FPC1011F3 Area Sensor Package

Product Specification

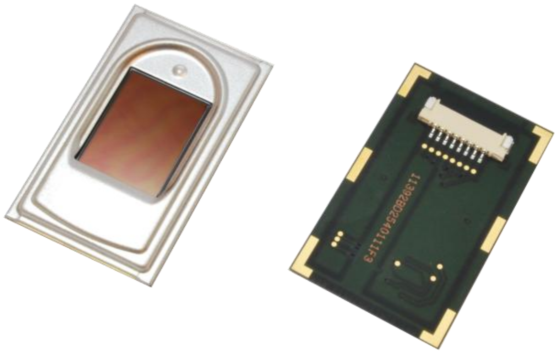
FINGERPRINTS

Features

- Fingerprint area sensor
- Hard and scratch resistant protective surface coating
- Superior image quality
- 3D image with 256 true gray scale values
- Ergonomic frame for optimized finger guidance
- High speed SPI interface
- New ultra-thin flex film connector
- 2.5 to 3.3 volt operation
- Extended ESD range 30kV
- >10 million finger placements

RoHS Compliant
Directive 2002/95/EC

LEAD FREE



Application examples

- Computer peripheral
- Physical access control
- Time and attendance
- Wireless devices
- Security application
- Medical equipment & storage

General description

FPC1011F3 is a new compact CMOS fingerprint sensor with several significant advantages. FPC1011F3 delivers superior image quality, with 256 gray scale values in every single pixel. The reflective measurement method sends an electrical signal via the frame directly into the finger. This technique enables the use of an unbeatably hard and thick protective sensor surface coating. The sensor with its 3D pixel sensing technology can read virtually any finger; dry or wet.

Thanks to the hard and durable surface coating, FPC1011F3 is protected against ESD above 30 kV, as well as scratches, impact and everyday wear-and-tear. The FPC1011F3 includes a designed micro-ergonomic guidance frame, supporting easy integration, simplifying proper fingerprint guidance and hence improving algorithm performance.

The FPC1011F3 sensor also includes an ultra-thin flex film connector, supporting a high speed 4 pin serial SPI interface.

Quick reference data

PARAMETER	DESCRIPTION	VALUE	UNIT
Sensor dimension	Sensor body (W x L x T), nominal	20.4 x 33.4 x 2.3	mm
Interface	Flex connector, 4 pin SPI	8	pin
Supply voltage	DC voltage, typical	2.5 - 3.3	V
Supply current	Typical at 3.3V, 4MHz and RT (room temp)	7	mA
Supply current sleep mode	Power down, typical	10	µA
Clock frequency	Serial SPI	32	MHz
Read out speed	Serial SPI	4	Mpixel/s
Active sensing area	Pixel matrix	10.64 x 14.00	mm
Size sensing array	Pixel matrix (363 dpi)	152 x 200	Pixel
Pixel resolution	256 gray scale values	8	Bit
ESD protection [1]	IEC61000-4-2, level X, air discharge	± 30	kV
Wear-and-tear	Finger placements	> 10 million	times

Note: Data represents typical values or limit values. Details are defined in the subsequent sections.
Note 1: With proper integration according to this specification.

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1 Functional description

1.1 Introduction

The FPC1011F3 sensor component is suitable for numerous types of authentication systems. These systems may be based on highly integrated low power solutions utilizing Fingerprint Cards' (FPC) companion chip, or a large variety of standard micro-controllers or high performance DSPs.

The FPC1011F3 sensor package is built around Fingerprint Cards' sophisticated 3rd generation CMOS implementation FPC1011, offering a superior fingerprint images and a high speed serial interface.

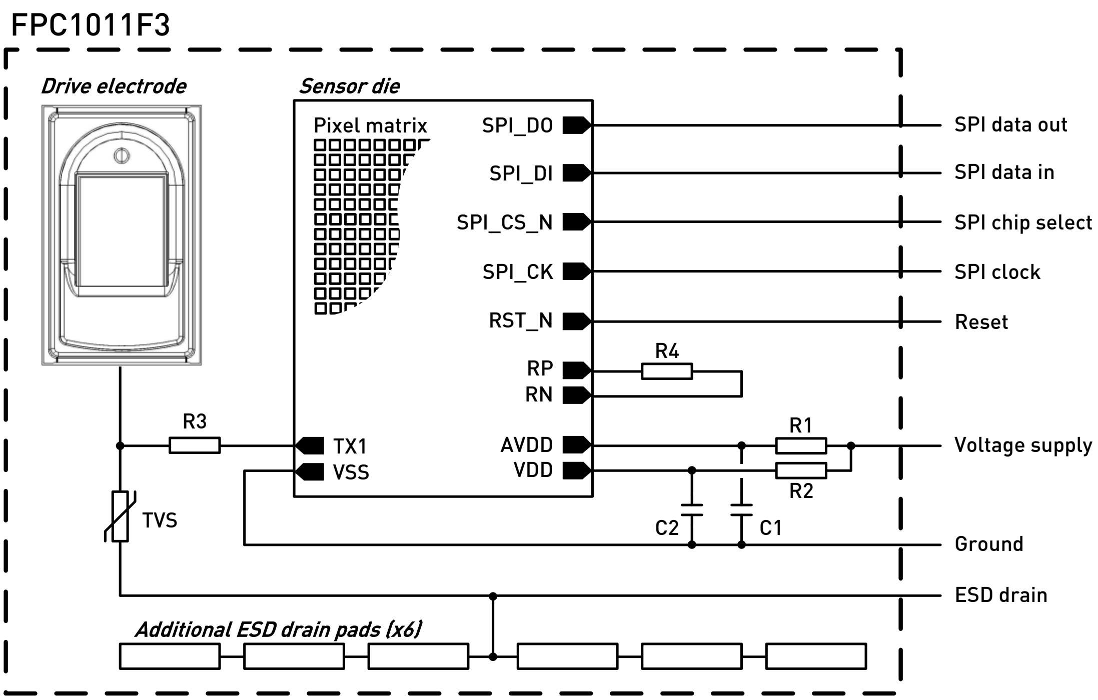
1.2 Block diagram

The FPC1011F3 electrical interface, including the high speed serial interface is outlined in the figure below.

FPC1011F3 interface features:

- Analog and digital power supplies both have individual filtering/decoupling.
- The entire system is run on the SPI clock.
- Integrated ESD protection with supplementary drain pads for best performance.

Note the incoming RC filters added to reduce incoming noise. This filter is part of the current path and will hence cause a slight voltage drop.



Block diagram - Overview *(R1=R2 =10Ω, C1=C2=470nF)*

1.3 Technical features

PARAMETER	DESCRIPTION	VALUE	UNIT
Dimension [1]	Sensor body	20.4 x 33.4 x 2.3	mm
	Sensor body including connector	20.4 x 33.4 x 3.5	mm
Weight	Sensor body including connector	3.1	gram
Active sensing area		10.64 x 14.00	mm
Size sensing array		152 x 200	pixel
Spatial resolution		363	dpi
Pixel resolution	256 gray scale levels	8	bit
Operating temperature		- 20 ... + 60	°C
Storage temperature		- 40 ... + 85	°C
ESD [2]	IEC61000-4-2 level X, air discharge	±30	kV
Package type	FPC1011F3 - 8 pin flex connector, 1mm pitch, Non-ZIF	8	pin

Note 1: Dimensional data is based on nominal values. Tolerance ranges are defined in the corresponding mechanical drawing.
Note 2: With proper integration according to this specification.

1.4 Sensor surface properties

PARAMETER	DESCRIPTION	CONDITION	RESULT
Mechanical wear-and-tear	Repetitive fingertip placements with maintained functionality.	> 10 000 000 times	PASS
Foreign substances	Repetitive strokes with: Acetone, Artificial sweat, Coca cola, Coffee, Isopropyl, Ethanol, Ketchup, Mosquito repellent, Oil, Petrol, Soap	200 cycles @ 6N	PASS

1.5 Application limits

The FPC1011F3 package is designed for indoor, non-condensing, applications. Do not expose the sensor to direct contact with the elements, such as rain, snow or sunlight. The sensor surface is hard and extremely robust, and will withstand years of normal wear-and-tear. However, do not subject the sensor to sharp or hard objects since this might cause permanent damage.

Cleaning should be done with a lint-free cotton textile, also see section on *Sensor cleaning*. Do not subject the sensor surface to mechanical force. The fingerprint sensor is a high-performing semiconductor device and should be handled accordingly. Additional information on proper product integration is offered in the section *Sensor integration*.

1.6 Absolute maximum ratings

Supply voltage V_{DD}	-0.5 V to +7.0 V
Input voltage	-0.5 V to V_{DD} + 0.5 V
Output voltage	-0.5 V to V_{DD} + 0.5 V
Total power dissipation	50 mW
ESD on IO's	±2 kV
Fingertip force on sensor[1]	25 N

Note:
Stress beyond values listed under "Absolute Maximum Ratings" can cause permanent damage to the device. This is a stress rating only. Functional operation of the device, at these or other conditions beyond those indicated as normal operation in this specification, is not implied. Exposure to absolute maximum rating conditions for extended periods, may affect device reliability.

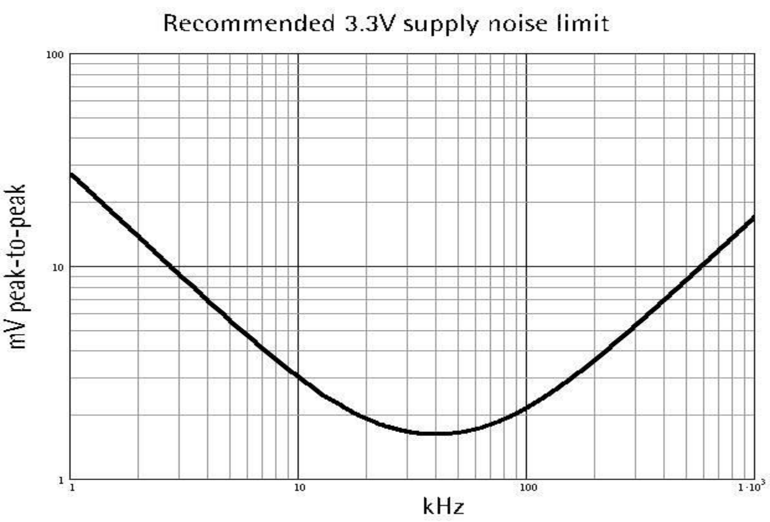
Note 1: Additional information on proper product integration is offered in the section, Sensor integration.

2 Electrical characteristics

Measured at room temperature (RT)

SYMBOL	PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
FPC1011F3						
V_{DD}	Voltage supply (total)		2.35 [2]	2.5 - 3.3	3.45	V
I_{DD}	Current supply, total [1,3]	V_{DD} = 2.5V@4MHz	-	7	-	mA
		V_{DD} = 2.5V@32MHz	-	9	-	mA
		V_{DD} = 3.3V@4MHz	-	7	14	mA
		V_{DD} = 3.3V@32MHz	-	12	-	mA
FPC1011F3 - digital inputs						
V_{IL}	Logic '0' voltage		N/A	N/A	$0.2V_{DD}$	V
V_{IH}	Logic '1' voltage		$0.8V_{DD}$	N/A	N/A	V
I_{IL}	Logic '0' current (V_I = GND)		-	-	±10	uA
I_{IH}	Logic '1' current (V_I = V_{DD})		-	-	±10	uA
C_{IND}	Input capacitance		-	6	-	pF
FPC1011F3 - digital outputs						
V_{OL}	Logic '0' output voltage		-	0.2	0.4	V
V_{OH}	Logic '1' output voltage		$0.85V_{DD}$	$0.90V_{DD}$	-	V

Note 1: Details on clock frequency are available in the General Timing section.
Note 2: Represents MIN voltage for the sensor die. Current consumption and hence the incoming voltage drop will increase with clock frequency, se Block diagram.
Note 3: Current values given above correspond to the average value measured over a 100ms time frame, during image readout.



Typical differential power supply disturbance

The graph shows the typical supply disturbance level (sinus rms), which will give less than one gray level rms disturbance in the fingerprint image readout. If the supply voltage is noisy, additional filtering may be required.

3 Operation

3.1 Introduction

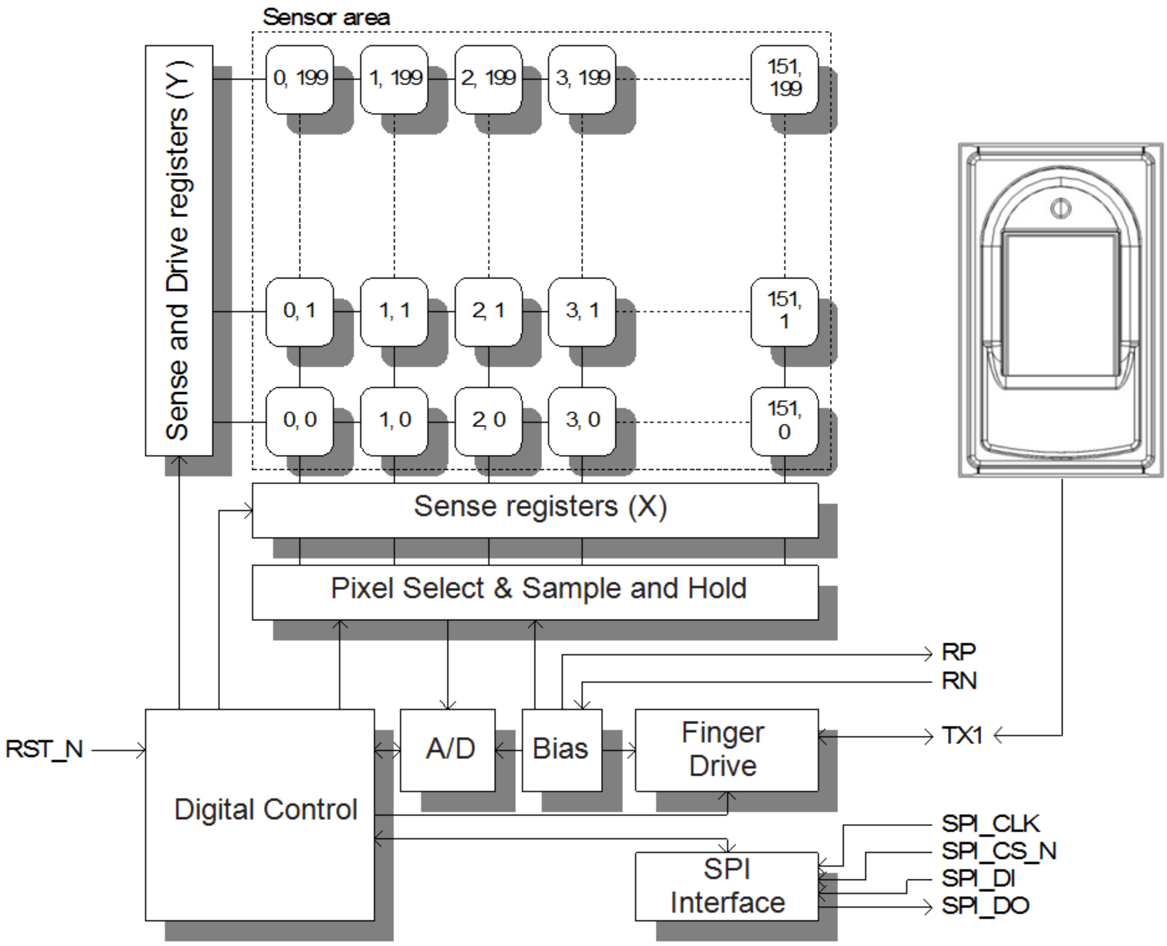
If the sensor is used together with a companion chip from Fingerprint Cards, no detailed knowledge about the sensor circuit/matrix is required in order to operate the sensor component properly.

However, if the sensor component is used together with e.g. a standard micro-controller or a DSP, a detailed understanding of the sensor operation is recommended.

3.2 Sensor technology

The sensor component uses an architecture where individual sensor elements sense a separate charge from the finger. A general block diagram for the sensor circuit is shown in the figure below.

The TX1-signal is used to supply a drive signal to the finger. Hence this signal is connected to an electrode (frame) directly surrounding the sensor area. This electrode (frame) is also part of the ESD protection.



Block diagram - Sensor circuit

3.3 Image properties

The FPC1011F3 sensor matrix contains 30400 pixels. On rare occasions some pixels may not be fully operational, called pixel errors (PE). A small number of imperfections do NOT degrade biometric performance. All sensors are thoroughly tested to ensure excellent image quality.

To verify the image quality and establish a proper signal-to-noise ratio (SNR), internal test functionality based on test patterns is implemented; Checkerboard and Inverted Checkerboard. To ensure conformity of the results, tests are always performed on these two internal test patterns, generated by the SENSEMODE parameter.

To meet image quality standards, test patterns must satisfy the following requirements:

PARAMETER	VALUE
PE total	$\leq$ 60 pixels
PE on any single row	$\leq$ 30 pixels
PE in any single column	$\leq$ 40 pixels
PE within any 12x12 pixel area	$\leq$ 4 pixels

Note: Entire non-operational columns or rows are not accepted and hence scrapped.

A pixel error is defined as a pixel value that deviate more than 20 grayscale levels from its local image median. The local image median is the median value over a sub-image consisting of 5 complete rows, where one of the rows contains the error pixel. (The sub-images are defined as rows 1-5, 6-10, 11-15, …, 196-200).

A proper Checkerboard (CB) pattern and Inverted Checkerboard (ICB) pattern is generated with the following parameters:

DRIVC	ADCREF	SENSEMODE
70	3	1 (CB)
70	3	2 (ICB)

Note: Further details are available in the SENSEMODE register setup.

3.4 Interface

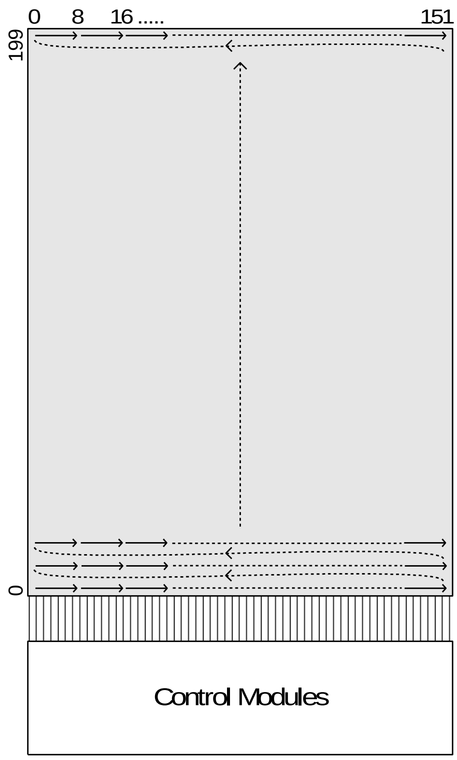
The sensor circuit contains a Serial Peripheral Interface (SPI). The SPI interface enables high-speed readout of data with a minimum of wires. The SPI interface supports a speed up to the current system clock speed. This feature makes the sensor usable for a wide range of control units. The SPI interface is a slave interface with CPHA = '0' and CPOL = '0'.

Through the communication interface, pixel data from the sensor circuit is entered into a FIFO, which in turn is read by applying read instructions. The maximum readout speed in serial mode is 4 Mpixel/s.

3.5 Sensor readout

The sensor matrix consists of 152 x 200 sensor elements. The entire sensor, or a part of it, is read by applying a read sensor instruction. The size of the active area is set by the values of the XSHIFT and YSHIFT registers.

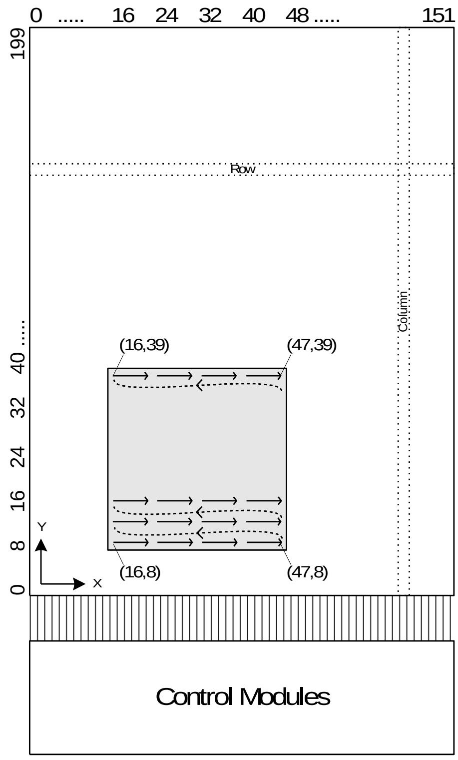
The default values for these registers select the complete sensor area to be read once. The readout sequence is illustrated in the figure below.



During all read operations, 8 pixels are captured simultaneously. By default the first 8 pixels being read are pixel (0,0) to (7,0), followed by pixels (8,0) to (15,0).

The readout area can be reduced by setting the XSHIFT and YSHIFT registers.

The sense area (a row of 8 pixels) is shifted in the x-direction XSHIFT times before it is shifted in the y-direction. The default start position can be changed by manually loading the SENSEX and SENSEY registers.



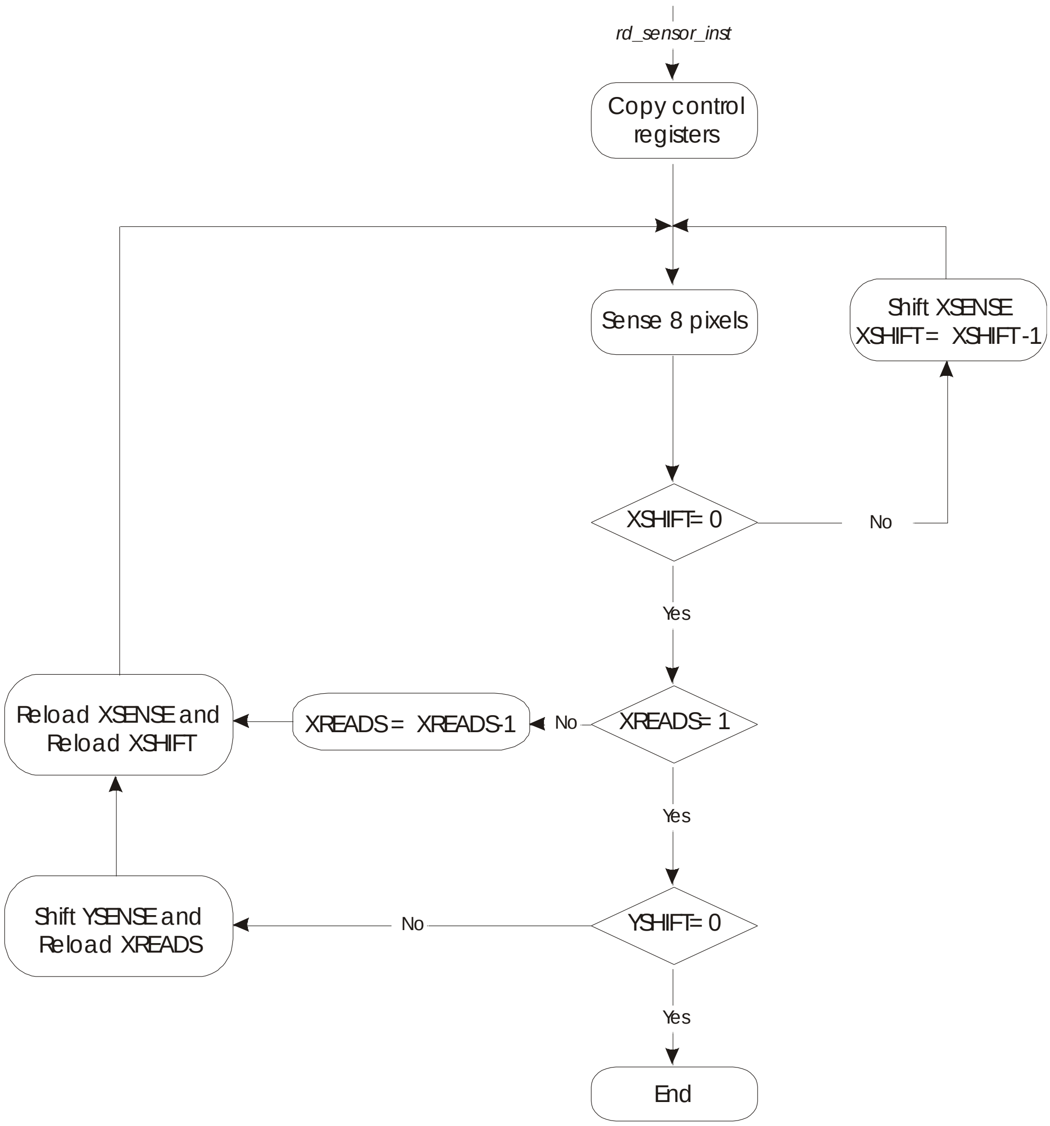
By setting XSENSE and YSENSE to start with pixels (16,8) to (23,8) and setting XSHIFT to 3 and YSHIFT to 31 the rectangle defined by the pixels (16,8) and (47,39) will be read, giving a total of 1024 pixels. Partial readout is illustrated in the figure to the left.

It is possible to read one row of pixels several times before shifting to the next row. This is done by setting the XREADS register.

The number of pixels being read is given by the following formula:

$$\#pixels = 8 \cdot (XSHIFT+1) \cdot (YSHIFT+1)$$

Figure below shows the read sequence in detail.



Sensor read sequence

4 Serial mode communication

In this section are all commands available for serial mode communication described.

4.1 Instruction summary

INSTRUCTION	INSTRUCTION CODE	DESCRIPTION
rd_sensor	11_H	Start sensing of finger. Data is placed in the FIFO.
rd_spidata	20_H	Read from FIFO (only applicable when the SPI interface is used)
rd_spistat	21_H	Read internal status registers in the SPI interface (only applicable when the SPI interface is used)
rd_regs	50_H	Read internal registers. All registers are read in one operation. The register content is placed in the FIFO.
wr_drivc	75_H	Write DRIVC register. Set finger drive amplitude.
wr_adcref	76_H	Write ADCREF register. Set ADC sensitivity.
wr_sensem	77_H	Write SENSEMODE register. Set self-test mode.
wr_fifo_th	$7C_H$	Write FIFO_TH register. Set the FIFO fill threshold for activation of data available signal, DA bit in SPI_STAT register.
wr_xsense	$7F_H$	Shift data into the XSENSE register.
wr_ysense	81_H	Shift data into the YSENSE register.
wr_xshift	82_H	Write XSHIFT register. Set number of shifts to be performed in the x-direction.
wr_yshift	83_H	Write YSHIFT register. Set number of shifts to be performed in the y-direction.
wr_xreads	84_H	Write XREADS register. Set number of times the same row should be read before shifting the YSENSE register.

4.2 Sensor setup

If the FPC1011F3 sensor is **NOT** used together with a companion chip from Fingerprint Cards, but instead with a standard micro-controller, a DSP or similar, an easy register setup is necessary.

The appropriate default parameters are indicated in table below. For detailed instructions on how to perform the actual register setup, please refer to the *Serial mode instructions* section in this document.

DRIVC	ADCREF	SENSEMODE
255	3	0

4.3 Serial mode instructions

Below all instructions are described in detail. Relevant timing diagrams are showed in the section *Timing properties*.

In addition to the long shift-registers controlling the pixels in the sensor array, the sensor component contains one SPI status register and 13 control registers. All write instructions to registers operate in the same way. The FIFO-pointers are reset when any instruction except <rd_spidata> and <rd_spistat> is applied.

Read sensor instruction

INSTRUCTION	rd_sensor (11_H)
Mode	serial
Input parameters	1 dummy byte
Data delay[1]	$(363\pm2)t_{CLK}$
Returned bytes	0

Note1: Data delay is the delay time from when the instruction is given, until data is available in the FIFO.

This instruction is used to read the entire sensor or a part of it. Timing for reading in serial mode is defined in the section *Timing properties*.

The read sensor instruction is only used to start the sense-sequence, and the instruction itself does not return any data. The first data from the sensor array will enter the FIFO after approximately 363 clock-cycles. After that, a new byte will enter the FIFO every 8th clock-cycle until the area defined by the XSENSE, YSENSE, XSHIFT and YSHIFT registers has been read.

When the FIFO is filled to a level equal to or greater than the value set by the FIFO_TH register, the SPI_STAT register will indicate that data is ready for fetching.

If the FIFO is filled up with data, overflow is avoided by stalling sensing until data is read from the FIFO. During this stall-period all analog modules are active, and the ASIC will draw current as during a regular sense operation.

Read SPI data instruction

INSTRUCTION	rd_spidata (20_H)
Mode	serial
Input parameters	1 dummy byte
Data delay	0
Returned bytes	n

After the read SPI data instruction is sent, <rd_spidata>, pixel data will be returned as shown in Figure 11. Data will continue to be returned as long as SPI_CS_N and SPI_DI are kept low.

SPI_DI should be kept low after the <rd_spidata>, instruction is entered to avoid the subsequent byte to be interpreted as a new instruction.

The reading of data can be stopped at any time without data-loss by setting SPI_CS_N high, as long as SPI_CS_N is set high between the last bit of the current byte being read and the first bit in the next byte.

If SPI_CS_N is released at any other time (e.g. during a byte transfer) one or more bytes will be lost. To continue readout after a stop caused by setting SPI_CS_N high, the <rd_spidata> instruction has to be applied again.

Read SPI status instruction

INSTRUCTION	rd_spistat (21_H)
Mode	serial
Input parameters	1 dummy byte
Data delay	0
Returned bytes	1

The SPI status register holds status information for the SPI interface. When the read SPI status instruction is applied, the content of the SPI_STAT register is returned. Applying this instruction does not interrupt sensor readout if sensor readout is in progress.

When the FIFO fill threshold is reached, the DA bit in the SPI_STAT register will be set.

REGISTER			SPI_STAT				
Size (active bits)			3				
7	6	5	4	3	2	1	0
-	-	-	-	-	UFL	STL	DA
000 (00_H)			Reset value				
001 (01_H)			Data available in FIFO.				
010 (02_H)			Stall. Bit is set if sensing is stalled due to a full FIFO.				
100 (04_H)			Underflow. Bit is set if underflow occurs.				

Read registers instruction

INSTRUCTION	rd_regs (50_H)
Mode	serial
Input parameters	1 dummy byte
Data delay	0
Returned bytes	0

The read register instruction fills the FIFO with the value of all the internal control registers. The order in which the registers are entered into the FIFO is given in the table below.

This instruction does not return any data. Data has to be read with the <rd_spidata> instruction The read SPI data instruction can directly follow this instruction for readout of register data.

RETURN ORDER	REGISTER
1	STATUS
2	NOT USED
3	DRIVC
4	ADCREF
5	SENSEMODE
6	FIFO_TH
7	NOT USED
8	XSHIFT
9	YSHIFT
10	XREADS
11	NOT USED
12	NOT USED
13	NOT USED
14	00_H
15	00_H
16	00_H

Return order for register values

The STATUS register is a read only register, which holds the status information for the FIFO.

REGISTER			STATUS				
Size (active bits)			2				
7	6	5	4	3	2	1	0
-	-	-	-	-	-	STL	UFL
00 (00_H)			Reset value				
01 (01_H)			Underflow. Bit is set if underflow occurs.				
10 (02_H)			Stall. Bit is set if sensing is stalled due to a full FIFO.				

Remaining control registers (3-10) can be operated with both read and write instructions. Details on these registers are available together with the write instructions for each register.

All flag generation is based on comparing write-pointer with read pointer synchronized to SPI clock. This means that if a read instruction, resulting in an underflow, occurs one clock period before new data enters the FIFO, an undetected underflow will occur. To avoid this, the procedure for reading from the FIFO, which is outlined in FIFO_TH register description, should be followed.

The entire register is reset when a <rd_regs> instruction is executed.

Write to DRIVC register

INSTRUCTION	wr_drivc (75_H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The DRIVC register sets the amplitude for the drive signal, active on the drive electrode (frame).

The recommended DRIVC setting is listed in the *Sensor setup* section. With the reset value set, the drive signal is disabled.

REGISTER			DRIVC				
Size (active bits)			8				
7	6	5	4	3	2	1	0
x	x	x	x	x	x	x	x
0_D			Min voltage, electrode drive off (reset value)				
127_D			Approximately $V_{DD}/2$				
128_D - 255_D			Max voltage, approx V_{DD}				

Write to ADCREF register

INSTRUCTION	wr_adcref (76_H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The ADCREF register sets the dynamic range for the internal A/D converter. This register is set to '11' at reset.

The recommended ADCREF setting is listed in the *Sensor setup* section.

REGISTER			ADCREF				
Size (active bits)			2				
7	6	5	4	3	2	1	0
-	-	-	-	-	-	x	x
00 (00_H)			0.125 x V_{DD}				
01 (01_H)			0.250 x V_{DD}				
10 (02_H)			0.375 x V_{DD}				
11 (03_H)			0.500 x V_{DD} (reset value)				

Write to SENSEMODE register

INSTRUCTION	wr_sensem (77H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The SENSEMODE register is a 2-bit register, which sets the test mode. In normal operation, this register should be cleared.

REGISTER			SENSEMODE				
Size (active bits)			2				
7	6	5	4	3	2	1	0
-	-	-	-	-	-	x	x
00 (00H)			Regular image capture mode (reset value)				
01 (01H)			Checker board test				
10 (02H)			Inverted checker board test				
11 (03H)			Black test				

If the SENSEMODE register value is non-zero, different types of test patterns are generated internally in the sensor when an image is captured. The Checkerboard test pattern has high grayscale values for pixels on all even columns on even rows, and odd columns of odd rows. Subsequently, pixels on even columns on odd rows, and odd columns on even rows has a low grayscale value, creating a checkerboard pattern all over the image area.

Similarly, the Inverted checker board test pattern has high grayscale values where the regular checkerboard test pattern has low grayscale values, and vice versa.

Finally, the Black test pattern mode makes all grayscale values high. (The normal procedure when looking at a captured image is to first invert the image, since this makes an image of an actual finger look like an inked fingerprint. Therefore an image with all grayscale values high is considered to be an all black image.)

Write to FIFO_TH register

INSTRUCTION	wr_fifo_th (7CH)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The FIFO_TH register holds the threshold value for the FIFO. When the fill level for the FIFO is higher than or equal to this value, the DA bit in the SPI_STAT register is set.

The internal sensor data FIFO is 16 bytes deep and the threshold level can be set between 1 and 16. If this register is set to 00H the DA bit will be set to indicate when all 16 bytes are holding valid data. The relation between the register value and the threshold level is shown below.

REGISTER			FIFO_TH				
Size (active bits)			4				
7	6	5	4	3	2	1	0
-	-	-	-	x	x	x	x
0000 (00H)			Threshold level 16				
0001 (01H)			Threshold level 1				
0010 (02H)			Threshold level 2				
:			:				
1000 (08H)			Threshold level 8 (reset value)				
:			:				
1111 (0FH)			Threshold level 15				

Write to XSENSE/YSENSE register

INSTRUCTION	wr_xsense (7F$_H$)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

INSTRUCTION	wr_ysense (81$_H$)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

These registers are used to select which pixels are active during sensing.

The values of these registers can be changed using the <wr_xsense> and <wr_ysense> instructions. When any of these instructions are applied, the XSENSE and YSENSE register, respectively, are shifted 8 bits towards the MSB and the 8 LSB's are replaced with the new byte.
The sensor circuit contains 8 sample-and-hold modules. Column n·8+m, where n={0..18} and m={0..7}, are connected to the sample-and-hold module number m, through pass gates.

These pass gates are controlled by the XSENSE register. It is important not to let two pixels drive the same sample-and-hold module when loading a non-default value to these registers.

It is also important that only one row is active at a time. The YSENSE register controls which row is active. Please make sure that only one bit in the YSENSE register is set to '1' at any time. If more that one bit in the YSENSE register is set to '1', the returned picture will be invalid, and current-consumption will increase.

To activate a pixel (sensing), the associated bits in both the XSENSE and the YSENSE registers have to be set.

During the fingerprint sensing period, the 8 sample-and-hold modules sample data simultaneously. This data is then digitized before a new sample-and-hold operation is performed. Data is always returned starting with sample-and-hold number 0 and ending with sample-and-hold number 7.

This means that if XSENSE is set to start sensing column 3 to 10 (instead of 0 to 7 which is default) and the shift mode is set to shift 8 positions, the pixels will be read out in the following order (by column number): 8, 9, 10, 3, 4, 5, 6, 7, 16, 17, 18, 11, 12, 13, 14, 15 and so on. This is illustrated in the table below.

REGISTER	XSENSE
Size (bit/bytes)	152 / 19
Reset	00 ... 00FF$_H$ (default value)

REGISTER	YSENSE
Size (bit/bytes)	200 / 25
Reset	00 ... 0001$_H$ (default value)

XSENSE START VALUE	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
COLUMN NO	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
CONNECTED TO SH NO	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7	0	1	2	3	4	5	6	7
SAMPLE CYCLE NO				1								2								3				

Illustration of readout sequence with a non-standard start value for XSENSE

Write to XSHIFT register

INSTRUCTION	wr_xshift (82_H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The XSHIFT register holds the number of shifts performed in the x direction. The number of sense operations performed in one row exceeds the value stored in this register by one.

REGISTER			XSHIFT				
Size (active bits)			8				
7	6	5	4	3	2	1	0
x	x	x	x	x	x	x	x
12_H (18_D)			Reset value				

Write to XREADS register

INSTRUCTION	wr_xreads (84_H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The XREADS register holds the number of times the same row is read before shifting to the next.

REGISTER			XREADS				
Size (active bits)			8				
7	6	5	4	3	2	1	0
x	x	x	x	x	x	x	x
01_H			Reset value				

Write to YSHIFT register

INSTRUCTION	wr_yshift (83_H)
Mode	serial
Input parameters	1 byte
Data delay	NA
Returned bytes	NA

The YSHIFT register holds the number of shifts performed in the y-direction. The number of lines sensed exceeds the value stored in this register by one.

REGISTER			YSHIFT				
Size (active bits)			8				
7	6	5	4	3	2	1	0
x	x	x	x	x	x	x	x
$C7_H$ (199_D)			Reset value				

4.4 Sample Implementation

This section describes step-by-step how the SPI interface of FPC1011F3 can be used to perform a basic image readout process. We will outline in detail which commands the SPI host needs to transmit to receive the full sensor image.

a) Establish an SPI connection between the SPI host and slave, using CPHA='0' and CPOL='0', at any clock speed <32MHz, and big endian bit order. Also, let the host enable the Chip Select signal in the SPI interface.

b) Send the three instructions <wr_drivc>, <wr_adcref>, and <wr_sensemode> with corresponding parameter values 255, 3, and 0 (recommended default values) to set the sensor readout parameters.

DRIVC	ADCREF	SENSEMODE
255	3	0

If all other registers are left at their default values, the complete image area is read.

c) Tell the sensor to capture an image by sending the instruction <rd_sensor>, with a dummy parameter value.

d) It will take some time before the first pixel data is available for reading in the FIFO. In SPI mode there are two ways to know when to start reading pixel data:

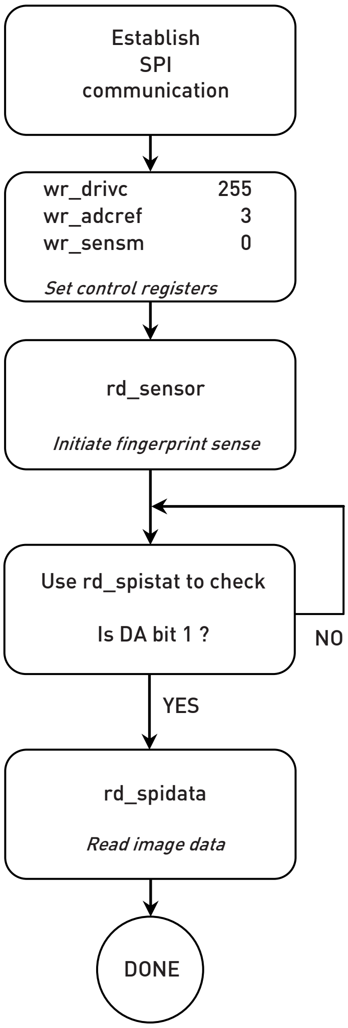
- *Counting cycles*, after 363 +/- 2 cycles the first pixel data will be available for reading. The FIFO gives a flexibility to safely start reading pixel data in cycle 365 - 489.

- *Polling the SPI_STATUS register*, when the FIFO threshold (FIFO_TH register) is reached, the DA bit (data available bit) is set (high).

Further details on how to operate the FIFO_TH register is available in the section *Serial mode instructions*.

e) Now, use the <rd_spidata> instruction to read 30400 bytes of pixel data. The read pixel data is delivered row by row, with 1 byte per pixel, forming an image with dimensions 152 columns times 200 rows.

f) Finally, let the host disable the Chip Select Signal, and (if applicable) shut down the connection to the sensor.



5 Timing requirements

5.1 General timing

Estimated values

SYMBOL	PARAMETER (CONDITION)	MIN	TYP	MAX	UNIT
f_{CK}	System clock frequency	2.5	32[2]	32	MHz
t_{RST}	Reset time	30[2]	-	-	ns
t_{RD}	Rise time for digital inputs	-	-	3 [3]	ns
t_{FD}	Fall time for digital inputs	-	-	3 [3]	ns

Note 1: It is recommended to run the entire system on 32MHz to minimize possible influence from external common mode disturbances.

Note 2: Reset is guaranteed for this duration, but may occur for shorter pulses.

Note 3: Simulated value

5.2 Serial interface timing

Estimated values

SYMBOL	PARAMETER (CONDITION)	MIN	TYP	MAX	UNIT
f_{SPI_CK}[1]	Frequency for SPI clock.	0	-	f_{CK}[2]	MHz
t_{SCKL}	Part of SPI_CK clock period, during which SPI_CK is low.	14	-	-	ns
t_{SCKH}	Part of SPI_CK clock period, during which SPI_CK is high.	14	-	-	ns
t_{CSCKF}	Time from falling edge on SPI_CK to edge on SPI_CS_N	4	-	-	ns
t_{CSCKR}	Time from edge on SPI_CS_N to rising edge on SPI_CK	4	-	-	ns
t_{DSU}	Setup time for data before rising edge of SPI_CK	5	-	-	ns
t_{DH}	Hold time for data after rising edge of SPI_CK	5	-	-	ns
t_{SCKD}	Delay from falling clock to data available.	0	-	8	ns
t_{SSU}	Delay from SPI_CS_N low to SPI_DI mode change.	0	-	5	ns

Note 1: On FPC1011F3 the system clock CK is internally connected with SPI_CK and cannot be set separately.

Note 2: To reach the full SPI communication speed (32MHz), it is necessary to meet all timing requirements above.

Figure 1 shows the general timing for the SPI interface. The figure only shows input and output of 1 byte, but can be extended to more bytes by keeping SPI_CS_N low for more clock cycles. Dependencies between SPI_DI, SPI_DO and SPI_CK are only shown once, but apply to all clock cycles.

All instructions applied consist of one instruction byte and one data byte. This is illustrated in Figure 2 and Figure 3 for instructions without and with return parameters.

The first byte applied, after the SPI_CS_N signal is set low, is interpreted as an instruction byte. After that every other byte is interpreted as a new instruction. This makes it possible to apply new instructions without releasing SPI_CS_N.

If no new instruction should be applied after the first, e.g. during data readout, the following bytes should all be zeroes. The first byte after an all-zero byte is always interpreted as an instruction-byte.

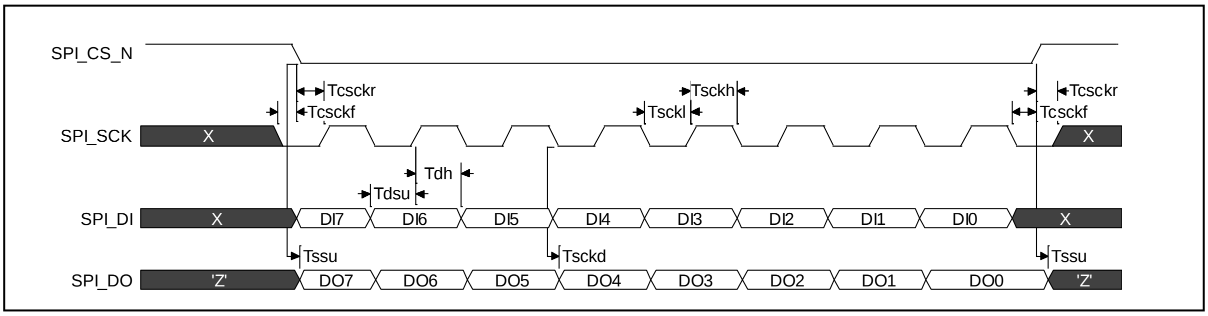


Figure 1
General SPI timing

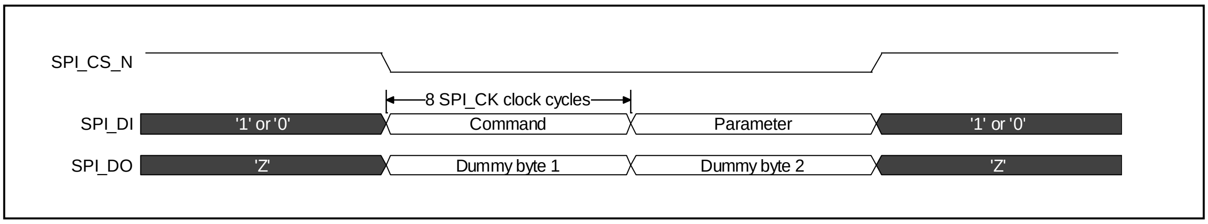


Figure 2
Applying an instruction without return data.

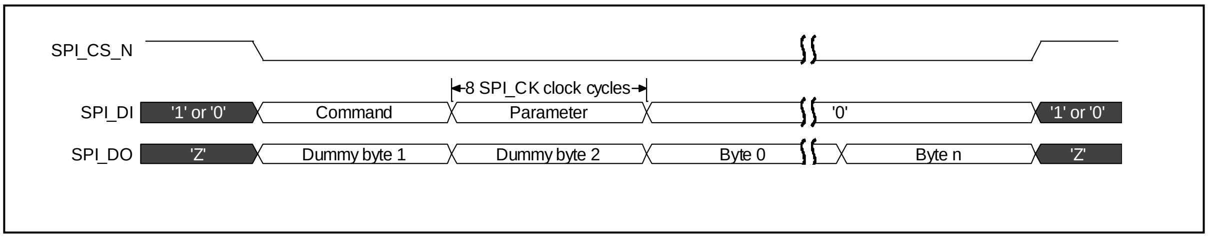


Figure 3
Applying an instruction with one or more return data.

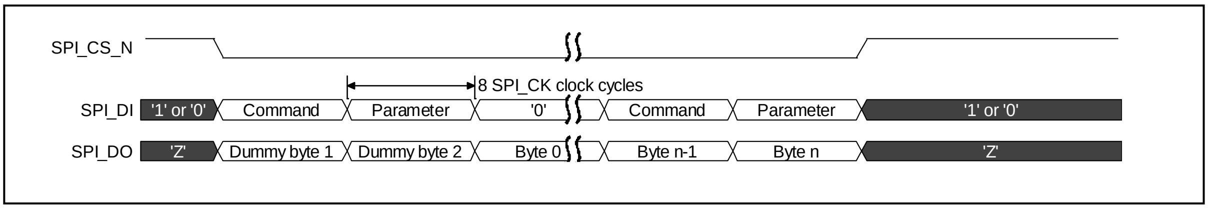


Figure 4
Terminating read by applying a new command.

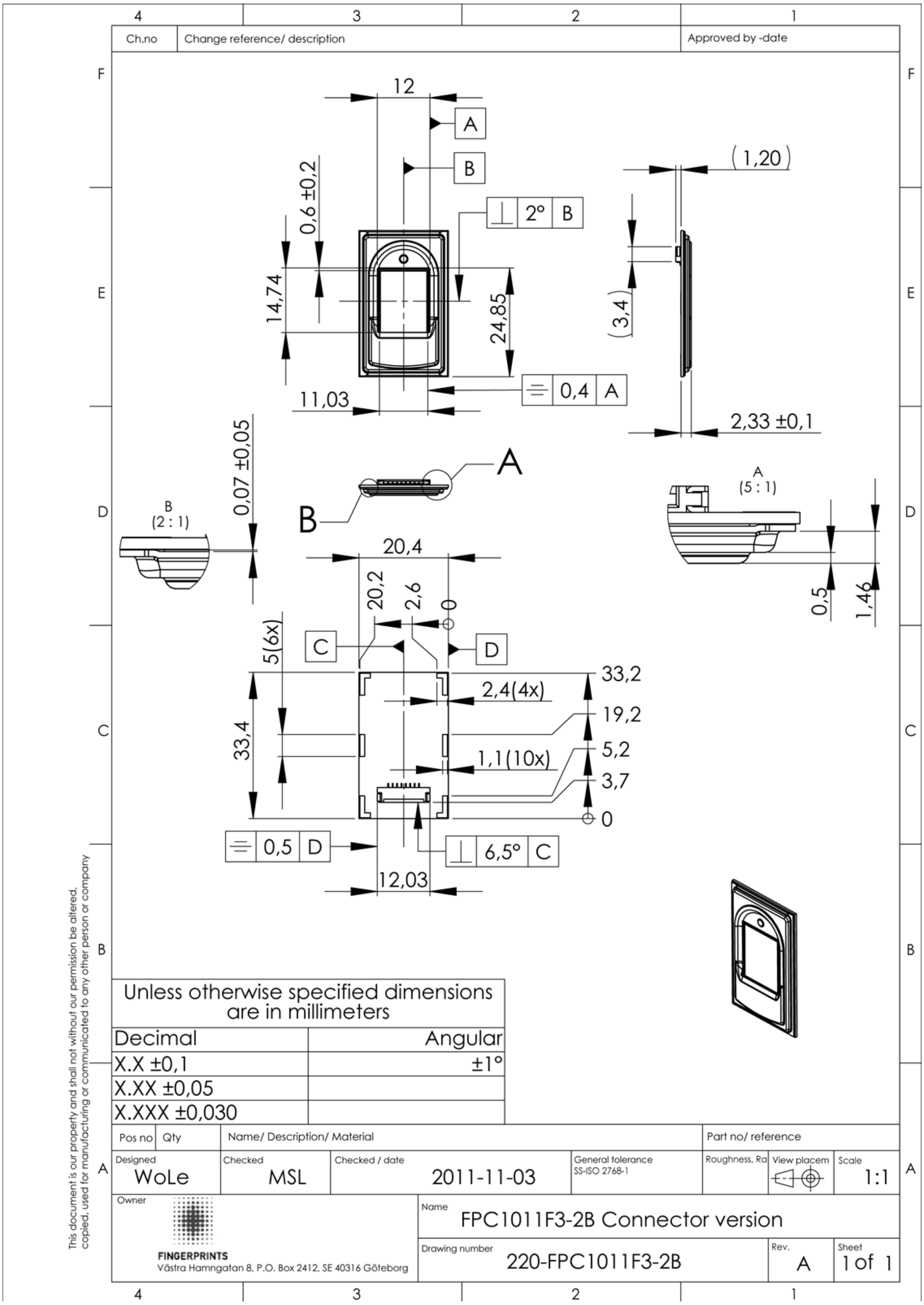
Figure 4 shows the case where a new instruction stops the execution of the previous instruction.

The only difference between signals for the first and second instruction, is that during the first instruction SPI_DO holds dummy data during instruction and parameter entry, while SPI_DO continues to return data during the second instruction and parameter entry.

There are no restrictions on how many instructions, or which instruction, that can be entered during the same SPI_CS_N low period.

6 Mechanical properties

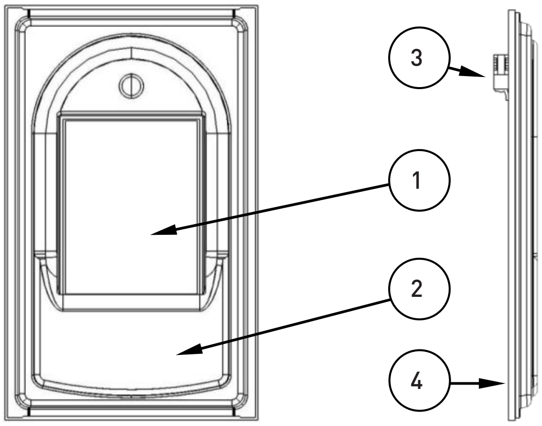
6.1 Part drawing



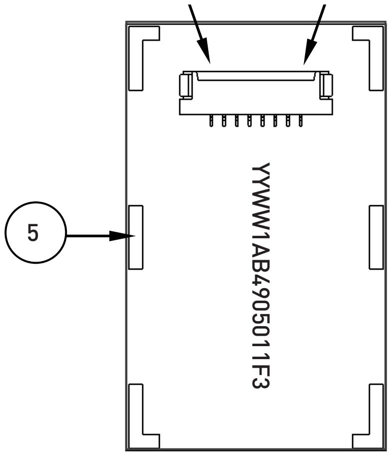
Note: Measures in brackets are only given as information and are not guaranteed.

6.2 Package outline

ITEM	DESCRIPTION
1	FPC1011 fingerprint area sensor chip
2	Drive electrode, called frame or bezel
3	Low insertion force connector: 8 pin, 1 mm pitch
4	BT substrate
5	Additional ESD drain pads (x6)



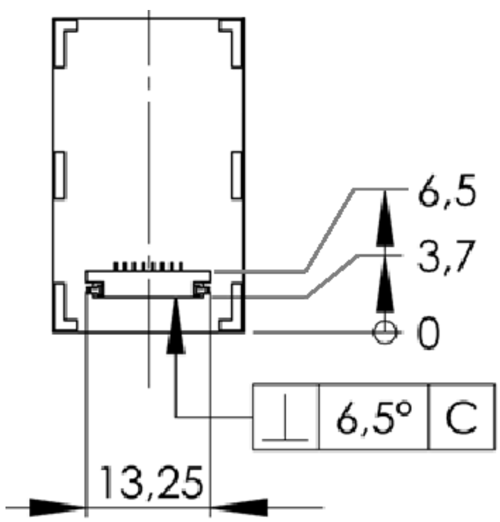
Connector pin configuration
Pin 8 - - - - - - Pin 1



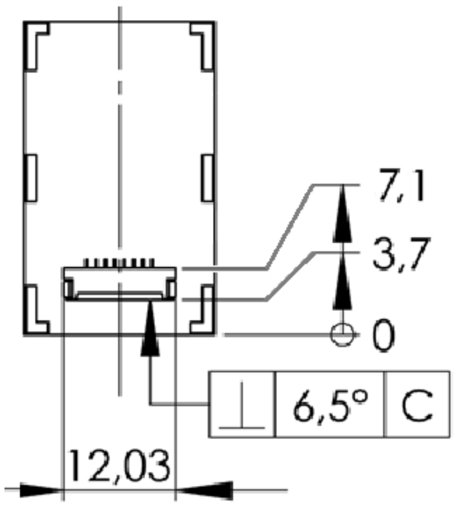
6.3 Pin configuration

PIN	SIGNAL NAME	DESCRIPTION
1	SPI_DO	SPI data output. Tri state when SPI_CS_N is high.
2	VDD	Power supply, 2.5 or 3.3 V
3	RST_N	Reset, active low.
4	SPI_CK	SPI clock input. Internal pull down (system clock is connected to SPI clock internally).
5	GND	Signal ground
6	SPI_DI	SPI data input
7	SPI_CS_N	Chip select, active low. Resets the SPI interface when high.
8	ESD drain	ESD discharge path, connect to signal ground if no protective ground is accessible

6.4 Ultra-thin flex connector versions



FPC1011F3-1A & 2A Connector version
(Almita: BHL118-08R)



FPC1011F3-2B Connector version
(Amtek: FPC3BMR1A-08-U)

7 Cosmetic properties

7.1 Sensor surface quality

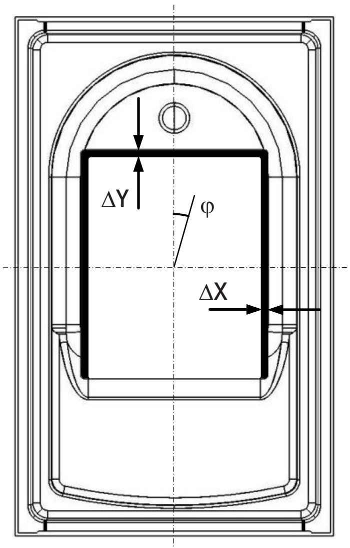
Minor defects not affecting the biometric performance are accepted.

This includes:
- Scratches not wider than 50 µm (0.05 mm).
- Spots, opaque or transparent, not larger than 2 pixels (0.01 mm^2).

Note that the above listing specifies the acceptance level for surface quality at delivery. Defects occurring after delivery, due to normal use or rough handling, are not applicable.

7.2 Assembly accuracy

Relevant mechanical tolerances are specified in enclosed part drawings. Besides specified tolerances, a number of cosmetic inspection criteria apply.



Accepted vertical deviation ΔY (tolerance range for the gap between the silver colored frame and the sensor die), depends on the combination of horizontal deviation ΔX and die rotation φ.

Maximum deviation criteria (accepted combinations):

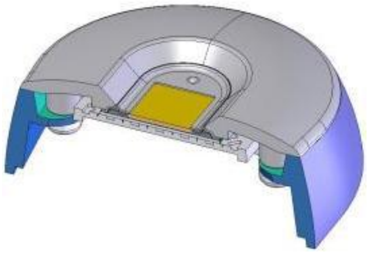
CRITERION	ΔX [mm]	φ [°]	ΔY [mm]
C1	0,485 $^{+0,050}_{-0,050}$	± 0,2	0,545 $^{+0,250}_{-0,200}$
C2	0,485 $^{+0,200}_{-0,200}$	± 1,0	0,545 $^{+0,200}_{-0,200}$

All sensor products are visually inspected and are required to fulfill either criterion C1 or C2, or both.

8 Application information

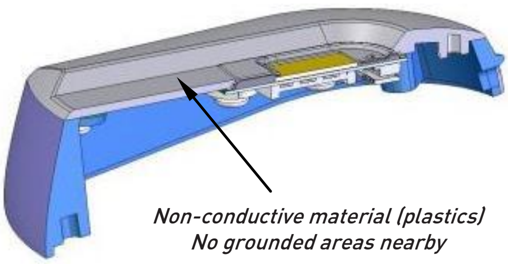
8.1 Sensor integration

Avoid galvanic contact
Thanks to the conductive frame, containing micro-ergonomics, a smooth transition to exterior mechanics can easily be obtained (example below).

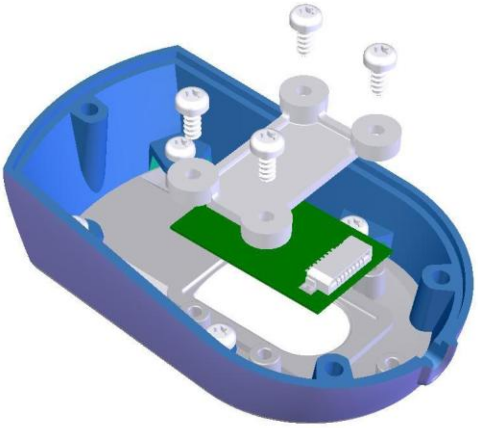


Contact Fingerprint Cards to receive details on the mechanical reference design (2D and 3D drawings).

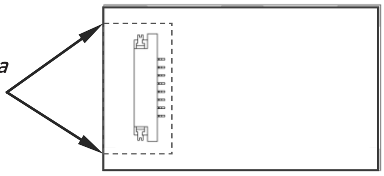
Note that the sensor and its drive electrode (frame) must be mounted in such way that electrical insulation to adjacent conductive surfaces is achieved. It is also recommended to avoid grounded surfaces nearby the drive electrode, since this might interfere with sensor operation.



Proper mechanical support
The best way to ensure a solid sensor mount is to apply a stable, non-conductive, support to the backside of the sensor component.



This non-conductive support can preferably be attached to the entire backside area, except for the connector.



Mechanical force outside the maximum rating may permanently destroy the sensor product.

8.2 Sensor shut down mode

In software controlled authentication systems, where all capture image tasks are initiated by software it is recommended to disconnect the power supply when sensor is not in use. This procedure will improve life time and overall reliability. All communication signals should also be set to low (GND) to avoid feeding the CMOS circuitry through the I/Os. This especially applies to active low signals.

Stand by procedure for FPC1011F3:

1. Disconnect sensor power supply VDD.
   Indicated as switch S10 in the reference layout.

2. Set SPI communication pins low.
   (SPI_DO, SPI_DI, SPI_CK)

3. Set SPI_CS_N and RST_N low.

The start-up procedure is the reverse.

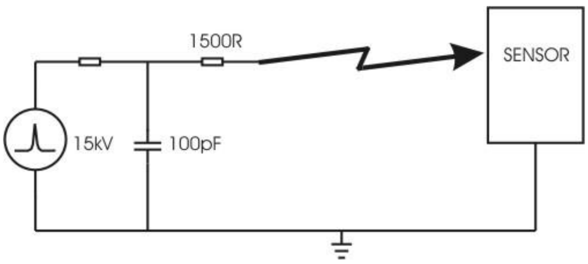
8.3 ESD protection

The importance of ESD protection
To generate an image, capacitive fingerprint sensors require a finger to be in contact with the sensor surface. This will expose all capacitive sensors to severe ESD discharges, as they usually are the "first point of contact". ESD discharge voltages are often under-estimated and the actual voltage levels may be surprisingly high. Discharges in the 1 to 2 kV range will typically not even be noticed, i.e. felt in the finger.

All sensors from Fingerprint Cards incorporate extensive internal ESD protection for all accessible front surfaces. The protection level is well in excess of 30 kV using a standard Human Body Model discharge.

Human Body Model
The Human Body Model consists of a 100 pF capacitor, which simulates the capacitance between body and ground. This capacitor is charged to a test voltage. The resistance of the finger and skin is approximated by a 1500 ohm series resistor. The discharge will have a time constant of, 100pF x 1500 ohm = 150 nS. For a 15 kV discharge the peak current would be 15kV/1500 = 10A.

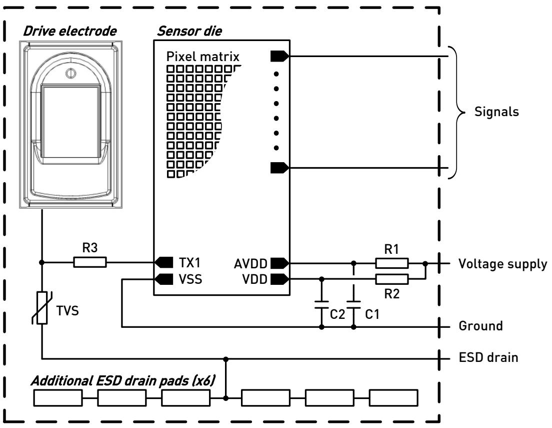
Although the ESD-specification is given as a voltage level it is important to realize that an ESD test is more of a current discharge test.



Human Body Model

Internal sensor protection
ESD discharge issues are best illustrated by considering the simplified internal schematic in the figure below. Sensors from Fingerprint Cards have a robust sensor surface coating, which will deflect discharges to the sensor drive electrode (frame). From the electrode, the discharge current will be conducted via the Transient Voltage Suppressor (TVS) to the local ESD drain node. The voltage at the drive electrode is thereby limited. The 100 ohm resistor will limit the current towards the sensor chip to very safe levels.

It is recommended to also directly connect the additional drain pads to protective ground for best performance.



Sensor internal schematic

Voltages induced by the ESD current
In a simplified model, two currents occur during an ESD event - the main ESD current flowing through the TVS to the sensor ESD drain, and the much smaller current flowing through the 100 ohm resistor back into sensor chip input protection.

The current flow through the 100 ohm resistor will depend on the clamping voltage over the TVS. A 15kV discharge will generate a 200 mA current pulse into the chip protection diodes, well within the chip ESD rating. The duration of the pulse will be in the order of 600nS. After this time the current will decay exponentially. The charge through the protection diode can be estimated to 0.15 nC.

Sensor cable extensions
When using longer sensor cable lengths, the electromagnetic coupling between the current in the ESD drain connection and other signal and supply connections need to be considered.

This coupling is rather complicated and will depend on the cable geometry. With the standard, short connection between the sensor and the receiving electronics, these effects are not significant and can be ignored.

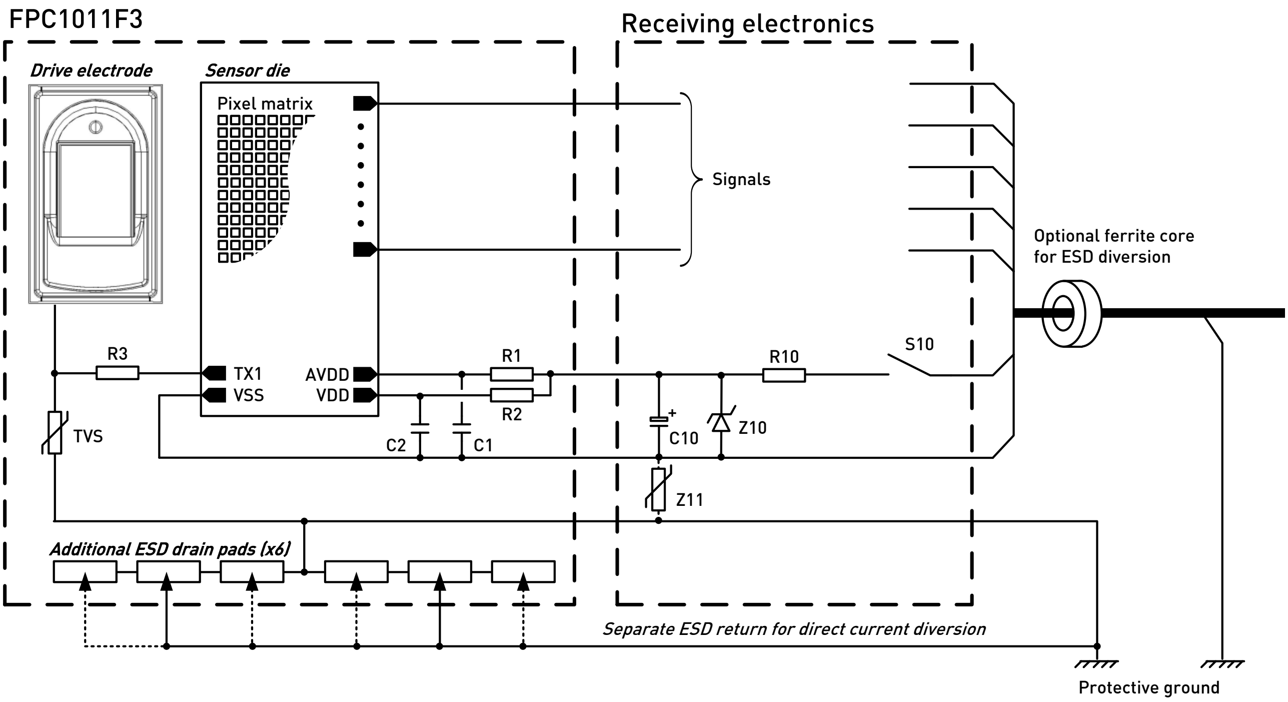
Longer cable lengths between sensor and the receiving electronics can in some cases be acceptable. Exact guidelines are not possible since the ESD effects will depend on the actual installation but up to 0.2 meter would in general not cause any problems.

Extensions will also affect signal fidelity and the digital waveforms need to be checked for adverse reflections. Problems with ringing become more evident as the length increases. At 1 m the ringing will cause waveforms that are questionable.

Minimizing effects on downstream electronics
The ESD pulse will continue past the sensors drain path and spread into the receiving electronics ground plane and most likely further on to a "protective earth" ground via a connecting cable. This connection will often have considerable length and hence potential ESD problems.

To help alleviate the risk of electromagnetic coupling a separate ESD return to divert the ESD current to some "suitable" point is recommended. A way to prevent problems with stray currents due to dual ground paths, is to front the separate ESD return with a TVS in order to break this current path at low voltages while allowing the ESD pulse to pass freely.

Even higher ESD diversion can be achieved by also increasing the inductance of the signal cable connection from the receiving electronics. The common mode inductance forms a "barrier" to help steer the ESD current over to the separate ESD return. One of the easiest means is to mount an EMI ferrite core on the cable near the electronics.



Recommended ESD precaution in application / External TVS (e.g. Transguard VC060309A200, www.avx.com)

8.4 Power supply and filtering

Depending on the overall quality of the connected power supply, i.e. noise, different filter and/or decoupling circuitries may be necessary. In normal cases a standard buffer capacitor in the range of 5-10µF (C10) is enough. In case of a noisy environment, other types of filtering (C10/R10) may be required to obtain optimal performance.

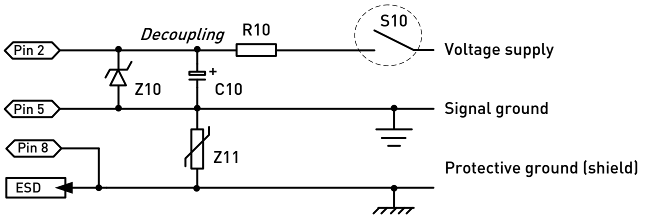
Although the sensor is specified for a voltage supply range between 2.5 - 3.3 volts, different protection and decoupling circuitries may be necessary to reach full communication speed over the entire voltage range.

8.5 Ground reference and CMR

A sensor in a fingerprint based authentication system will, by definition, always come in physical contact with the end user. In order to suppress Common Mode disturbances, e.g. induced by the end user, the sensor or the receiving electronics should be connected/related to a protective ground reference. For example, common mode disturbance may occur with isolated low cost switch-mode power supplies that do not have a direct connection (or EMI capacitor) from the AC line input to the DC output.

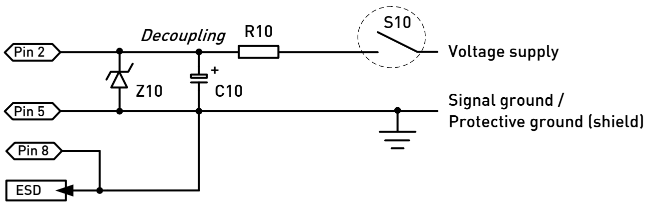
8.6 ESD discharge path

It is recommended to connect the separate ESD discharge path directly to a protective ground/ shield node. It is also recommended to connect the additional drain pads, directly to the protective ground, for best ESD performance. If a switch (S10) is used to disconnect the sensor for power save reasons, it is important not to break the ESD protection circuit as well.



Discharge path is connected to protective ground.

In case a separate ESD return is not possible, the ESD return can be connected directly to the signal ground plane. This solution requires the ground plane and the receiving electronics to consume the entire discharge induced by the end user. The ground plane connection should preferably be done close to a large decoupling capacitor.



Discharge path is connected directly to signal ground

8.7 Reference layout

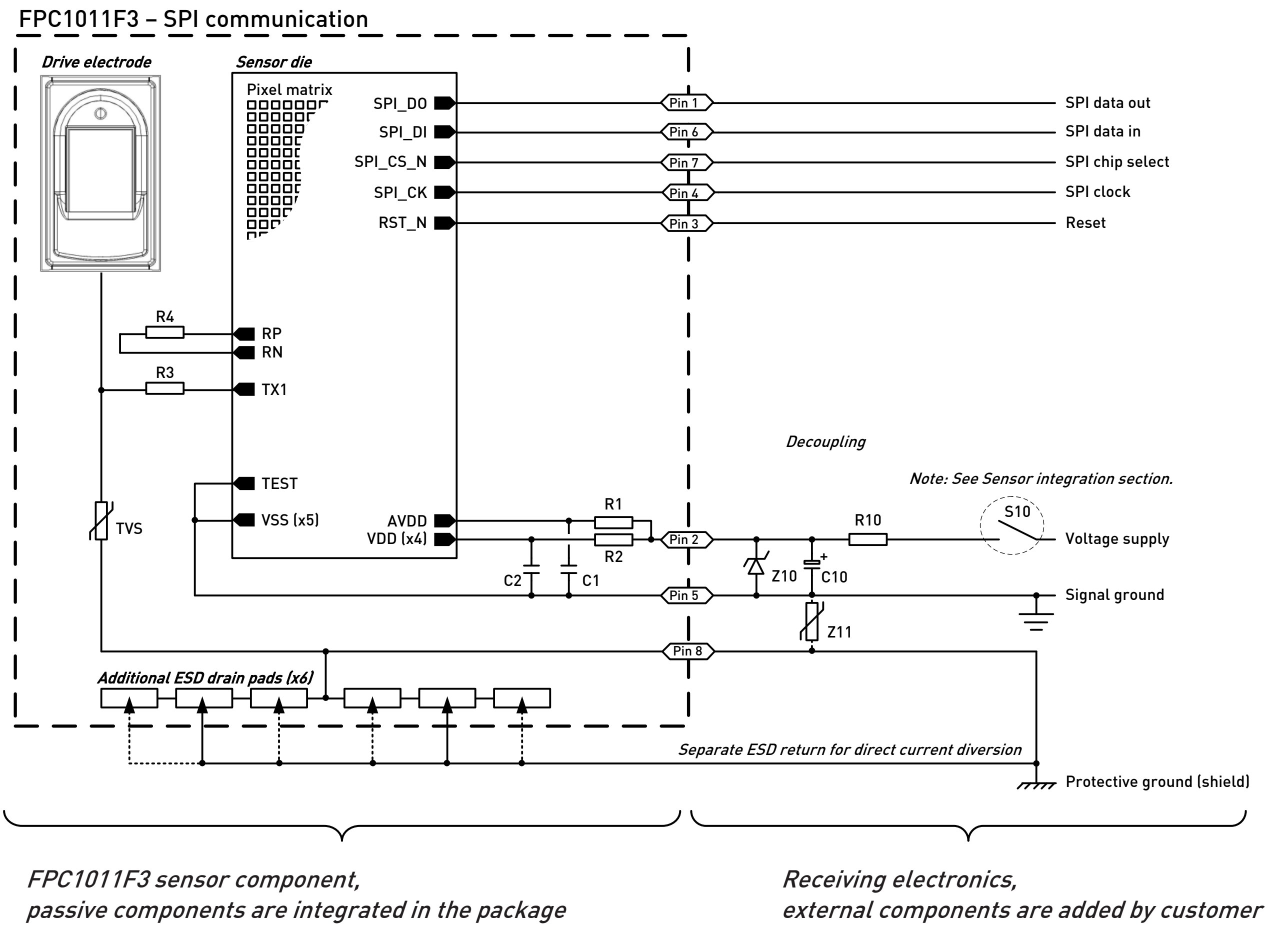
The FPC1011F3 sensor component is supplied with an 8 pin flex connector interface.

Please note that the reference layout is only an example and is not guaranteed to be the best implementation for all applications.

It is recommended to connect the additional drain pads directly to protective ground for best ESD performance.

Refer to the following sections for details:
- *Serial mode* section for SPI communication
- *FPC1011F3-Pin configuration*

It is also recommended to carefully read section:
- *Sensor integration*
- *Power supply and filtering*
- *Ground reference and CMR*
- *ESD discharge path*



Reference schematic

8.8 Mating flex strip

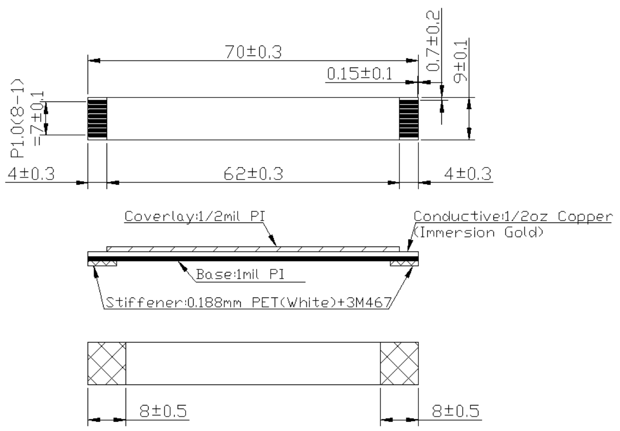
FPC1011F3 is prepared for a standard 8-pin flex cable and thus provided with an ultra-thin low insertion force type of connector.

There are several flex cable brands available and many of them will probably perform well. It is also possible to manufacture a custom design flex. Normally this type of flex is much easier to bend and is also possible to shape to fit the application entirely. The recommended maximum flex length is 200 mm.

Below a custom design type of flex, a standard type of flex and four different connector configurations are presented. The custom design flex cable is available from Fingerprint Cards in low volumes (samples). Volume orders can be placed directly with the supplier in Taiwan.

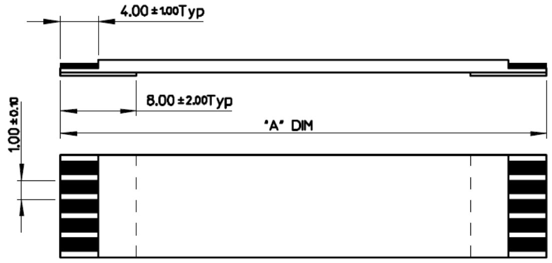
Custom design flex cable, based on current tooling:
(Other lengths are available on request)

Supplier:	Techwave Industrial Co LTD
Contact:	Mr. Alex Liao alex@techwave.com.tw
Part number:	FPC5207 rev 1B EL-0005 (Techwave internal no)
Description:	Soft flex, 1.00mm Pitch Same Side Contacts, 8 Circuits 70 mm Length, 0.2 mm Thickness
Additional:	Minimum bend radius - Static application 0.3 mm - Dynamic application 1.5 mm
IMPORTANT:	The flex should not be bent close to the stiffener. Exposing the stiffener to mechanical stress can degrade the reliability.



Standard type of flex cable (example):

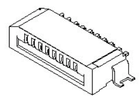
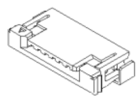
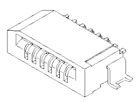
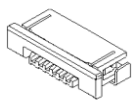
Supplier:	Molex (www.molex.com)
Part number:	0210390227 (Standard type) 0982670227 (High temperature)
Description:	1.00mm (.039") Pitch Premo-Flex™ FFC Jumper, Same Side Contacts (Type A), 8 Circuits, 76.00mm (3.000") Length
Additional:	Other lengths are available



Mating connector data (examples):

Supplier: Molex (www.molex.com)

Part number:

	Non-ZIF	ZIF
Top side connector	*0527930870* 	*0522070860* 
Bottom side connector	*0528520870* 	*0522710869* 

Top or bottom side configuration is selected to fit a particular application.

Description: 1.00mm (.039") Pitch
FFC/FPC Connector,
SMT, Right Angle,
8 Circuits, Lead-free

9 End user information

9.1 Sensor cleaning

Cleaning the fingerprint sensor from time to time ensures top performance. However, for normal use it is not necessary to clean the sensor every day. If only minor cleaning is needed just use a lint-free cloth and carefully wipe the sensor surface. If a more thorough cleaning is needed follow one of the two suggested methods presented below. For the best results choose the first method, if this is impractical choose the second tape based method.

Cleaning with Alcohol Based Solvent

Material to use:
Lint-free cloth OR cotton swab.
Isopropyl alcohol (IPA) or another alternative cleaning agent (see below).

How to clean:

1. Put a small amount of IPA on a lint-free cloth or cotton swab. Only a small amount is needed to make the cloth or cotton swab slightly damp. If the surface is heavily contaminated with a greasy substance the amount of IPA should be increased so that the contaminant can be fully dissolved.
2. Gently rub the cloth or cotton swab over the whole sensor surface. Make sure to reach the area close to the frame where dirt/grease can accumulate.
3. Use a dry piece of cloth or cotton swab and wipe the sensor surface dry. Look carefully at the sensor surface and make sure that no residual liquid remains on the sensor.
4. Repeat the process if necessary.

Alternative Cleaning Agents
For simple cleaning and good results it is best to use easily evaporating liquids that can dissolve grease and fats. Ethanol and Acetone can be used in the same manner as IPA. Make sure that the surrounding materials are resistant to the chemical used.

IMPORTANT: Avoid using detergents and soaps containing oily substances since they can leave contaminants that negatively affect the sensor performance.

Cleaning with Adhesive Tape

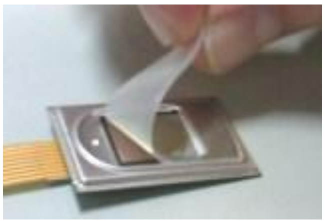
Material to use:
Adhesive cellophane tape, i.e. regular office tape.

How to clean:

1. Apply a piece of adhesive cellophane tape to the sensor. The sticky side of the tape should face the sensor surface.

2. Press on tape for best result.

3. Gently remove the tape and any contaminants that are now attached to the tape.



4. Repeat with new tape until the sensor surface is clean.

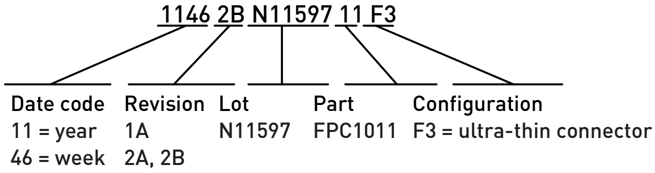
10 Order information

10.1 Part numbers

Part number	Description	MOQ
FPC1011F3	Area sensor package with ultra-thin flex connector	200

10.2 Production codes

All parts are laser marked on the backside with a unique production code (1.5 x 8 mm). This code comprises information about production date, revision, production lot, part number and configuration.



10.3 Package information

Parts are supplied face up in standard ESD safe JEDEC trays, 40 sensor units per tray.

FPC1011F3 is arranged in the trays to match standard industry norms; pin 1 at the tray chamfered corner.

Five trays and one lid are stacked, wrapped and packed in one ESD safe bag, i.e. 200 parts per full stack/box, and placed in a standard cardboard box (tray box).

The tray box is marked with necessary product information, both text and barcode (code 39).

Six tray boxes are packed in one rigid exterior card board box for shipping (shipping box), containing 1200 units.

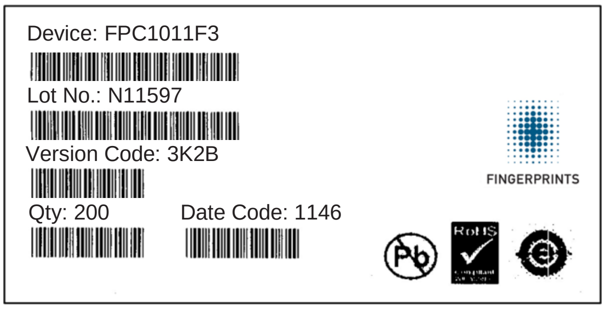
Tray and shipping box dimensions:

PARAMETER	TRAY BOX	SHIPPING BOX	UNIT
Length	380	440	mm
Width	190	440	mm
Height	100	350	mm
Weight	1,8	12	kg

Tray box data:

DATA	DESCRIPTION
Device	Device number (FPC1011F3)
Lot No	Internal batch code (N11597)
Version code (ss/rr)	ss = Supplier code (3K) rr = Product revision (2B)
Qty	Number of units in box (200)
Date code (yy/ww)	yy = Production year (2011) ww = Production week (46)

Tray box label:

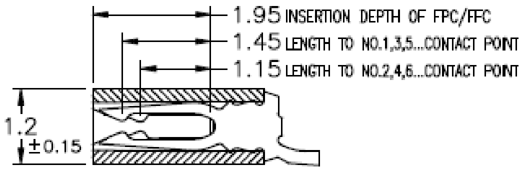
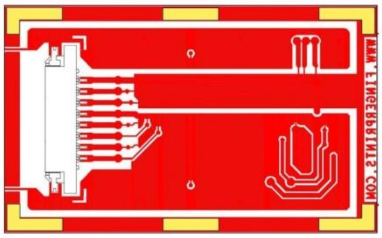
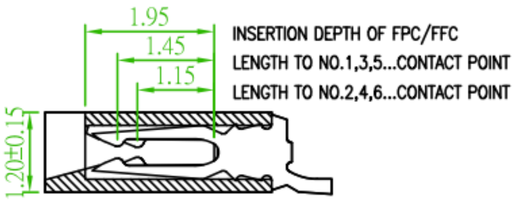


10.4 ESD sensitivity

This device is sensitive to electrostatic discharges. Ensure proper handling during device assembly.

11 Product updates

11.1 Product revision history

REVISION	DESCRIPTION	DETAILS
1A	First release with the BHL118-08R ultra-thin flex connector from Almita Co LTD.	
2A	Additional ESD drain pads added to back side (6x)	
2B	The ultra-thin flex connector replaced with FPC3BMR1A-08-U from Amtek Technology Co LTD.	
2C	Substrate panels optimized. No change in sensor package.	

12 Document control

12.1 Terminology

Typical value - Value measured value on a limited population. Indicates value to expect, not guaranteed.
Estimated value - Value approximated through calculations. Indicates value to expect, not guaranteed.
Simulated value - Value derived through computer simulations. Indicates value to expect, not guaranteed.
Nominal value - Target value for the design. Either prequalified or monitored in manufacturing. Guaranteed within the corresponding tolerance range.
Max/min value - Deviation from nominal value, defines the tolerance range. Max and min values are guaranteed.
Tolerance - Deviation from nominal value. Range is guaranteed.

12.2 Abbreviations

CMOS - Complementary metal oxide semiconductor
DSP - Digital signal processor
EMI - Electromagnetic interference
ESD - Electro static discharge
FIFO - First in first out
FPC - Fingerprint Cards
IPA - Isopropyl alcohol
JEDEC - JEDEC Solid State Technology Association
MOQ - Minimum order quantity
RMS - Root mean square
RT - Room temperature
SNR - Signal to noise ratio
SPI - Serial peripheral interface
TBD - To be determined
TVS - Transient voltage suppressor
ZIF - Zero insertion force

12.3 Document revision history

REVISION	DATE	CHANGE	AUTHOR	APPROVED
A	2011-05-30	New product, first release	MSL	PJÄ
B	2011-12-20	ESD drain pads added, flex connector replaced	MSL	PJÄ
C	2012-05-25	Connector dimension on p1 removed Wear and tear conditions refined	MSL	PJÄ