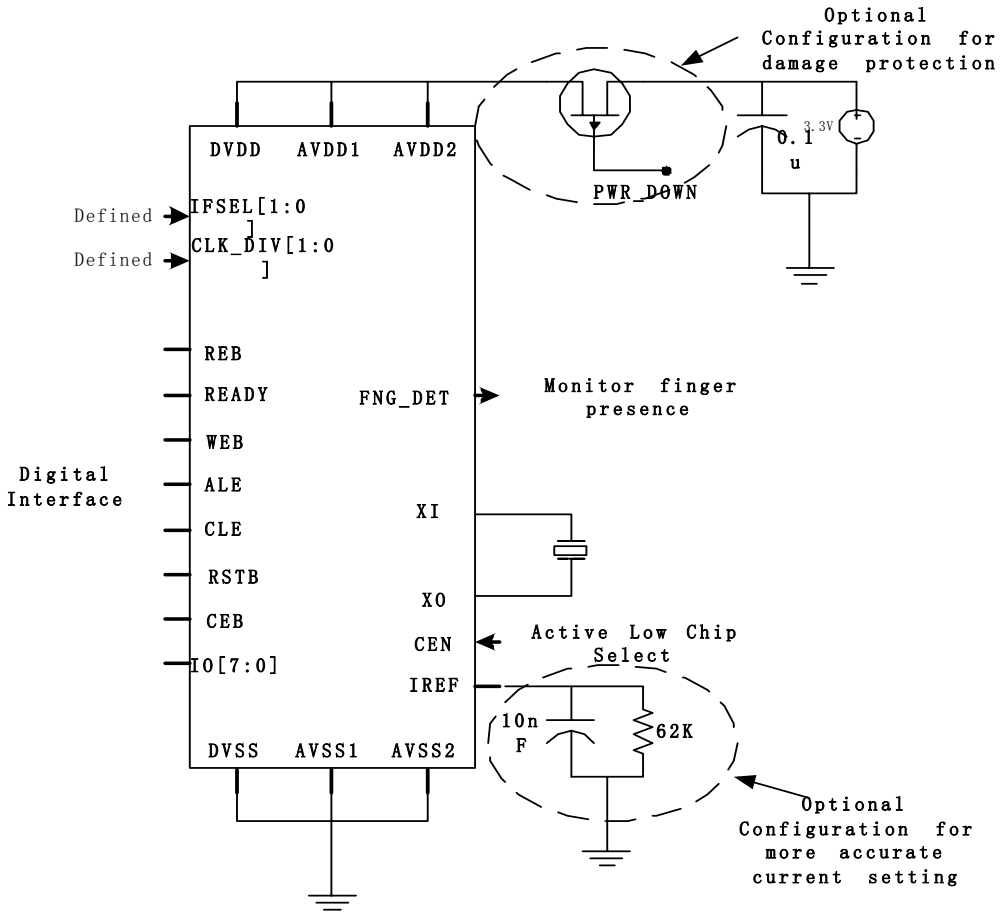


Note: Parameter is guaranteed by design and characterization testing.

OPERATION

Implementation Diagram

SW6888 requires minimal external components. The following is an implementation circuit reference:



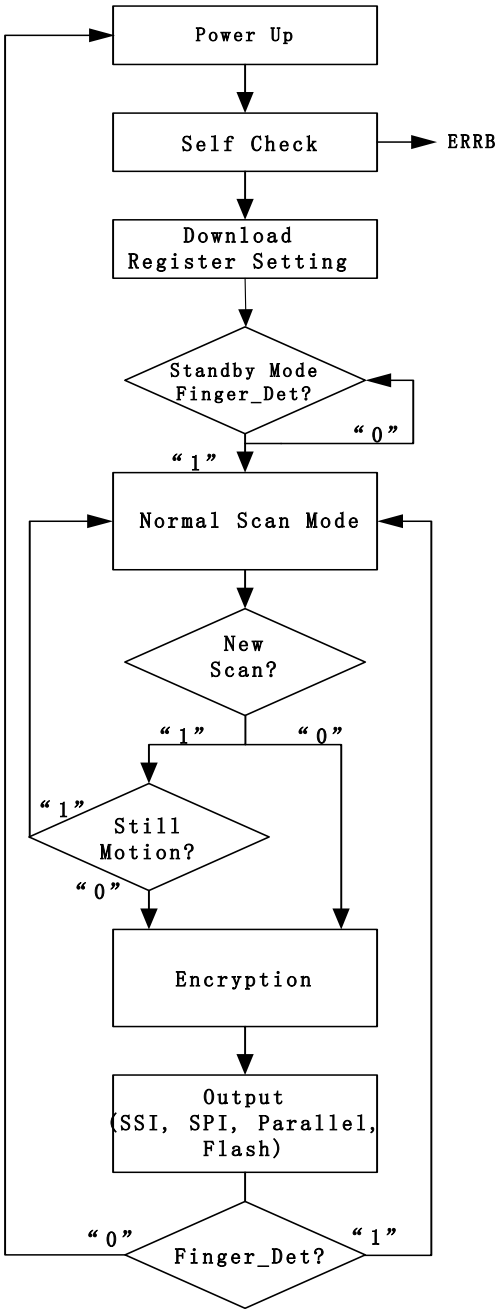
Beside the bypass capacitors for the power supply, other external components are optional. SW6888 is fully integrated with internal voltage and current references, however, it is recommended to use an external 62K Ohm resistor with bypass a capacitor for pin **IREF**. Such a configuration will guarantee a more accurate current setting for internal circuits. If the user chooses not to use the external resistor, **IREF** should be left floating.

Another optional configuration shown in the above diagram is due to the nature of silicon based fingerprint sensor. In the event that the chip is damaged, usually such an event will cause a large current. The SW6888 is integrated with a large current detection circuit. When a large current is detected, pin **ErrB** will be set to 0. The host computer can monitor this pin, and then disconnect SW6888 from the system if such an event occurs. This configuration allows the end user to prevent the damaged chip from further draining power.

The SW6888 can fully operate through a standard digital interface. However, taking additional measures such as monitoring **FNG_DET** and **ErrB**, as well as using a CPU controlled clock for **XI**, can potentially optimize power consumption and reliability for certain applications. This is further discussed in *Operation Description*.

Operation Description

The SW6888 supports three operational modes: standby, normal scan, and navigation mode. When **FNG_DET** = "0", the chip stays in standby mode to reserve power. When finger is detected, **FNG_DET** will be set to 1, and the controller powers up the analog circuits, including the Bandgap, Sensing Matrix, and ADC, and normal scan begins. In normal scan mode, the SW6888 will continue to scan the finger until the finger is removed. The following is a flow chart of normal scan mode:



SW6888 also supports low power navigation mode for fingerprint navigation and mouse pad applications. Instead of scanning the full sensor matrix, a smaller scan window can be set through register writes. In the navigation mode, the chip will automatically power itself down to preserve power, except during the defined scan window.

In both normal scan and navigation scan mode, there are several additional features, such binary mode (on-chip *binarization*), and still motion detection. The following is a detailed description of different operation mode.

Standby Mode

SW6888 will automatically power down most of the internal circuit when a finger is not detected. The user only needs to monitor pin **READY** occasionally to figure out whether a new scan has started or not. Such a configuration is simple for the implementation; however, in order to prevent the internal FIFO from overflowing, the host computer must respond within the time listed in "*Preventing memory overflow*". To reduce the computer load, READY can be checked in a much less frequent manner, i.e. 0.1sec, but this will almost guarantee that when the computer sees a valid READY, the on-chip buffer will have already overflowed. In this case, the host computer must apply RSTB for force SW6888 starts a new scan.

Note: memory overflow is troublesome, due to fact that data decryption is not possible after an overflow. A new scan must be forced.

When a host-controlled clock is used for pin **XI** instead of a crystal, the host computer can terminate the clock through pin **XI** to SW6888. This configuration will allow the user to achieve even lower power consumption in standby mode. In such configuration, the internal clock and the digital interface will be completely shut down. The host computer must monitor pin **FNG_DET** instead of **READY**. When **FNG_DET** is set high, which indicates finger presence, the host computer should turn on the clock to pin **XI**, reset SW6888 through **RSTB** immediately, and download the register settings. The scanned image can then be received when pin **READY** is set high. Such configuration will also reduce the load to the host computer significantly. The host computer also only needs to check the sensor status every 0.1 second without losing much of the scan image.

Normal Scan Mode

When a finger is detected, SW6888 will automatically switch from standby mode to normal scan mode. The sensor will continue scanning the fingertip as long as the finger is in contact with the sensor surface. The data is divided into frames. Each frame contains 192 x 16 pixels, and the data is encrypted internally to enhance the security. All frames with information of fingerprint image will be processed externally through software. This software can be obtained from Symwave, Inc.

In normal scan mode, there are two additional features: binary mode, and still motion detection mode, which can be set through register settings. For regular scan, each pixel has an 8-bit code or 256 gray levels, resulting in a fairly high data rate. Binary mode, or on-chip *Binarization*, is designed to reduce the transmission data rate as well as to allow longer on-chip buffering time. The mechanism of on-chip Binarization is described in *Hardware Description*.

Still motion detection is another feature supported by the SW6888. It only operates in Binary mode. This feature allows the user to disregard the data at the beginning of each scan, when finger has not started to move. With this feature, the user can implement SW6888 with much less system memory.

For each scan, SW6888 will transmit a *HEADER* at the beginning and a *FOOTER* at the end. The *HEADER* and *FOOTER* will also indicate whether it is a binary scan or regular scan with 8bit per pixel resolution. The following are the *HEADER*'s and *FOOTER*'s for different scan mode:

HEADER for normal scan with 8bit per pixel:

0x74,0x72,0x61,0x74,0x53,0x4e,0x23,0x41,
0x24,0x65,0x76,0x61,0x77,0x6d,0x79,0x53,
0x8b,0x8d,0x9e,0x8b,0xac,0xb1,0xdc,0xbe,
0xdb,0x9a,0x89,0x9e,0x88,0x92,0x86,0xac;

FOOTER for normal scan with 8bit per pixel:

0x4e,0x23,0x41,0x24,0x65,0x76,0x61,0x77,
0x6d,0x79,0x53,0x64,0x6e,0x65,0x6d,0x6c,
0xb1,0xdc,0xbe,0xdb,0x9a,0x89,0x9e,0x88,
0x92,0x86,0xac,0x9b,0x91,0x9a,0x92,0x93

HEADER for normal scan in with 1bit per pixel (binary mode):

0x8b,0x8d,0x9e,0x8b,0xac,0xbd,0xdc,0xbe,
0xdb,0x9a,0x89,0x9e,0x88,0x92,0x86,0xac,
0x74,0x72,0x61,0x74,0x53,0x42,0x23,0x41,
0x24,0x65,0x76,0x61,0x77,0x6d,0x79,0x53;

FOOTER for normal scan in with 1bit per pixel (binary mode):

0xbd,0xdc,0xbe,0xdb,0x9a,0x89,0x9e,0x88,
0x92,0x86,0xac,0x9b,0x91,0x9a,0x92,0x93,
0x42,0x23,0x41,0x24,0x65,0x76,0x61,0x77,
0x6d,0x79,0x53,0x64,0x6e,0x65,0x6d,0x6c;

The following are the transmission sequence for different scan mode:

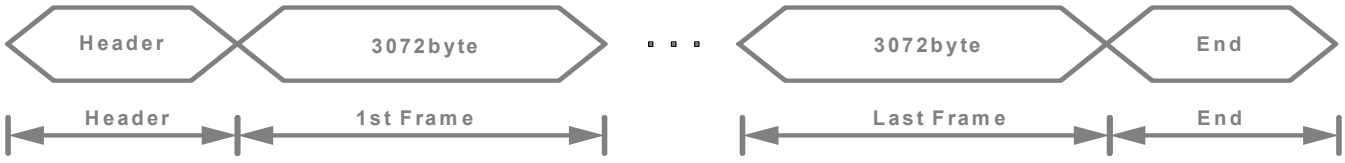


Image Format with 256 Gray Level

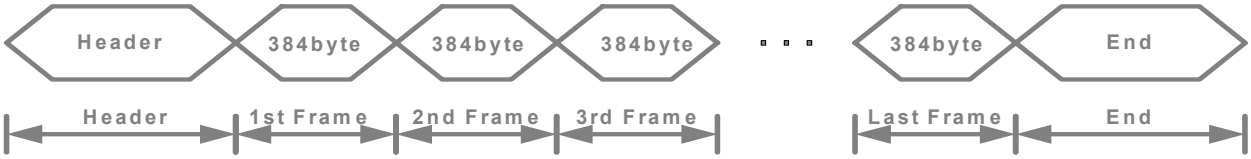


Image Format with Binarization

In between *HEADER* and *FOOTER*, the user must count the number of bytes received in order to separate each frame. Except for the *HEADER* and *FOOTER*, the entire image is encrypted on chip. The decryption code can be obtained from Symwave, Inc.

Navigation Scan Mode

Navigation scan can be set through register settings. This mode is designed to support low power fingerprint navigation or mouse pad applications. There are four different scan windows that can be chosen, 16x16, 32x16, 64x16 and 192x16. In Navigation mode, the internal scanning circuit is only activated within the scan window. The sensor will power down most of the circuit to preserve power when the scan is out of the scan window. Each window is centered at the middle of the sensor.

The data transmitted out during Navigation mode is not for the purpose of processing the fingerprint image, but for calculating the speed and direction of the finger movement. When scan window is set to 16x16 or 32x16, which represents only small portion of the finger, the data is **not** encrypted internally.

The Navigation scans also supports both 8-bit per pixel and 1-bit per pixel (binary mode). The HEADER and FOOTER of the transmission is the same as the normal scan mode. Assuming a 16x16 window is set, the transmission sequence of navigation scan with 8bit per pixel is as follows:

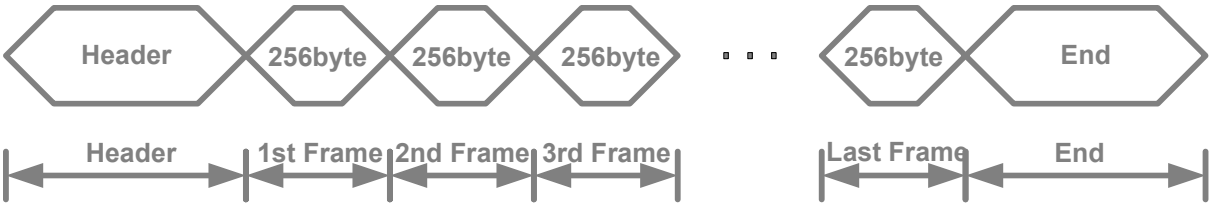


Image Format in 16x16 Navigation Mode

The controller looks at the result of Still Motion Detection result. Only when the finger starts to move will valid outputs be generated and transferred. The output will be shut down again when the Still Motion Detection detects still motion. In this state, the SW6888 still scans the finger until the finger is removed. Then the SW6888 is set to be in standby mode again.