ClearPad Series 7 Platform Datasheet

PN: 505-000193-01 Rev. 3

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Conventions used in this document

The table below describes the documentation conventions. These conventions are used in all Synaptics technical literature.

Term	*Meaning*
$	Hexadecimal numbers are marked with a leading ‘$’ sign: The number $7FF is equal to 2047 decimal.
—	Bits shown as “— ” in register diagrams are equivalent to bits marked *Reserved.*
italics	*Italicized* words introduce a term described in the adjacent text or in the Glossary.
Reserved	*Reserved* is used to signify a bit or bit-field not currently used in any (published) way.
`Courier`	Courier font is used for text to be entered on a command line or in a program, or for text output from a device.
	This “caution” icon is used to indicate information about something bad that might happen if the guidelines for usage are not followed, or if care is not taken.

Contents

1. Introduction

Synaptics ClearPad™ touch sensors are thin, transparent, capacitive touch screens that can be placed over viewable surfaces for input and navigation. Synaptics ClearPad Series 7 products are the ideal solution for notebooks, slates, and consumer electronics that demand rich functionality and MultiTouch support for large touch screens. The ClearPad Series 7 product family includes a variety of solutions that target different sensor size and performance requirements: ClearPad 7010, ClearPad 7100 and ClearPad 7200.

This document serves as a generic datasheet for Synaptics ClearPad Series 7 sensors and should be read in conjunction with the relevant Synaptics Product Specification for a particular sensor model. This datasheet represents typical values. Actual values may vary. The information in the Synaptics Product Specification supersedes the information in this datasheet.

Contact your local Field Application Engineer (FAE) for a copy of the *ClearPad Series 7 Integration Guidelines* (PN 506-000251-01) application note, which contains guidelines for sensor integration.

2. Feature summary

The ClearPad Series 7 sensor family is the best-in-class for MultiTouch functionality using its patented technology. Key features and benefits include:

- Best-in-class capacitance sensing:
  - 10-finger detection and simultaneous tracking on 7100/7200. 7010 supports up to 5 fingers
  - 7010 and 7100 support 560 nodes (28 × 20 electrodes); 7200 supports 1120 nodes (28 × 40 electrodes) with positional interpolation providing best-in-class accuracy and resolution
  - Up to 333 kHz sensing frequency
  - Up to 80 Hz report rate; other report rates available on request
  - Supports sensors up to 10.1” in size (measured on the diagonal)
- Wide voltage operation: 2.8V to 3.3V nominal supply voltage (2.7V to 3.6V absolute) for I^2C
- Response time to touch less than TBD ms, subject to configuration
- Supports 2-D sensing
- Finger size (Z) and width (W) reported for each finger
- Self-calibrating- no host side calibration needed
- I^2C communication protocol supported
  - I^2C slave mode up to 400 kb/s
  - Synaptics RMI4 over I^2C host
  - Detection and simultaneous tracking of up to ten fingers
  - Linux driver
- Hover control
- In-system reprogrammability (reflash) supported
- Internal power-on reset/brownout detector
- Noise suppression including automatic frequency hopping and noise filtering
- Robust accidental activation mitigation
- RoHS compliant

3. Design options

A ClearPad Series 7 sensor is a glass substrate with a grid of transparent traces (made of Indium Tin Oxide) arranged in a pattern that is designed to optimize finger sensing performance and optical clarity. The sensor substrate is laminated under a cover lens that can be made out of glass (CS, tempered, and standard glass) or plastic (acrylic, polycarbonate). The “tail” which consists of the flex interconnect and component area is typically bonded to the transparent touch panel using anisotropic conductive film (ACF).

Synaptics provides a variety of tail-only solutions (flex interconnect and component area) for the customer to integrate with their own touch sensor. See Figure 1 for details. Depending on the customers’ needs, the tail can be a “Circuit on Flex” (both sensor interconnect and components are laid out on a flex kapton) or “Circuit on PCB” (component area on a FR4 daughterboard PCB) design.

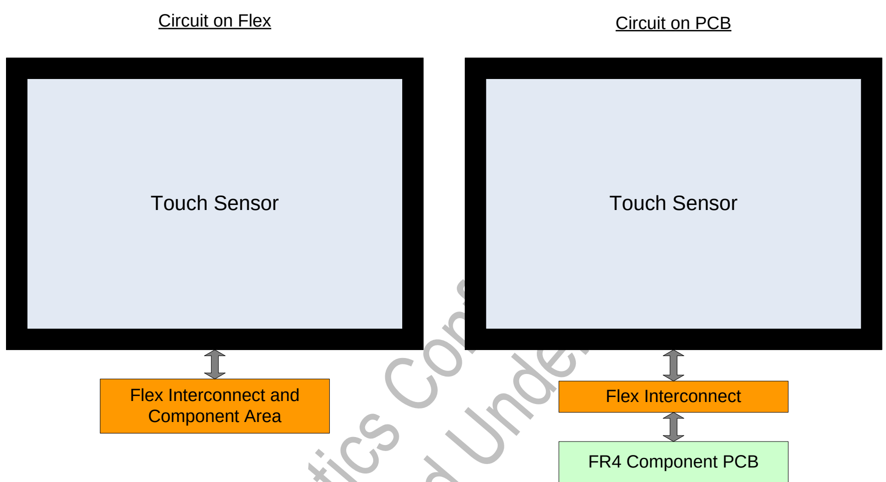

Figure 1. Circuit on flex versus circuit on PCB

ClearPad module areas

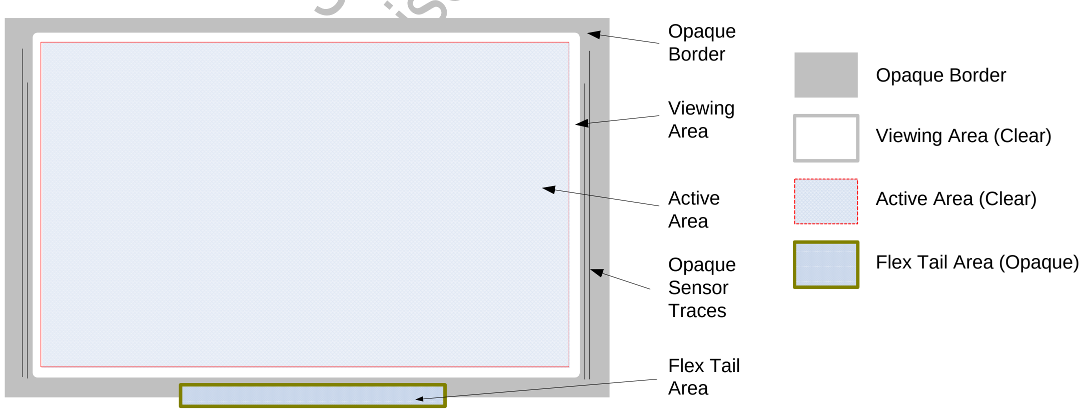

Figure 2. provides additional information about the areas of a ClearPad module.

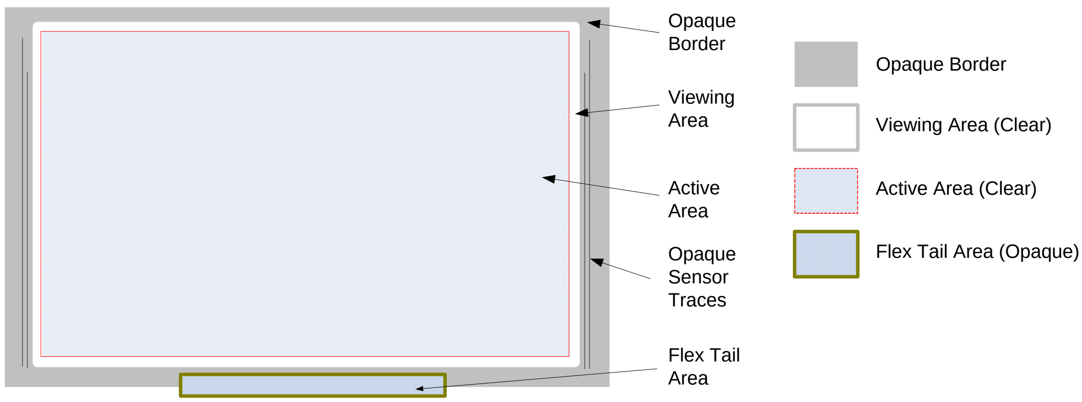

Figure 2. ClearPad module areas

- *Opaque Border*
  The border that covers the ClearPad sensor traces.
- *Viewing Area*
  The viewing area is the ClearPad touch panel minus the space required for routing the sensor traces.
- *Active Area*
  The active area is the region of the ClearPad touch panel that will report that a finger is detected. That is, the Finger Present register reports that a finger is present to the host. Note that this area is based on Synaptics' proprietary finger capacitance algorithms. The active area *is not* a purely mechanical parameter like the physical area or the viewing area. Also note that the active area *is not* the same as the exact size of the touch panel's conductive trace matrix.
- *Flex Tail Area*
  The flex tail connects the sensor traces with the component area. The flex tail area is also where the Anisotropic Conductive Film (ACF) is heat- and pressure-bonded to merge the flex tail with the ClearPad touch panel. Therefore, the flex tail area is sometimes referred to as the ACF Hotbar Area.

Typically, it is best if the LCD pixel area and the display opening are the same size, or smaller than, the ClearPad touch panel's active area. This ensures that a finger will be sensed along the edges and in the corners of the ClearPad touch panel. ClearPad modules can be customized to meet a variety of design needs.

Generally, there is a 0.5 mm to 1 mm clearance between the viewing area and the edge of the ClearPad touch panel. For details on accuracy and linearity of the ClearPad touch panel's active area, see section 4.

3.1. ClearPad Series 7 touch panel dimensions

The ClearPad Series 7 family includes the ClearPad 7010, ClearPad 7100 and ClearPad 7200 product offerings. For any product configuration, the sensor pitch will determine the tradeoff between overall active area size and minimum detectable finger separation.

The ClearPad 7010 Series product line includes one image sensing IC within the design, as shown in Figure 3.

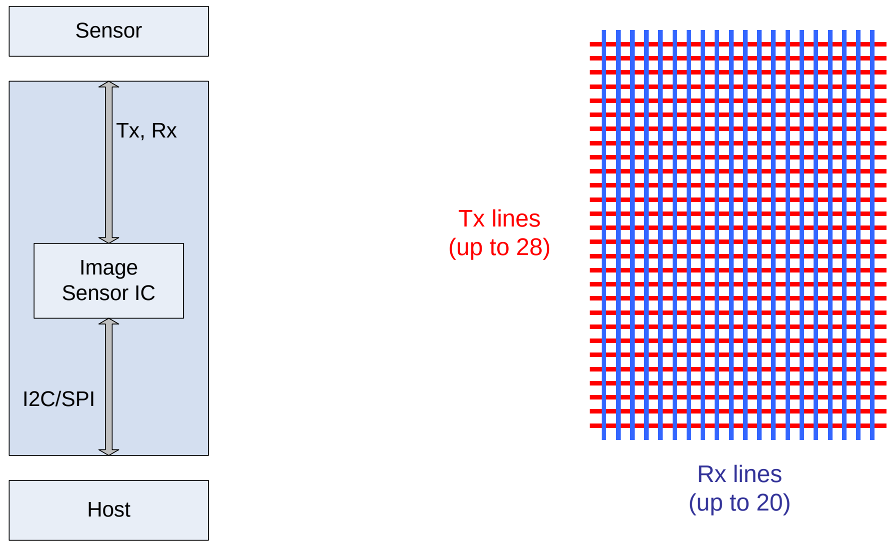

Figure 3. ClearPad 7010 diagram and sensor layout

Table 1. ClearPad 7010 Series profile summary

TouchScreen size (diagonal)	5 to 8.2 inches
Max number of transmitters and receivers (See Figure 4.)	28 × 20 (28 rows × 20 columns)

The ClearPad 7100 Series product line includes one image sensing IC within the design, as shown in Figure 4.

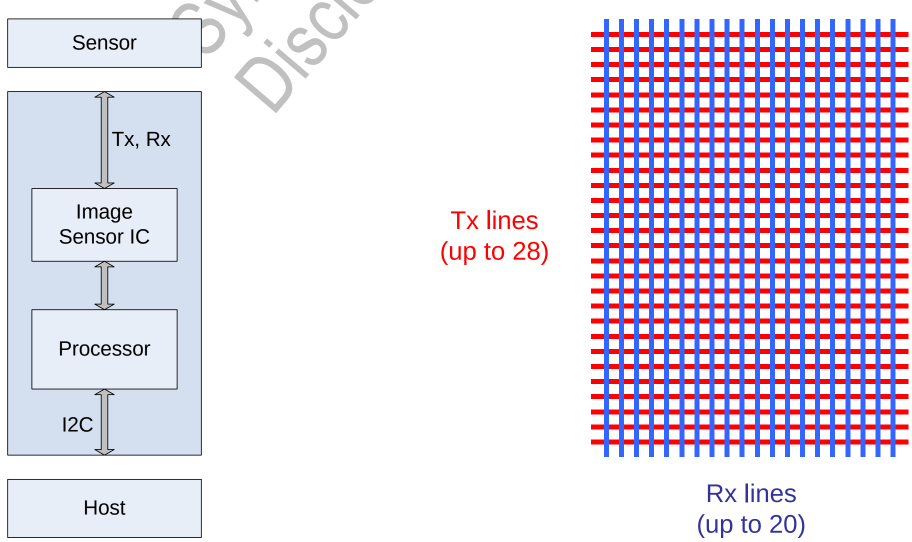

Figure 4. ClearPad 7100 diagram and sensor layout

Table 2. ClearPad 7100 profile summary

TouchScreen size (diagonal)	5 to 8.2 inches
Max number of transmitters and receivers (See Figure 4.)	28 × 20 (28 rows × 20 columns)

The ClearPad 7200 product line includes two image sensing IC within the design, as shown in Figure 5.

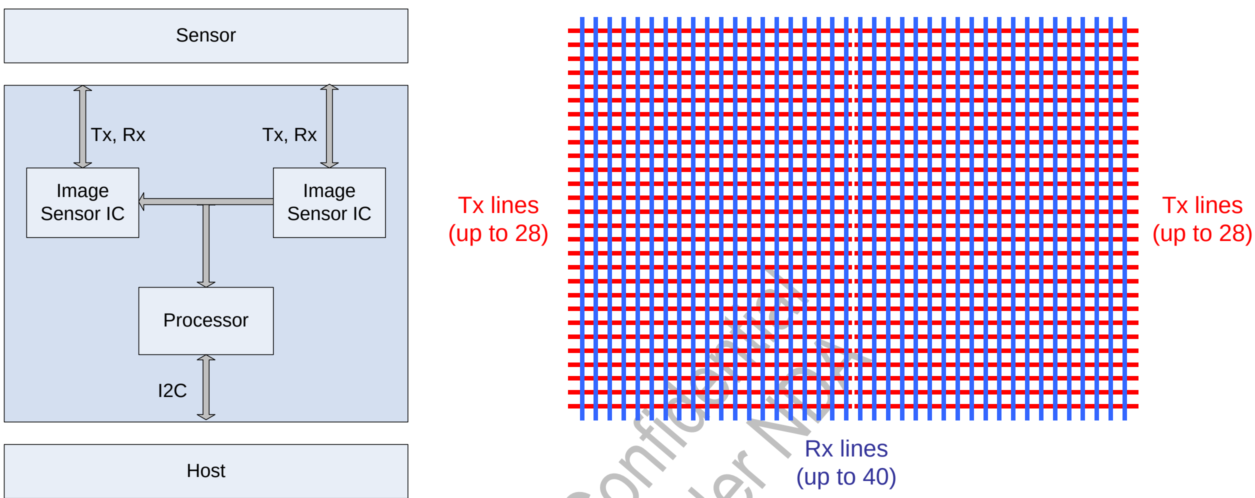

Figure 5. ClearPad 7200 diagram and sensor layout

Table 3. ClearPad 7200 profile summary

TouchScreen size (diagonal)	7 to 10.1 inches
Max number of transmitters and receivers (See Figure 5)	56 × 40 (28 rows × 40 columns)

3.1.1. Flex tail and component area

The flex tail is usually made from a flexible polyimide substrate. The tail has a component area that contains the ClearPad capacitive sensing electronics (IC and passives) and a host connector. The flex tail dimensions are typically customized to fit different shapes and orientations of different designs. Table 4 summarizes the typical component area dimensions.

Table 4. Typical Component area dimensions

	7010	*7100*	*7200*
Circuit on flex component area	TBD	22 mm × 26 mm	25 mm x 27 mm

Note: Component area dimension does not include ACF bonding area.

The overall thickness of the component area depends on the ASIC packaging type. The overall thickness includes the stiffener, flex, solder, and component.

Synaptics adheres to the following IPC specifications for flex construction:

- IPC-2221, Generic Standard on PCB design
- IPC-2223, Sectional Design Standard for Flexible Printed Boards
- IPC-6013, Qualification and Performance Specification for Flexible Printed Writing

Flex Polyimide construction includes four key variables:

- Adhesive-less versus adhesive-based
- Copper weight
- Roll anneal versus electro-deposited copper
- Panel plating versus button plating

Synaptics typically employs an adhesive based 1/3 oz. rolled annealed, button plating technique to guarantee quality and ensure flexibility.

3.2. Lens and mounting

Synaptics ClearPad touch panels can sense through non-conductive lens materials. Typical lens materials are acrylic, polycarbonate plastic, and glass. Table 5 lists nominal maximum lens thicknesses.

Table 5. ClearPad Series 7 Lens

Lens Material	*Maximum Lens Thickness*
Acrylic (PMMA)	1.0 mm ± 0.1 mm
Polycarbonate Plastic (PC)	1.0 mm ± 0.1 mm
Glass	0.5 mm to 1.2 mm ± 0.1 mm

3.2.1. Front lens recommendations

Using the casing of the device to frame the ClearPad touch panel's active area eliminates the need for a bezel. The casing, therefore, cannot have any conductive materials in the immediate sensor area. Conductive materials must be at least 1.0 mm away from the sensor area. Similarly, 1.0 mm minimum clearance should be maintained between the Synaptics IC and other components in the host system.

The casing material in the sensor area must be uniform in thickness and composition to minimize variations in sensor performance. The casing material over the entire surface should be of a constant thickness and should not include any conductive materials. Some black inks may contain enough carbon to be conductive. Dielectric values of at least 3.0 are recommended. Refer to the application note, *Inappropriate Materials for Use Over Capacitive Sensors* (PN 506-000017-01) for additional information.

The casing material should have similar composition throughout the sensor area. Any cosmetic treatments or plastic additives should be uniformly applied. If the design includes a bezel, to prevent performance degradation from air gaps between the sensor and the device casing, the surface of the bezel must be flat (within ± 0.04 mm) in the sensor area. There are no physical limitations outside the sensor mounting area.

3.2.2. Sensor mounting

The ClearPad touch panel should be firmly supported from below. This prevents the touch panel from moving as a result of forceful finger taps.

For mechanical and optical quality reasons, Synaptics recommends that ClearPad touch panels be mounted on the front lens using the pressure-sensitive optically clear adhesive (OCA) supplied on the top surface of the sensor. Attaching the ClearPad touch panel to the front lens with an OCA (known as *lamination*) helps to prevent the sensor from moving and eliminates any air gaps that would introduce internal reflections in the optical stack-up. A ClearPad module will not function with an air gap anywhere between the finger and the ClearPad touch panel.

Synaptics recommends having a 0.4 mm minimum spacing (air gap) between the LCD and the sensor. Do not place conductors on or near the circuit traces on the component side of the sensor module.

ClearPad touch panels are capacitive sensors that will pick up the proximity of metal objects, especially if they move or flex during operation. Lens paint thickness should be 10 µm or thinner. If the paint is too thick, it can create air bubbles during or after the lamination process.

Note: Synaptics must approve any mounting supports that deviate from these requirements.

The following diagrams illustrate the recommended stack-up for ClearPad glass sensors.

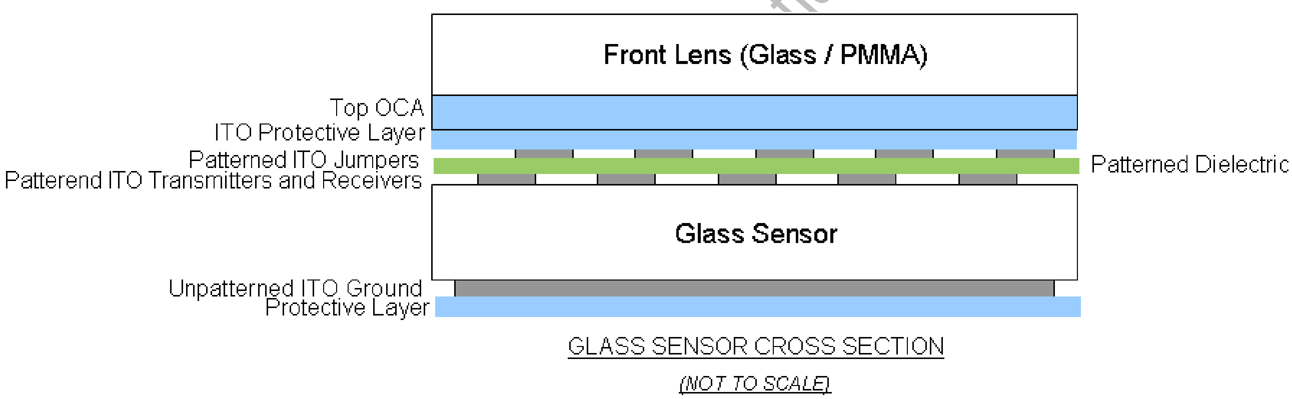

Figure 6. Glass sensor stack-up

4. Accuracy, linearity, finger separation, and hover

Synaptics ClearPad products go through extensive testing to guarantee proper detection of finger position. Accuracy and linearity deal with the comparison of actual finger position with reported position, and finger separation distance provides information on the minimum distance required between two fingers on the sensor in order for their location to be detected correctly. Hover tests ensure that a finger is not detected before it has reached the sensor surface or after it is removed from the sensor.

4.1. Accuracy

4.1.1. Measurement methodology

Accuracy is defined as the difference between reported finger position versus the actual finger position as the finger moves across the entire active area.

Accuracy error results can vary, depending on the approach of the finger, due to the hysteresis created as a finger traverses the sensor. The testing process is comprised of taking a 9 mm slug representation of a finger and mechanically stepping it across the device under test (DUT).

The slug is programmed to first secure contact with the sensor, and then move across the sensor surface without being lifted up. Finger data are collected while the slug traverses across the sensor surface. These measurements are made on the sensor and lens and not over an LCD or in the presence of other noise sources, not touching any conductive surface, and with no mechanical constraints which inhibit the movement of the slug. The recorded data at each position includes the following information:

- Finger position on the sensor (x and y); finger position refers to the center of the slug
- Reported finger position (x and y)
- Finger presence status

Figure 7 is a sample diagram of the slug traverse path during an accuracy scan:

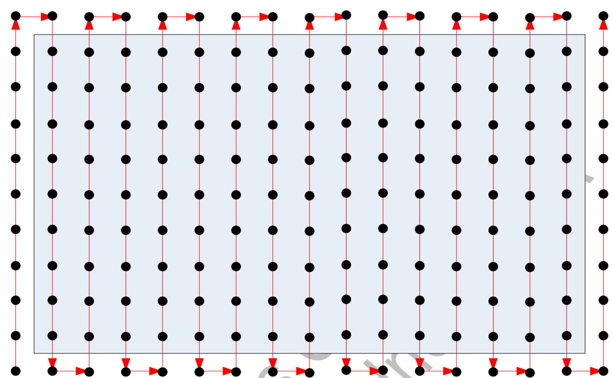

Figure 7. Sensor scan traverse path

The ClearPad regions, such as the active area, are described in section 0. Accuracy measurements are done on the ClearPad touch panel's active area. Active area dimensions vary between sensors, and are documented in the corresponding product specification. For accuracy measurements, the active area is "discovered" when the Finger Present register is triggered as the DUT undergoes a sensor scan with a 9 mm slug. Section 0 provides additional information about the accuracy test.

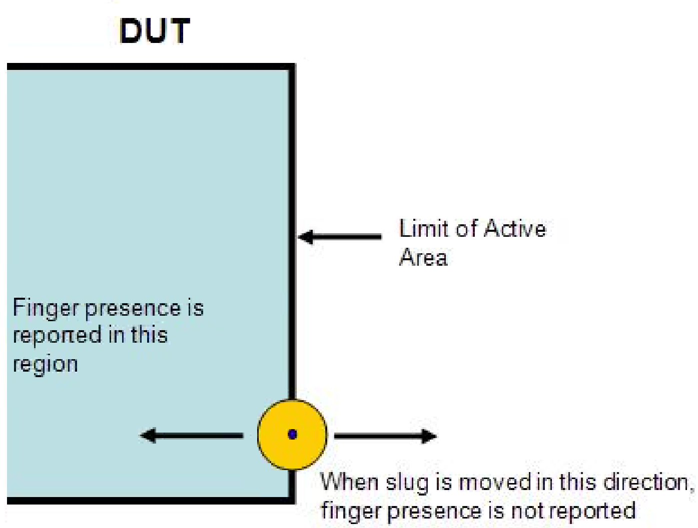

Figure 8. Positional accuracy measurement area methodology

The active area is further divided into two zones when undertaking accuracy measurements. The following diagram provides an example of how the zones are divided. The width of the edge region, Zone 2, depends on product type as in Figure 9.

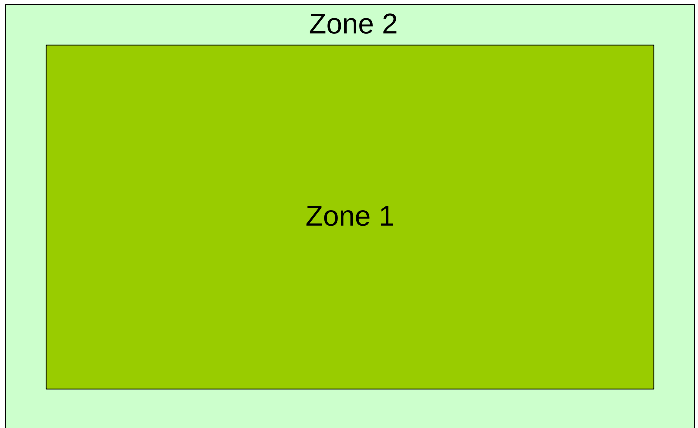

Figure 9. Division of the active area

Table 6. Edge regions

	7010	*7100 Series*	*7200 Series*
Edge region width	8 mm	8 mm	5 mm

Accuracy is determined by a comparison of the actual slug position and the reported position when the DUT undergoes a sensor scan with a 9 mm slug, as shown in Figure 10.

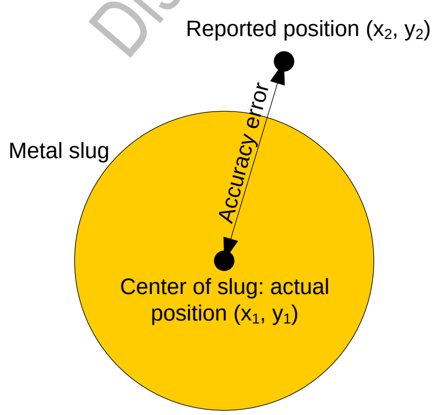

Figure 10. Accuracy methodology

The formula used for accuracy is:

$$\text{Accuracy Error} = \text{square root } [(x2 - x1)^2 + (y2 - y1)^2]$$

Accuracy varies across the ClearPad touch panel's active area. The *x* position error is the absolute deviation between reported and actual positions in the X direction, while the *y* position error is the absolute deviation between reported and actual positions in the Y direction.

Generally, the highest accuracy of reported position is in the center of the ClearPad touch panel and the lowest accuracy is at the edges of the touch panel's active area.

For information regarding finger contact area on touch surfaces and optimal sizing of screen targets (GUI elements), refer to the *Finger Size for Touch Sensor Optimization Technical Report* (PN 508-000020-01).

4.1.2. Accuracy specification

Using the methodology explained above, ClearPad Series 7 sensors have the following estimated accuracy for a 9 mm slug with maximum sensor pitch size of 5 mm:

Table 7. ClearPad Series 7 accuracy error specification

Zone	*Estimated average accuracy error*		
	7010	*7100*	*7200*
1	± 1.6 mm	± 1.6 mm	± 1 mm
2	± 2.5 mm	± 2.5 mm	± 2 mm

Note that the above figures assume the largest sensor size for each of 7010/7100/7200; smaller sensor sizes will exhibit superior performance.

4.2. Linearity

4.2.1. Measurement methodology

Linearity is defined as the difference between reported finger positions versus the actual finger position as the finger moves linearly across a specified trajectory of the active area. Figure 11 provides an example of trajectories that a finger slug could follow to test for linearity. Other sample trajectories can be performed.

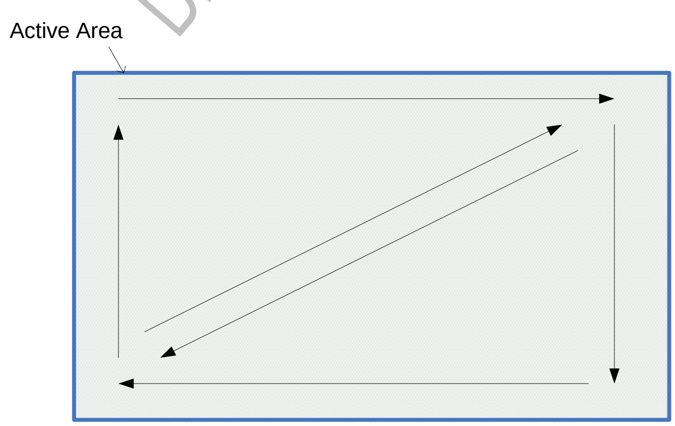

Figure 11. Sample finger trajectories for linearity testing

A linearity error is defined as the max delta error (ΔE) of reported finger position. The black line labeled AB is the path the slug traverses across the sensor. The red line in the diagram represents the positional data collected from the sensor as the slug moves.

Maximum delta error is the maximum difference between the straight line and the data line:

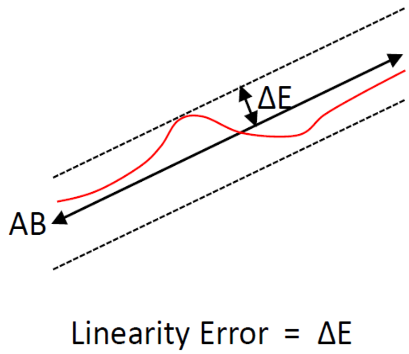

Figure 12. Linearity error calculation

4.3. Jitter

4.3.1. Measurement methodology

Jitter is the deltas of reported positions when a conductive slug is in stationary contact with the sensor cover lens. A total of twenty sequential samples are collected with each stationary contact of the slug with the sensor cover lens. Each position is tested independently with a 9 mm slug. Reported positions must be within a 1 mm diameter circular area:

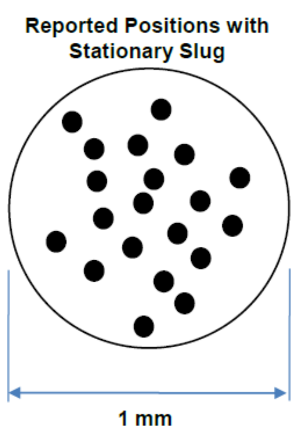

Figure 13. Jitter sample collection

Measurements of jitter samples are collected at twelve locations on the sensor cover lens surface, as shown in Figure 14.

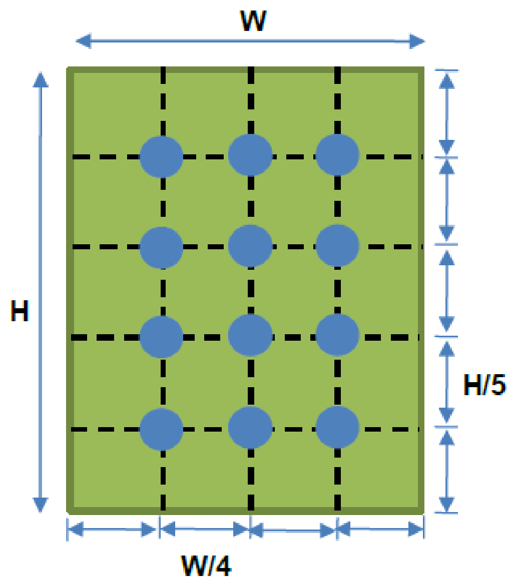

Figure 14. Jitter samples collection locations

4.4. Finger separation

4.4.1. Measurement methodology

Finger separation is the minimum physical distance between two fingers on the sensor required for the fingers to be detected as two individual fingers rather than one. Any two fingers on the sensor must be separated by at least the finger separation distance in order to be detected correctly, as shown in Figure 15.

Figure 15. Finger separation distance definition

Measurements of finger separation are made manually, using a set of conductive slugs in different diameters. The use of various-sized slugs provides more realistic measurements, as fingers vary in size. The measurements are made by placing a pair of slugs on the sensor close together, which prompts the sensor to recognize the pair as one finger. The slugs are moved apart from each other, incrementally. Distance between the two slugs is then measured when the sensor first detects two fingers instead of one.

Refer to the *Use of Metal Slugs in Capacitive Sensor Design* (PN 506-000240-01) application note for more information on the use of metal slugs for capacitive sensor testing.

The minimum finger separation distance is, in general, the maximum of the finger diameter and a fixed constant which is sensor-dependent. The constant is defined as:

$$\sqrt{P_x^{\,2} + P_y^{\,2}}$$

where P_x is the sensor electrode pitch in the horizontal direction and P_y is the pitch in the vertical direction. This number provides the best case scenario: actual minimum finger separation distance may vary due to other design factors.

4.4.2. Characterization data summary

The following table measures finger separation distance on a ClearPad Series 7 sensor using slugs of different sizes. Finger separation distances are measured as the distance between the centers of the slugs, instead of the edge-to-edge distance. All measurements are given in millimeters.

Table 8. Relationship between finger separation distance and slug size

Slug size	*Separation distance (center to center)*
6.5 mm	TBD
9 mm	TBD

4.5. Hover

4.5.1. Measurement methodology

Hover occurs when the sensor is overly sensitive, such that finger presence is reported when the finger approaches the sensor surface or when the finger is hanging above the surface without contact. This can lead to unintentional activations of user interface controls.

To minimize hover and produce an optimal user experience, finger hover tests are performed on all ClearPad Series 7 sensors to help adjust the sensitivity of each sensor design. The test uses a brass slug that is enclosed by a plastic shell, as shown in Figure 16.

Figure 16. Slug with plastic shell for hover test

The plastic shell suspends the slug above the sensor surface to simulate a hovering fingertip. The plastic shell must be hollow and provide a significant distance between the slug and the shell. The hollow cavity of the shell must be at least 13 mm high. The gap between the shell and the slug is to ensure no electric field lines go through the plastic and invalidate the test results.

The slug is secured by a plastic set-screw, enabling the distance between the slug and the sensor surface to be changed. The distance between the slug and the sensor surface is calibrated using spacers of known heights that fit within the cavity of the shell.

The metal slug protrudes above the top of the plastic shell to allow contact with the operator's finger. The slug must be grounded by contact with an operator's finger or by attaching an explicit ground wire.

5. Report rate and response time

5.1. Report rate

ClearPad 7100/7200 sensors support a report rate of up to 80 Hz with up to 10 fingers; 7010 supports a report rate of up to 40 Hz with up to 5 fingers.

The RMI4 protocol allows for two report rates. Customers can specify firmware with one default report rate, and can also request a second report rate that is 50% of the default.

5.2. Response time

The following table outlines the amount of time, for a given power state, a ClearPad sensor requires to report a touch. Refer to section 7 for more details on power states.

Table 9. ClearPad response time in power modes

Power State	*Minimum time needed*	*Typical time needed*	*Maximum time needed*
No Sleep	TBD	TBD	TBD
Normal Operation	TBD	TBD	TBD
Sensor Sleep	TBD	TBD	TBD

Note: Responsiveness is based on I²C-configured firmware, and is the elapsed time from single-finger touch to ATTN line assertion.

The data above is for a sensor running at 80 Hz. Configuring the sensor to a faster report rate will lower response time. Timing may vary between sensors, depending on system configurations and settings.

6. Host interface

Synaptics ClearPad 7010 supports both I²C and SPI host interfaces; 7100 and 7200 support I²C.

6.1. Physical layer interface

6.1.1. I²C interface

Synaptics I²C protocol supports operating speeds of up to 400 kb/s with 7-bit addressing and 8-bit data bytes. Synaptics ClearPad modules usually include an attention signal (ATTN) that is asserted by the sensor to indicate that new data is available for reading by the host.

Table 10. Typical I²C pinout

I²C connector pinout	*Pin definition*
VDD	Power supply voltage
VBUS	Host communications bus voltage (7010 option only)
GND	Ground
SDA	I²C serial data line
SCL	I²C serial clock line
ATTN	Attention line (typically active low)

The ATTN signal is intended to be used as an interrupt source to a host processor. Figure 17 illustrates this type of connection to the host. For additional information, refer to the *QuickStart Guide for RMI4-over-I²C Synaptics Sensors* (PN 506-000202-01).

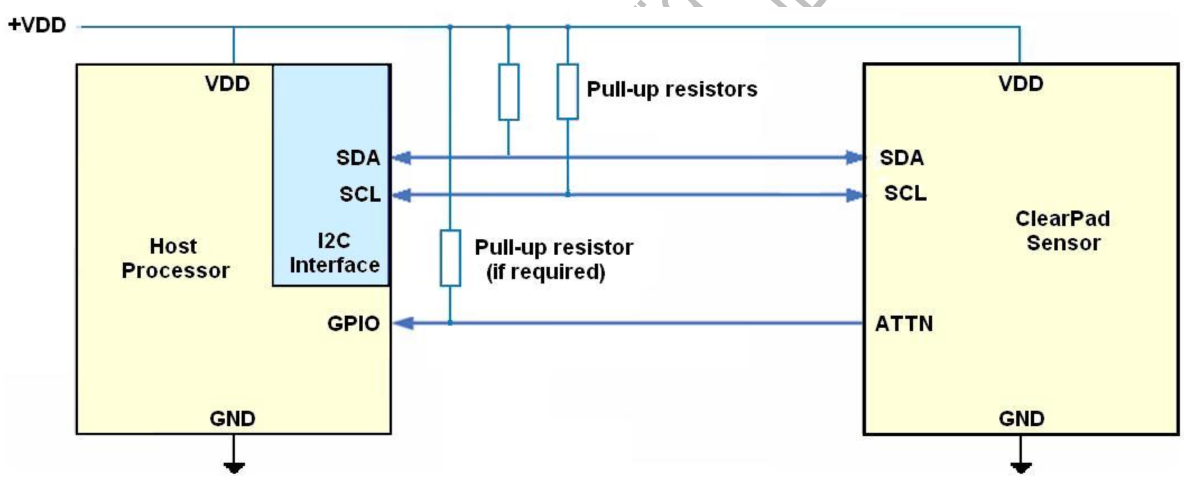

Figure 17. Typical connection of the sensor to the host

The values of the pull-up resistors should be chosen to ensure that the rise times of the SDA and SCL signals are within the limits set by the I²C specification. This depends on what other devices, if any, are on the I²C bus. Typical values fall within the range of 2.2 kΩ to 10 kΩ.

The host uses the sensor's fixed I²C slave address to communicate with the sensor. This address is customizable, product-specific, and can be found in the relevant Synaptics Product Specification.

6.1.1.1. I²C clock stretching

Pay special attention to clock stretching when interfacing with a Synaptics ClearPad module over I²C. The host processor must support clock stretching. The first byte of a transaction contains the slave address and "R/W" bit. At the end of the first byte, the sensor holds SCL low (clock stretches) and checks that the slave address matches. If the slave address fails to match, the sensor no longer clock stretches on subsequent byte transmissions until it detects the next start condition. When the slave address matches, the sensor acknowledges and may continue to clock stretch at the end of subsequent bytes within the same transaction (Figure 18).

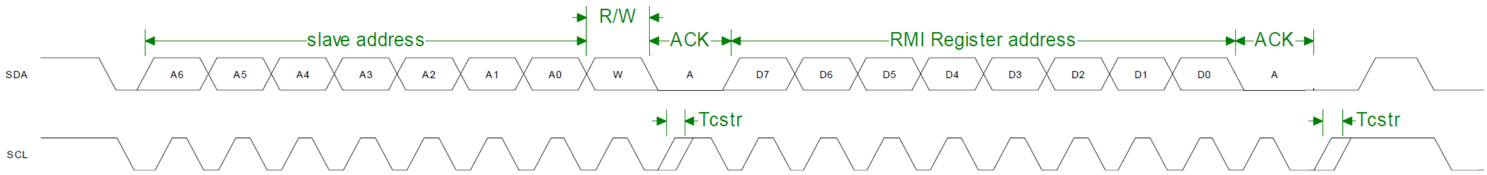

Figure 18. Typical I^2C transaction

The maximum clock stretch time (Tcstr) varies with different product complexities, configurations, and the timing of an I^2C interrupt with respect to the sensor (depending on what the sensor is doing at the time of the host command).

6.1.2. SPI interface (7010 only)

Table 11 lists the pins typically used in an SPI interface.

Table 11. Typical SPI system interface

Pin Name	*Pin Definition*
VDD	Power Supply Voltage
GND	Ground
SSB	Active-low slave select bit
SCK	SPI Clock
MOSI	Master Out/Slave In.
MISO	Master In/Slave Out.
ATTN	Attention Line (typically active low)
VBUS	Host communications bus voltage (7010 option only)

Most designs have SSB, SCK, MOSI, MISO, and ATTN pins. Synaptics ClearPad modules usually include an attention signal (ATTN) that is asserted by the sensor to indicate that new data is available for reading by the host.

The ATTN signal is intended as an interrupt source to a host processor. Sometimes the MOSI/MISO is referred to as SDI/SDO when the SDO on the master is connected to the SDI on the slave, and vice versa. For processors that do not have an SPI hardware interface, the SPI protocol can be implemented in software instead. A typical connection to the host is depicted in Figure 19.

The GPIO pin on the processor is assumed to be an input that can be configured as an interrupt source with a polarity to match that of the attention line. In this example, the attention line is active low. The pull-up resistor is required when the attention line output is open-drain, which is usually the case. The pull-up resistor on the MISO line is needed to prevent the processor input floating when there is no activity on the bus.

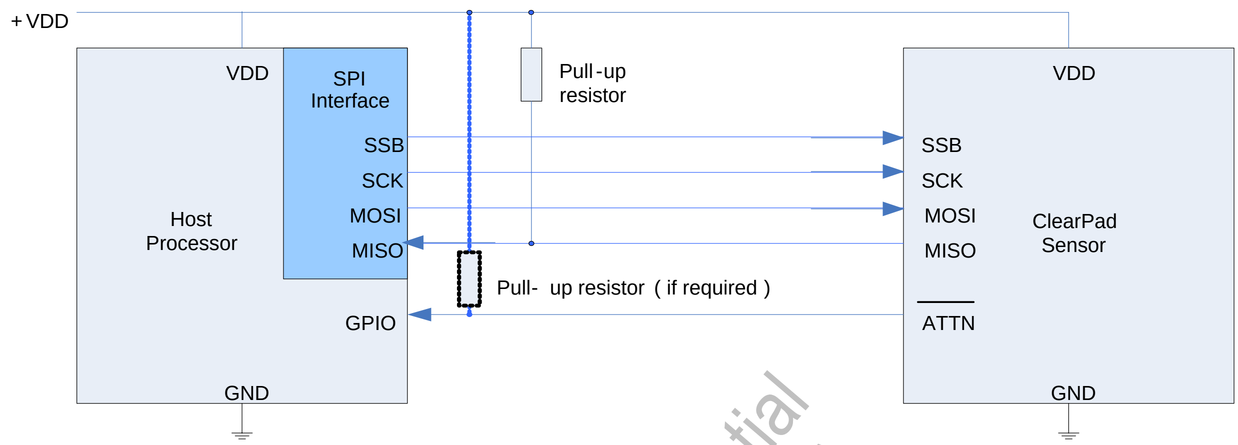

Figure 19. Typical connection of sensor to host

The host must be configured:

- to use the correct polarity and phase for the bus signals,
- to use the correct number of address/data bits, and
- to transmit/receive data bits in the correct order.

The clock polarity and clock phase (usually termed CPOL and CPHA) for SPI varies. Application processors that have a hardware SPI interface module normally provide configuration bits to set these parameters to suit the slave device. The host must also configure the clock using a frequency less than or equal to the maximum frequency the slave device supports. Synaptics ClearPad modules operate in either SPI mode 1 (CPOL = 0, CPHA = 1) or SPI mode 3 (CPOL = 1, CPHA = 1). The CPOL = 1 setting means that the idle level of the clock SCK is high. CPHA specifies which edge of SCK is used by the sensor to sample MOSI and by the host to sample MISO, so CPHA = 1 corresponds to the trailing (rising) edge of the clock. The choice of mode is fixed at design time.

6.1.3. Controlling incoming data with SPI

There is no support for clock stretching to help the slave control the flow of incoming data. The host must configure the clock using a frequency less than or equal to the maximum frequency the slave device supports.

For specific information regarding interfacing with a Synaptics ClearPad through SPI, refer to the *QuickStart Guide for RMI4-over-SPI Synaptics Sensors* (PN 506-000201-01).

6.1.4. Attention line behavior

The attention signal is designed to be connected to a host processor's interrupt request line and indicates when new data is available to be read from the sensor. Because of this, the host does not have to constantly poll the sensor when there is no finger on the sensor, or when there is a finger present but no motion is detected.

Attention lines are either active-high or active-low, depending on the product. Attention lines are compatible with both level- and edge-sensitive host interrupt behavior. The default polarity is active-low with open-drain output. However, ClearPad modules can assert the attention line when an RMI function needs to do so. Refer to the relevant Synaptics Product Specification for details.

When the attention line is asserted, the host must read data source registers in order to acknowledge it. To avoid having to read all data registers, the Interrupt Enable register can be set to only assert the attention line if there is new absolute data. This is done by setting the *ABS* bit to '1' and the other bits to '0' in the Interrupt Enable register.

Although the attention line is always de-asserted by sending any I^2C read or write command to the sensor, it will be re-asserted at the end of the transaction if the relevant registers were not read. This is shown in Figure 20.

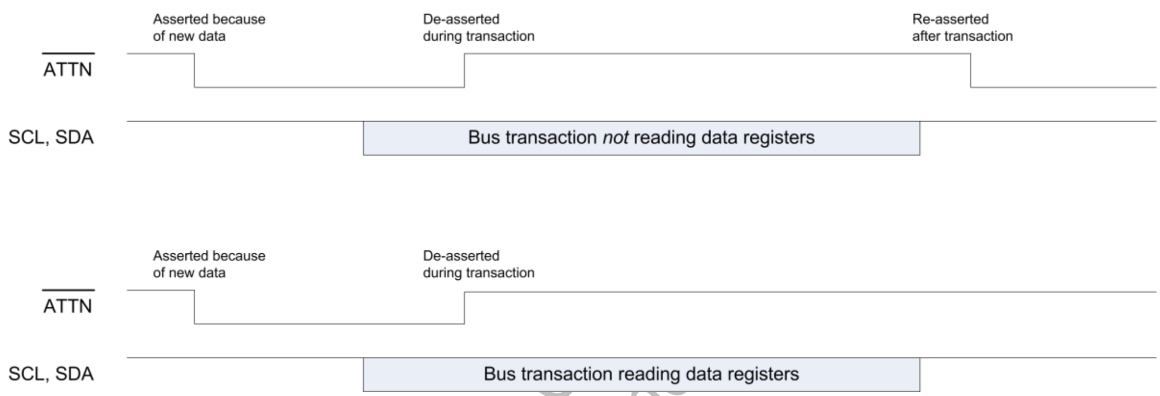

Figure 20. Attention line behavior

The data register contents for absolute or relative sources are not changed by reading them. The register contents are always valid and can be read any time. An attention line interrupt, however, typically triggers the reading of data registers.

6.2. Data layer interface

6.2.1. RMI4 introduction

Register Mapped Interface, Version 4 (RMI4) is the communications interface used in Synaptics embedded products. It communicates with industry-standard physical interfaces such as I^2C and provides self-discovery of our devices to the host.

6.2.2. Typical registers and functions

RMI4 defines a standard set of functions which further define registers included in the device:

- *Data Registers*
  Report sensor readings and other input data to the host. These registers are typically Read-Only.
- *Control Registers*
  Allow the host to initialize the device and control its functions. These registers are Read/Write. Some device-specific applications may define control registers to be read-only.

- *Command Registers*
  Allow the host to perform discrete commands or to signal discrete events. These registers are Read/Write.
- *Query Registers*
  Allow the host drive to determine what kind of RMI4 device is attached and what features it includes. These registers are Read-Only.

Table 12 lists the most frequently used RMI4 functions:

Table 12. RMI4 functions

Function	Name	Description
$01	Device Control	Common functionality for all Synaptics devices
$11	2-D Sensing	Single or Multi-Finger
$34	Flash Memory Management	In-system firmware upgrade

Each function defines a set of features found in a Synaptics RMI4 device. RMI4 functions are identified by an informal name and a standardized identifying number. All RMI4 registers follow a standard naming convention:

- The first part of the register number is determined by its function number (for example, F01 or F11).
- The second part of the register number is determined by its function name (for example, _RMI_ for "RMI device control" or _2D_ for "2-D sensors."
- The third part of the register number is a combination of the register type and its placement in the set of defined registers (for example, Ctrl1 is the second defined control register and Cmd0 is the first command register). Therefore, F34_Flash_Query0 is the first query register for Function $34, Flash memory management.

Each function is largely independent of any other functions that might be present in the same device, and each function is consistently defined among all devices that include that function.

6.2.3. Register map organization

All the registers in RMI4 are eight bits wide. Quantities larger than 8 bits (1 byte) are held in several consecutive registers typically read or written as a group. Registers are identified by 16-bit addresses ranging from $0000 (hex) to $FFFF (hex). The Register Address Map is further divided into pages of 256 related registers and a page offset in the range of $00xx to $00xx (the lower eight bits of the 16-bit address range). Every page contains global registers that perform the basic functions of selecting the proper page (Page Select register*)* and describing the RMI4 functions in it (Page Description table).

The Page Select register is defined for physical layers that are not capable of supplying the full 16 bits of register address information in a single transfer, such as SMBus. A Page Select register supplies any high order address bits that the physical layer is incapable of sending.

Offset	7	6	5	4	3	2	1	0
$xxFF	RMI address bits 15:8							

Figure 21. Page Select register

The *Page Description Table* in RMI4 defines a self-discovery mechanism that supplies enough information to enable a host to reconstruct a complete view of the RMI4 register address map for any given device. The discovery mechanism is page-based — each page with at least one RMI4 function contains a set of special read-only registers in a page description table. If a host reads the contents of the Page Description table on a particular address page, it can discover:

- The RMI4 functions that exist on that page,
- The starting page offsets for each kind of register block associated with each RMI4 function on that page,
- The number of interrupt sources associated with each RMI4 function on that page, and
- The versions of each RMI4 function on that page.

A comprehensive register map is unique for a given device. Refer to the relevant Synaptics Product Specification for details about its register map. For more information about RMI4, refer to the *Synaptics RMI4 Specification* (PN 511-000136-01). For more information about the register map discovery process, refer to the *RMI4 Register Map Discovery* Application Note (PN 506-000216-01).

6.2.4. Device control

Function $01 implements a set of registers suitable as the foundation for controlling a large family of RMI products. Every RMI4 product requires a device control function to be present. This function contains registers for manufacturer ID, product information, device serialization, reporting rate, device status, and interrupt status.

6.2.5. 2-D sensing

Function $11 implements two-dimensional touch position sensors and reports the positions of one or more fingers in the native X-Y coordinates of the 2-D device. The relative data source reports the delta X-Y coordinates.

This function also reports how many distinct 2-D sensors are present in the device. When more than one 2-D sensor is present in the device, each operates independently of the other. Each sensor reports its data in separate data registers with separate interrupt request and interrupt enable bits. Similarly each 2-D sensor's properties are described by a separate set of queries, and each is configured by a separate set of control registers. The grouping of query, control, data and command registers in the register map for multiple 2-D sensors is analogous to the grouping of RMI functions. For example, the data registers for the first 2-D sensor are followed by the data registers for the next. The grouping order for multiple sensors cannot be changed.

6.2.5.1. MultiFinger sensing

Synaptics ClearPad Series 7 sensors can detect and track multiple fingers. The device can report the number of fingers detected, X and Y position data, finger width, finger contact area, as well as amount of finger motion. The Synaptics device also reports finger states:

- 0 = Finger up (not pressed)
- 1 = Finger pressed, finger position information is valid

6.2.6. In-system reprogrammability

Synaptics ClearPad modules support flash programming to change the user interface firmware or alter the configuration of the device. This capability allows freedom and flexibility when designing with Synaptics devices; choose the firmware image that is applicable to your design. Figure 22. illustrates the firmware storage methodology.

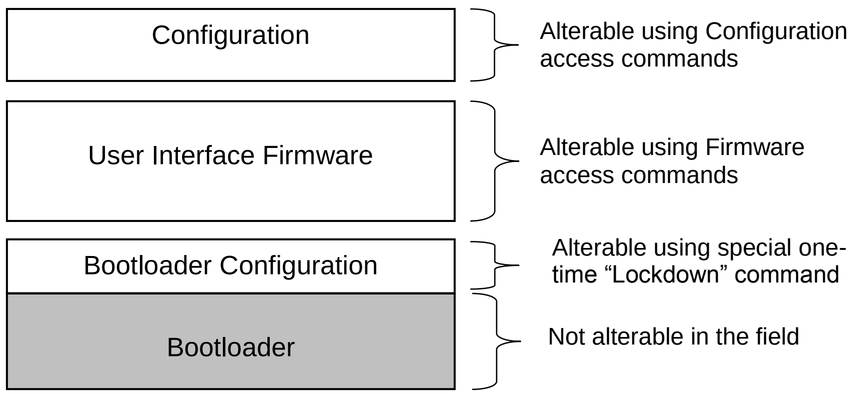

Figure 22. Firmware storage methodology

- **Configuration:**
  The configuration space stores the default values of the device’s control registers. The bootloader firmware provides a mechanism to erase and reprogram this space. Because an existing configuration may not be valid for a new firmware revision, any update to the UI firmware should be followed by an update of the configuration space.
- **User Interface firmware:**
  The UI firmware space contains the firmware that implements the primary function of the device. UI firmware images are provided by Synaptics in an encrypted form to ensure they can only be executed on an appropriate device. It is not possible to erase the UI firmware space without also erasing the configuration space.
- **Bootloader firmware:**
  This space contains the bootloader firmware. The bootloader firmware:
  - checks the integrity of the UI firmware space, and
  - provides the ability to re-flash a new UI or configuration area.

  To guarantee that a device can never be unrecoverably corrupted during a firmware update operation, this space is not field-programmable via Function $34. However, in order to implement the bootloader Lockdown command, a bootloader will permit a small, one-time change confined to the configuration area of the bootloader space. Because the bootloader space is not field-erasable, the lockdown operation is permanent.

Reference code is available which describes the steps for reprogramming the configuration and UI firmware space.

7. Electrical specifications

7.1. Absolute maximum ratings

Table 13 presents the absolute maximum ratings.

Table 13. Absolute maximum ratings

Subject	Minimum	Maximum
Voltage on any Pin with respect to DGND, AGND(1)	– 0.3 V	VDD + 0.3 V
VDD with Respect to Ground	– 0.3 V	+ 3.6 V

7.2. Power supply characteristics

Table 14 lists the operating power supply parameters.

Table 14. Power supply characteristics

Power Supply Voltage	VDD 2.8 V to 3.3 V ± 0.1 V. Absolute minimum VDD at 2.7 V, absolute maximum at 3.6 V with power supply ripple
Power Supply Ripple	100 mV p-p maximum. Voltage not to exceed absolute limits.
Power Supply Rise Time	TBD

7.2.1. Power on sequence and initialization

When powering the sensor module up or down, system design should ensure that the voltage on the signal pins in the Absolute Maximum Ratings table (Table 14) are observed. Failure to follow this requirement may lead to unreliable operation of, or damage to, the sensor module. The open-drain I/Os (ATTN, SDA, SCL) are pull-up with VDD.

During the initialization phase (Tpowerup), the sensor hardware reset and firmware initialization routines may take up to 150 ms. During this time, the ATTN signal will be de-asserted and no host commands will be recognized. After the sensor is fully initialized, the ATTN pin will be asserted and host communication is enabled.

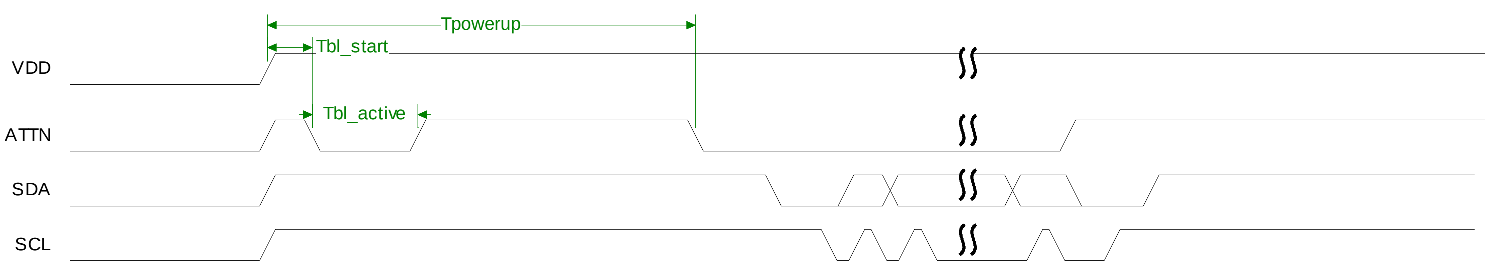

Figure 23. Power-on sequence for I^2C sensors

Table 15. Power on sequence timings

Subject	*Minimum*	*Estimated*
Tdata_valid (From VDD to 1st valid position data)	TBD	TBD
Tpowerup (From VDD to Host Communication Enabled)	TBD	TBD
Tbl_start (boot loader start)	TBD	TBD
Tbl_active (boot loader active)	TBD	TBD

Refer to the *Synaptics RMI4 Specification* (PN 511-000136-01) for additional information.

7.2.2. Power on reset

For the sensor module to initiate a power on reset, the sensor VDD must be below the minimum brownout voltage of 1.6V for at least TBD ms. Figure 24 illustrates a typical case where the sensor VDD is driven below 1.6V to power cycle the sensor with $T_{reset,min}$ = TBD ms.

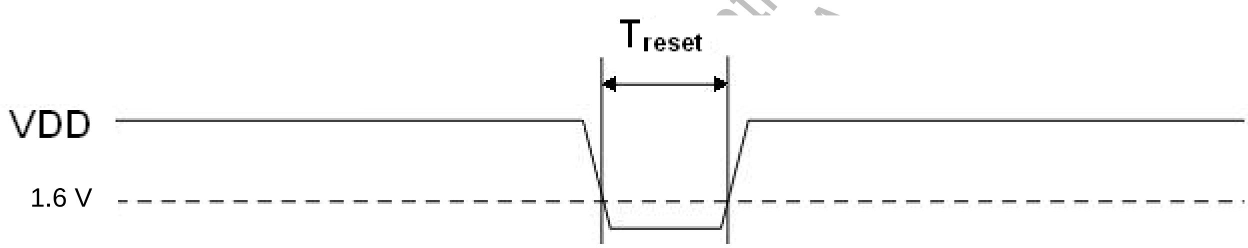

Figure 24. Typical power cycle (recommended)

However, if power is removed by floating VDD, while the sensor is asleep (on products that support low power operation), the VDD pin will take significantly longer to discharge below 1.6V before a power on reset is detected. In this case, Synaptics recommends $T_{reset,min}$ to be 1 second. See Figure 25.

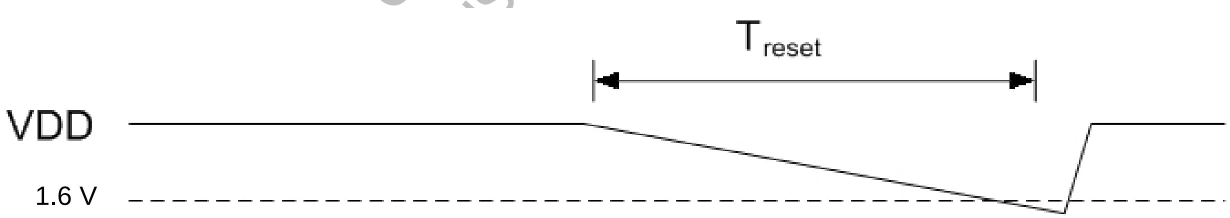

Figure 25. Power cycle (long discharge)

7.2.3. External reset

An external reset (XRES) option is available through firmware. It gives the host the ability to reset the touch controller directly from a pin and is equivalent to sending the RMI Reset command.

The following diagram illustrates the timing of the external reset signal if preset. XRES should be asserted (active low) for at least 1 µs. After de-asserting XRES, wait 1 ms for the firmware to reboot and re-initialize.

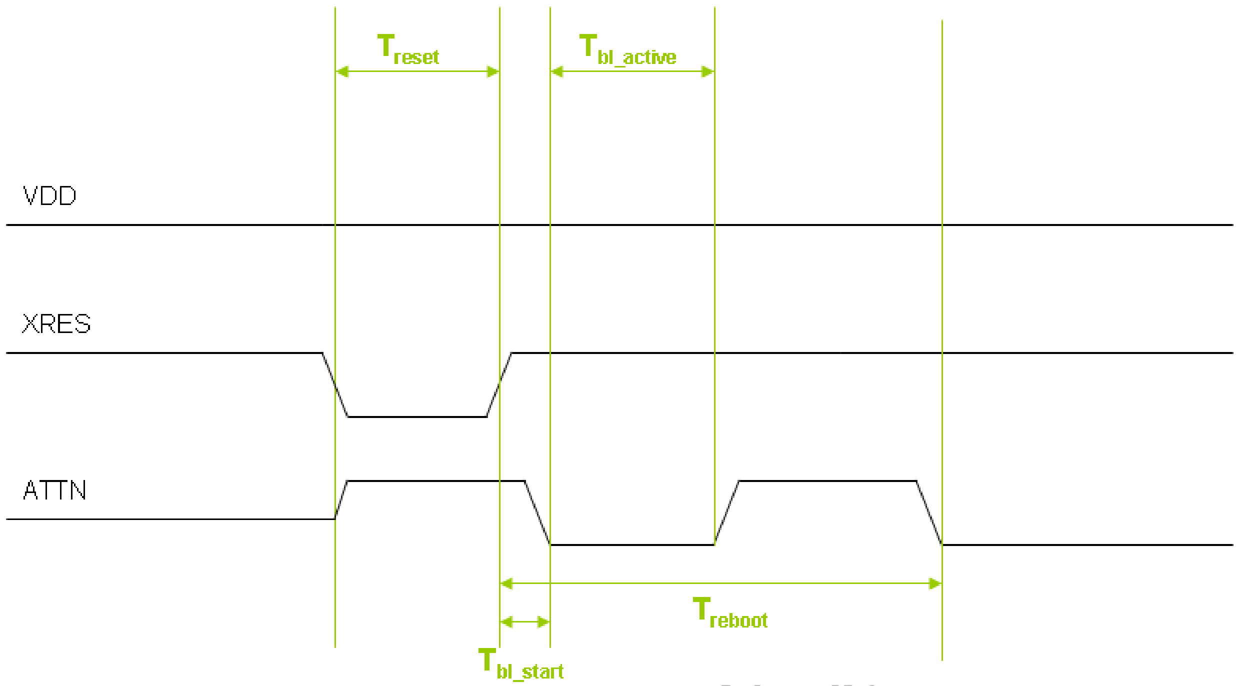

Figure 26. External reset sequence

Table 16. External reset timings

Subject	*Minimum*	*Maximum*
Treset	1 µs	–
Tbl_start	–	TBD
Tbl_active	–	TBD
Treboot	–	TBD

7.2.4. Power management

Synaptics ClearPad modules support low power modes, in which sensing can be disabled when not in use to reduce overall power consumption. Table 17 shows the supported modes. The wakeup interval defines the frequency at which the sensor is re-enabled to detect finger presence.

Table 17. RMI4 low power modes

Sleep Modes (F01_RMI_Ctrl0, Bits[1:0])	*Description*
'00' – Normal Operation	In this state, the device automatically and invisibly switches between full operation and "doze" state in which finger sensing happens at a reduced rate. The typical wakeup period is 30 ms. Refer to section 5 for overall response time to touches.
'01' – Sensor Sleep	This mode fully disables touch sensing. All touch sensors report the "not touched" state regardless of any finger presence. Digital inputs, such as mechanical buttons attached to GPI pins, continue to operate even in the Sensor Sleep state.
'10' and '11' – Reserved	In these sleep modes, encoding is reserved. Any specific products that use this encoding will have the modes defined in that product specification.

Note: Not all sleep modes are supported by every product. Refer to the relevant Synaptics Product Specification for supported modes.

In addition to the Sleep Mode field, RMI4 also controls power consumption with bit 2 of F01_RMI_Ctrl0, *No Sleep*. When set to '1', the *No Sleep* bit disables the *Sleep Mode* field and forces the device to run at full power, without sleeping. When reset to 0, the *Sleep Mode* bit is once again enabled.

The default reset state is device dependent. Most devices are defaulted to Normal Operation state upon reset. In general, power consumption of the device decreases as the sleep mode goes from No Sleep to Normal Operation. Sensor Sleep consumes the least power. The No Sleep mode is not recommended for normal operations from a power consumption standpoint.

The overall power supply current is a function of the operating VDD, sleep mode, and product configuration, which can vary significantly. Synaptics measures power supply current as an average current on the VDD pin.

The following electrical specifications are preliminary estimates for nominal operation and may vary with sensor size and configurations. Refer to the appropriate Product Specification for actual values.

Table 18. Nominal power supply current

	ClearPad 7010	*ClearPad 7100*	*ClearPad 7200*
Nominal Operating Voltage	3.3V	3.3V	3.3V
Active Current Consumption	TBD	TBD	TBD
Normal Current Consumption	TBD	TBD	TBD
Sensor Sleep Current Consumption	6 μA	TBD	TBD
Reflash Programming Current Consumption	20 mA	60 mA *****	60 mA *****

*Note: *Reflashing may last for up to 90 seconds.*

7.3. DC electrical characteristics

7.3.1. I²C DC parameters

Table 19. I²C DC parameters

TBD

7.4. AC electrical characteristics

7.4.1. I²C

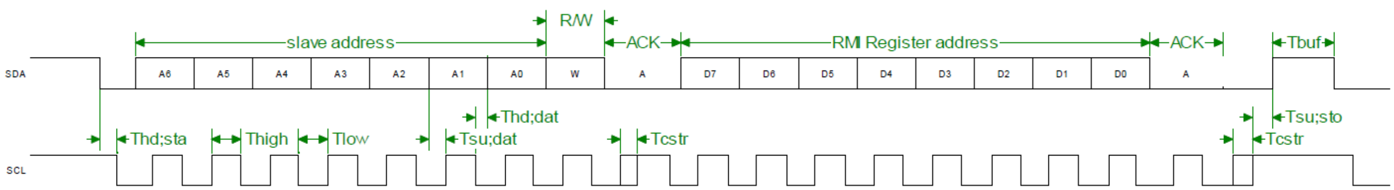

Figure 27. I²C timing

Table 20. I²C parameters

Parameter	*Symbol*	*Standard-Mode*		*Fast-Mode*		*Unit*
		Min.	*Max.*	*Min.*	*Max.*	
SCL clock frequency	f_{SCL}	—	100	—	400	kHz
START condition hold time	$t_{HD;STA}$	4.0	—	0.6	—	µs
LOW period of the SCL clock	t_{LOW}	4.7	—	1.3	—	µs
HIGH period of the SCL clock	t_{HIGH}	4.0	—	0.6	—	µs
Set-up time for a repeated START condition	$t_{SU;STA}$	4.7	—	0.6	—	µs
Data hold time	$t_{HD;DAT}$	0	—	0	900	ns
Data set-up time	$t_{SU;DAT}$	250	—	100	—	ns
Rise time of both SDA and SCL signals	t_r	—	1000	20 + 0.1 C_b (1)	300	ns
Fall time of both SDA and SCL signals	t_f	—	300	20 + 0.1 C_b (1)	300	ns
Set-up time for STOP condition	$t_{SU:STO}$	4.0	—	0.6	—	µs
Bus free time between a STOP and START condition	t_{BUF}	4.7	—	1.3	—	µs
Capacitive load for each bus line	C_b	—	400	—	400	pF

7.5. Signal-to-noise ratio

ClearPad Series 7 sensors typically have a SNR >35 dB. Higher VDD increases SNR. For definitions and further information, refer to *Signal-to-Noise Ratio for ClearPad Products* (PN 506-000292-01).

Synaptics local FAEs can work with customers to obtain display noise measurements for analysis and optimization of noise avoidance techniques by Synaptics Design Centers.

8. Environmental specification

8.1. ESD susceptibility

For protection against electrostatic discharge (ESD), the ClearPad touch panel can be mounted so that the front lens completely shields the module from external ESD strikes. The ACF/hot bar area that connects the Glass sensor to the flex tail must also be shielded from ESD strikes. This can be done with a PET cover applied to the ACF/hot bar area.

Table 21. ESD rating

Component ESD Rating (HBM)	± 2 kV

8.1.1. Grounding considerations

Ground the sensor pin to the system ground in order to accomplish the following:

- Protect against ESD
- Provide optimal finger sensitivity

For more information, see the *Design Validation Test Specification: Mobile Product Environmental Test* (PN 565-000183-01).

8.2. Thermal profile

Table 22. Environmental characteristics

Subject	*Range*
Operating temperature	–30° C to +70° C
Operating humidity (relative humidity, non condensing)	5% to 95%
Storage temperature	–30° C to +75° C

9. Environmental and regulatory compliance

Synaptics ClearPad modules are typically built in compliance with the RoHS Directive. Other environmental standards, such as Halogen-Free, may also apply. Refer to the relevant Synaptics Product Specification for actual compliance.

Synaptics ClearPad modules also typically comply with the following regulations. Refer to the relevant Synaptics Product Specification for actual compliance.

- CSA
- TUV
- Underwriters Laboratories (UL), Inc.

10. List of acronyms

ACF	Anisotropic Conductive Film
ATTN	Attention Signal (for I2C and SPI)
BGA	Ball Grid Array
BIST	Built in Self Test
CPHA	Clock Phase (for SPI)
CPOL	Clock Polarity (for SPI)
DUT	Device Under Test
EGR	Enhanced Gesture Recognition
EMI	Electro-Magnetic Interference
ESD	Electro-Static Discharge
FAE	Field Applications Engineer
FPC	Flexible Printed Circuit
FPT	Flexible Polyimide Tail
GPIO	General Purpose Input/Output
I^2C	Inter-Integrated Circuit
IC	Integrated Circuit
IPC	Association Connecting Electronics Industries
ITO	Indium Tin Oxide
LCD	Liquid Crystal Display
LGA	Land Grid Array
MISO	Master In/Slave Out (for SPI)
MOSI	Master Out/Slave In (for SPI)
NVM	Non-volatile Memory
OCA	Optically Clear Adhesive
PC	Polycarbonate (Plastic)
PET	Polyethylene Terephthalate
PI	Polyimide
PMMA	Polymethyl Methacrylate (Acrylic)
QFN	Quad Flat No lead
RF	Radio Frequency
RMI	Register Map Interface
SCK	Serial Clock (for SPI)
SCL	Serial Clock (for I2C)
SDA	Serial Data (for I2C)
SPI	Serial Peripheral Interface
SSB	Slave Select (for SPI)
Tcstr	Clock Stretch Time (for I2C)
UI	User Interface

11. Reference documents

- *Finger Size for Touch Sensor Optimization Technical Report* (PN 508-000020-01)
- *The I^2C Bus Specification Ver 2.1 Jan 2000* (http://www.nxp.com/acrobat_download/literature/9398/39340011.pdf)
- *Inappropriate Materials for Use Over Capacitive Sensors Application Note* (PN 506-000017-01)
- *QuickStart Guide for RMI4-over-I^2C ClearPad Sensors* (PN 506-000202-01)
- *QuickStart Guide for RMI4-over-SPI ClearPad Sensors* (PN 506-000201-01)
- *Design Validation Test Specification: Mobile Product Environmental Test* (PN 565-000183-01)
- *Synaptics RMI4 Specification* (PN 511-000136-01)
- *RMI4 Register Map Discovery* (PN 506-000216-01)
- *Use of Metal Slugs in Capacitive Sensor Design* (PN 506-000240-01)

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