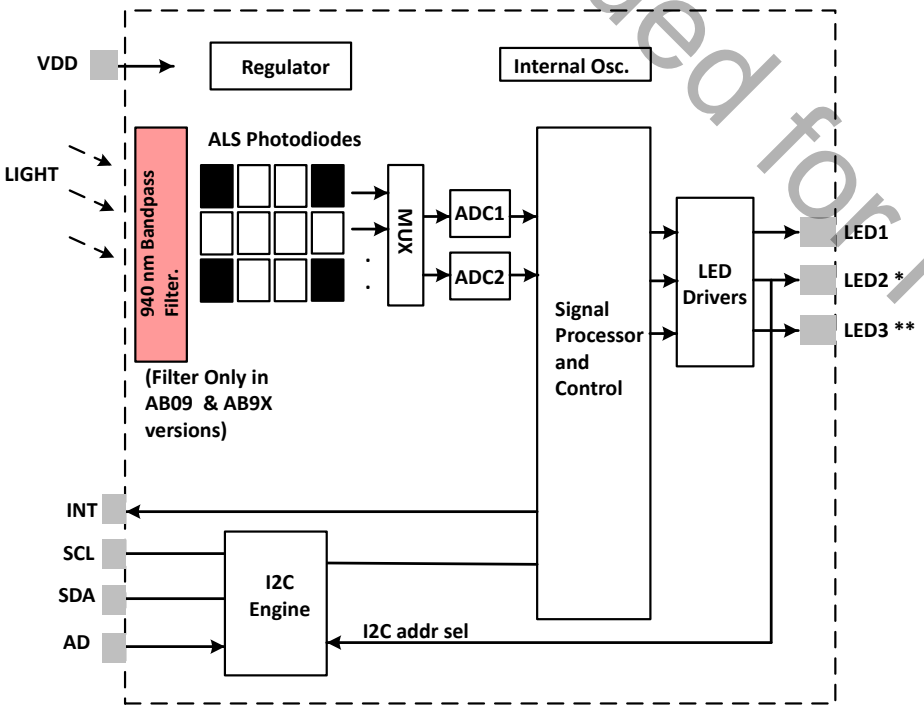
Si115x Data Sheet

Proximity/Ambient Light Sensor IC with I²C Interface

The Si115x-AB00/AB09/AB9x is an ambient light sensor, proximity, and gesture detector with I2C digital interface and programmable-event interrupt output.

This touchless sensor IC includes dual 23-bit analog-to-digital converters, an integrated high-sensitivity array of visible and infrared photodiodes, a digital signal processor, and up to three integrated LED drivers with programmable drive levels. The Si115x offers excellent performance under a wide dynamic range and a variety of light sources, including direct sunlight. The Si115x can also work under dark glass covers. The photodiode response and associated digital conversion circuitry provide excellent immunity to artificial light flicker noise and natural light flutter noise. With two or more LEDs, the Si115x is capable of supporting multiple-axis proximity motion detection. The Si115x is provided in a 10-lead 2x2 mm DFN package or in a 10-lead 2.9x4.9 mm LGA module with integrated LED, and is capable of operation from 1.62 to 3.6 V over the –40 to +85 °C temperature range.



*** Pull up to VDD with 47 kOhm resistor to select primary I2C address (0x53), or down to GND for alt I2C address 0x52. LED2 driving capabilities only available on Si1152 and Si1153.**

**** Pull up to VDD with 47 kOhm resistor. LED3 driving capabilities only available on Si1153.**

KEY FEATURES

- Proximity detector
  - From under 1 cm, to 50 cm without additional lensing.
  - From under 1 cm, to 200 cm with additional lensing (e.g., 5 mm hemispherical lens as in our EVB).
  - Up to three independent LED drivers.
  - 30 current settings from 5.6 mA to 360 mA for each LED driver.
  - Operates in direct sunlight with optional on-die 940 nm passband filter.
  - On die 940 bandpass filter that rejects unwanted visible light and IR from daylight and other sources (Si115x-AB09/AB9X).
- Ambient light sensor
  - <100 mlx resolution possible, allowing operation under dark glass.
  - Up to 128 klx dynamic range possible across two ADC range settings.
- Industry's lowest power consumption
  - 1.62 to 3.6 V supply voltage.
  - 9 µA average current (LED pulsed 24.4 µs every 800 ms at 180 mA plus 3 µA Si115x supply).
  - <500 nA standby current.
  - 24.4 µs LED "on" time keeps total power consumption duty cycle low without compromising performance or noise community.
  - Internal and external wake support.
  - Built-in voltage supply monitor and power-on reset controller.

APPLICATIONS

- Wearables
- Handsets
- Display backlighting control
- Consumer electronics

Table of Contents

1. Feature List

- Proximity detector
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  - From under 1 cm to 200 cm with additional lensing (e.g., 5 mm hemispherical lens).
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  - 30 current settings from 5.6 mA to 360 mA for each LED driver.
  - Operates in direct sunlight with optional on-die 940 nm passband filter.
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  - <500 nA standby current
  - 24.4 µs LED "on" time keeps total power consumption duty cycle low without compromising performance or noise community
  - Internal and external wake support
  - Built-in voltage supply monitor and power-on reset controller
- I^2C Serial communications
  - Up to 400 kHz data rate
  - Slave mode hardware address decoding
- Two package options:
  - 10-lead 2 x 2 x 0.65 mm DFN
  - 10-lead 2.9 x 4.9 x1.2 mm LGA module with integrated 940 nm LED
- Temperature Range: –40 to +85 °C

2. Ordering Guide

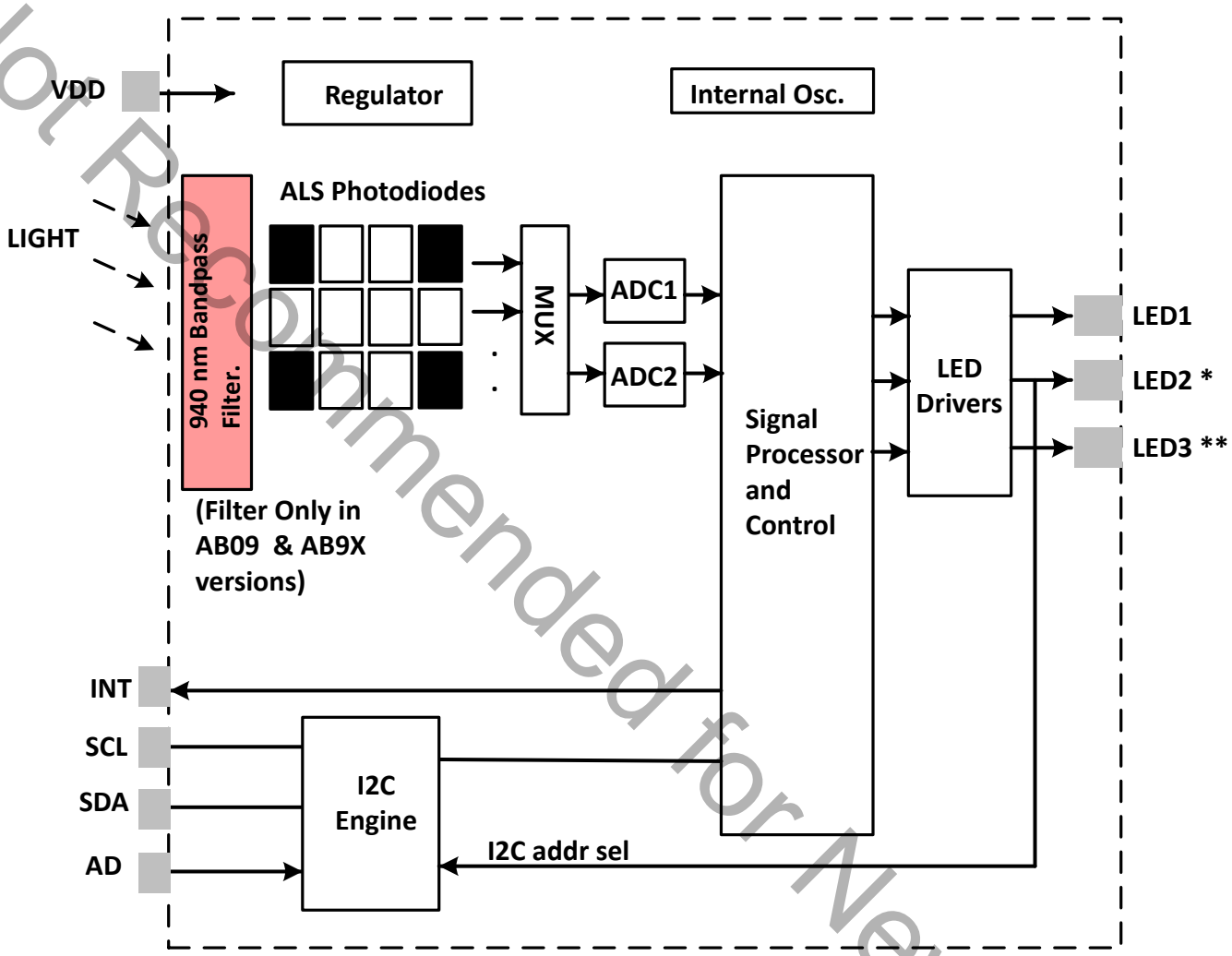
Table 2.1. Ordering Guide

Family	OPNs	Package	ALS	940 nm Filter	Proximity (# of LED Drivers)	# of LEDs Included
Si1151	Si1151-AB00-GMR[1]	2 x 2 mm DFN	Y		1	0
Si1151	Si1151-AB09-GMR[2]	2 x 2 mm DFN		Y	1	0
Si1152	Si1152-AB00-GMR[2]	2 x 2 mm DFN	Y		2	0
Si1152	Si1152-AB09-GMR[2]	2 x 2 mm DFN		Y	2	0
Si1153	Si1153-AB00-GMR[1]	2 x 2 mm DFN	Y		3	0
Si1153	Si1153-AB09-GMR[1]	2 x 2 mm DFN		Y	3	0
Si1153	Si1153-AB9x-GMR[2]	2.85 x 4.9 mm LGA Module		Y	3	1

Note:
1. This part is Not Recommended for New Design.
2. This part is End of Life.

3. Functional Description

The Si115x is an active optical reflectance proximity detector, with ambient light sensors whose operational state is controlled through registers accessible through the I2C interface. The host can command the Si115x to initiate on-demand Ambient Light or proximity measurements. The host can also place the Si115x in an autonomous operational state where it performs measurements at set intervals and interrupts the host either after each measurement is completed or whenever the sample is larger/smaller than a set threshold value or exits/enters a set threshold window. This results in overall system power saving, allowing the host controller to operate longer in its sleep state instead of polling the Si115x.



*** Pull up to VDD with 47 kOhm resistor to select primary I2C address (0x53), or down to GND for alt I2C address 0x52. LED2 driving capabilities only available on Si1152 and Si1153.**

**** Pull up to VDD with 47 kOhm resistor. LED3 driving capabilities only available on Si1153.**

Figure 3.1. Functional Block Diagram

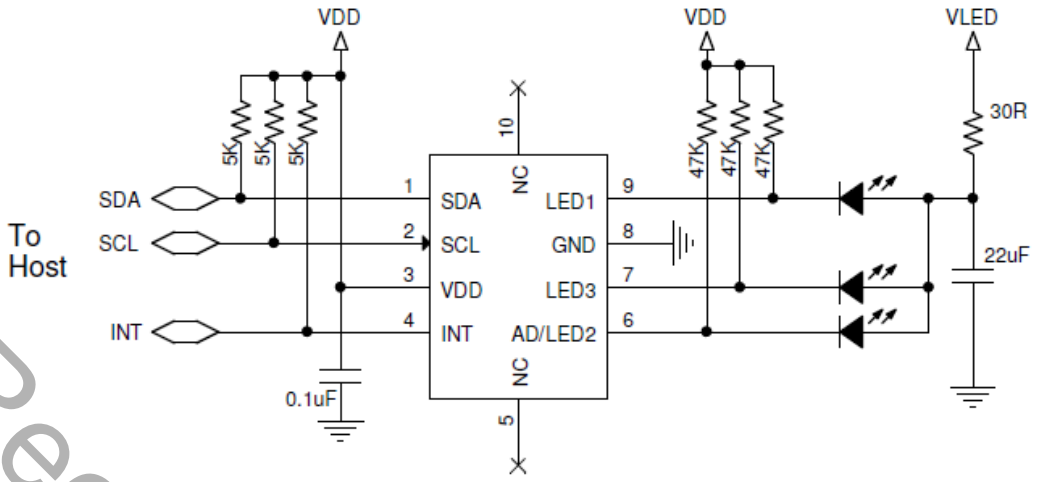


Figure 3.2. Si115x DFN Package Basic Application

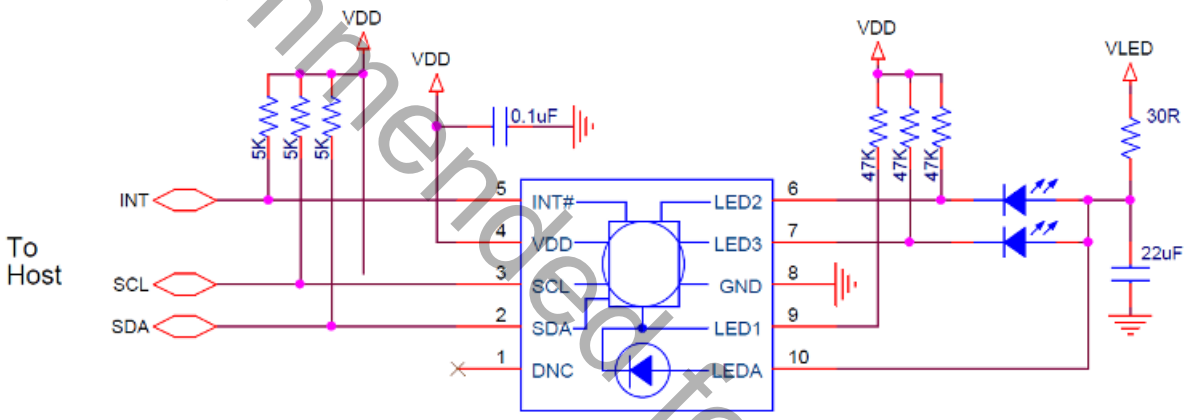


Figure 3.3. Si115x LGA Module Basic Application

3.1 Ambient Light Sensing

The Si115x has photodiodes capable of measuring visible and infrared light. However, the visible photodiode is also influenced by infrared light. The measurement of illuminance requires the same spectral response as the human eye. If an accurate lux measurement is desired, the extra IR response of the visible-light photodiode must be compensated. Therefore, to allow the host to make corrections to the infrared light's influence, the Si115x reports the infrared light measurement on a separate channel. The separate visible and IR photodiodes lend themselves to a variety of algorithmic solutions. The host can then take these two measurements and run an algorithm to derive an equivalent lux level as perceived by a human eye. Having the IR correction algorithm running in the host allows for the most flexibility in adjusting for system-dependent variables. For example, if the glass used in the system blocks visible light more than infrared light, the IR correction needs to be adjusted. Si115x parts with the bandpass 940 nm filter cannot be used for ambient light sensing.

If the host is not making any infrared corrections, the infrared measurement can be turned off in the CHAN_LIST parameter.

By default, the measurement parameters are optimized for indoor ambient light levels, where it is possible to detect low light levels. For operation under direct sunlight, the ADC can be programmed to operate in a high signal operation so that it is possible to measure direct sunlight without overflowing.

For low-light applications, it is possible to increase the ADC integration time. Normally, the integration time is 24.4 µs. By increasing this integration time, the ADC can detect light levels as low as 100 mlx. The ADC integration time for the Visible Light Ambient measurement can be programmed independently of the ADC integration time of the Infrared Light Ambient measurement. The independent ADC parameters allow operation under glass covers having a higher transmittance to Infrared Light than Visible Light.

When operating in the lower signal range, or when the integration time is increased, it is possible to saturate the ADC when the ambient light suddenly increases. Any overflow condition will have the corresponding data registers report a value of 0xFFddFF for 16-bit mode and 0x7FFFFF for 24-bit mode. The host can adjust the ADC sensitivity to avoid an overflow condition. If the light levels return to a range within the capabilities of the ADC, the corresponding data registers begin to operate normally.

The Si115x can initiate ALS measurements either when explicitly commanded by the host or periodically through an autonomous process. Refer to Section 4. Operational Modes for additional details.

Two ADCs can be used for simultaneous readings of the visible or proximity photodiode and black dark current reference photodiode. When subtracted, these differential measurements remove dark current, reducing noise that enables lower light sensitivity.

3.2 Proximity Sensing

The Si115x has been optimized for use as either a dual-port or single-port active reflection proximity detector. Over distances of less than 50 cm, the dual-port active reflection proximity detector has significant advantages over single-port, motion-based infrared systems, which are only good for triggered events. Motion-based infrared detectors identify objects within proximity, but only if they are moving. Single-port motion-based infrared systems are ambiguous about stationary objects even if they are within the proximity field. The Si115x can reliably detect an object entering or exiting a specified proximity field, even if the object is not moving or is moving very slowly. However, beyond about 30–50 cm, even with good optical isolation, single-port signal processing may be required due to static reflections from nearby objects, such as tables, walls, etc. If motion detection is acceptable, the Si115x can achieve ranges of up to 50 cm, through a single product window.

For small objects, the drop in reflectance is as much as the fourth power of the distance. This means that there is less range ambiguity than with passive motion-based devices. For example, a sixteen fold change in an object's reflectance means only a fifty-percent drop in detection range.

The Si115x can drive up to three separate infrared LEDs. When the three infrared LEDs are placed in an L-shaped configuration, it is possible to triangulate an object within the three-dimensional proximity field. Thus, a touchless user interface can be implemented with the aid of host software.

The Si115x can initiate proximity sense measurements when explicitly commanded by the host or periodically through an autonomous process. Proximity sensing is enabled by setting any of the LED drivers using the LED1_EN, LED2_EN, LED3_EN fields in a channel configuration.

Whenever it is time to make a proximity measurement, the Si115x makes up to six measurements, depending on what is enabled in the CHAN_LIST parameter. Other ADC parameters for these measurements can also be modified to allow proper operation under different ambient light conditions.

The LED choice is programmable for each of these six measurements. Each measurement can select which combination of 3 LEDs are turned on and which of two LED current setting banks are used to set the LED currents. Optionally, each proximity measurement can be compared against a host-programmable threshold. With threshold settings for each proximity channel, it is also possible for the Si115x to notify the host whenever the sample is larger/smaller than the threshold. In addition, a threshold window can be built by the host to trigger the interrupt whenever the sampler enters/exits the window. This reduces the number of interrupts to the host, aiding in efficient software algorithms.

The Si115x can also generate an interrupt after a complete set of proximity measurements, ignoring any threshold settings.

To support different power usage cases dynamically, the LED current of each output is independently programmable. The current can be programmed anywhere from 5.5 to 354 mA. (See Table 8.8 Typical LED Current vs. LED Code on page 53.) Therefore, the host can optimize for proximity detection performance or for power saving dynamically. This feature can be useful since it allows the host to reduce the LED current once an object has entered a proximity sphere, and the object can still be tracked at a lower current setting. Finally, the flexible current settings make it possible to control the infrared LED currents with a controlled current sink, resulting in higher precision. The ADC properties are programmable. For indoor operation, the ADC should be configured for low signal range for best reflectance sensitivity. When under high ambient conditions, the ADC should be configured for high signal level range operation.

When operating in the lower signal range, it is possible to saturate the ADC when the ambient light level is high. Any overflow condition is reported with a value of 0xFFFF for 16-bit mode and 0x7FFFFF for 24-bit mode. The host can then adjust the ADC sensitivity to avoid an overflow condition. If the light levels return to a range within the capabilities of the ADC, the corresponding data registers begin to operate normally.

The Si115x can be configured with three different sizes of proximity photodiode to enable the highest sensitivity without saturation.

Proximity detection ranges beyond 50 cm can be achieved with lensing and by selecting a longer integration time. The detection range may be increased further, even with high ambient light, by averaging multiple measurements.

The Si115x-AB09 version of the Si115x is designed with an on die 940 nm bandpass filter. It is designed to reject sunlight and to pass as much of the LED excitation energy as possible. 940 nm is selected as the operating wavelength since it corresponds to a dip in the energy of the solar spectrum.

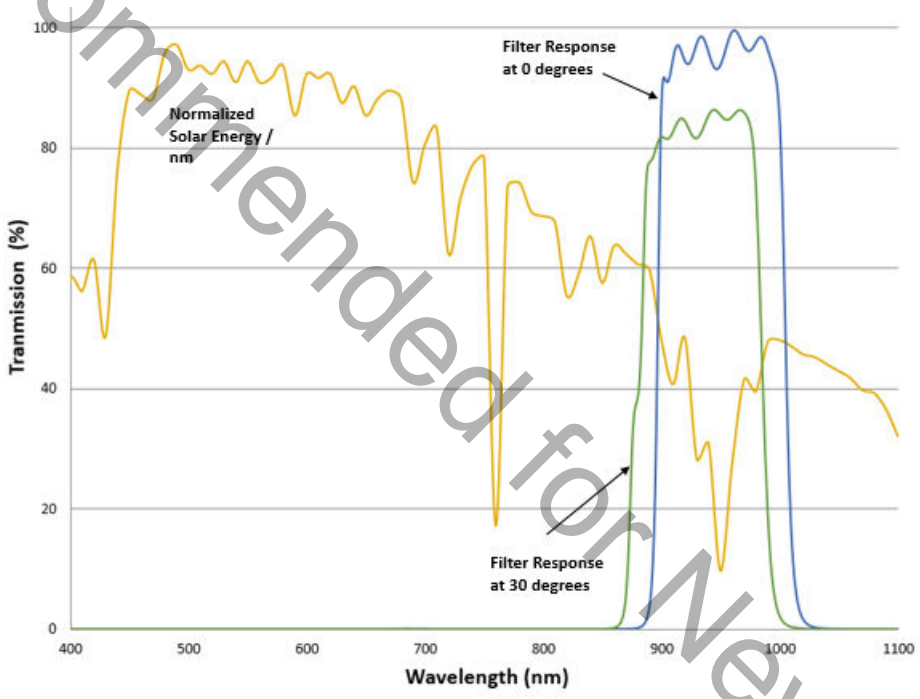


Figure 3.4. Typical Si115x-AB09 Filter Response Normalized to Peak Response Compared to the Sunlight Energy Spectrum

3.3 Power Consumption

While the Si115x is running, it cycles through internal power states of Active, Suspend, and Sleep. To calculate the average current consumption of the sensor, the current consumption of each of these states is multiplied by the normalized time in each sate.

The power consumption of the part depends on the measurement rate, the measurement mode, and the configuration for the measurements enabled. During measurements, the sensor cycles through internal power modes of Active, Suspend and Sleep. To calculate the average sensor current consumption, the instantaneous current of these power modes is normalized by the amount of time spent in each state.

The sleep state is the lowest current state when the sensor is idling between measurements. The sleep time is the configured measurement period minus the suspend time and active time.

The suspend state corresponds to when the ADC is performing the actual measurement. The suspend time consists of the ADC setup time and the ADC measurement time. The ADC setup time is defined in the Electrical Specification. The ADC measurement time is controlled by the DECIM_RATE, HW_GAIN, and SW_GAIN settings.

The active state corresponds to the initialization time and post processing time of the sensor. This time is listed in the in the Electrical Specifications as t_process.

The instantaneous current consumption of a measurement is shown in the figure below. The sensor is initially in the sleep state. The sensor wakes up for a measurement and initializes the measurements while in the active state. Two internal measurements are performed for the LED on and ambient light measurements during the suspend state. Finally, the results are post processed and outputted. Afterwards, the sensor returns to the sleep state.

AN950 provides exact details on the current consumption calculation.

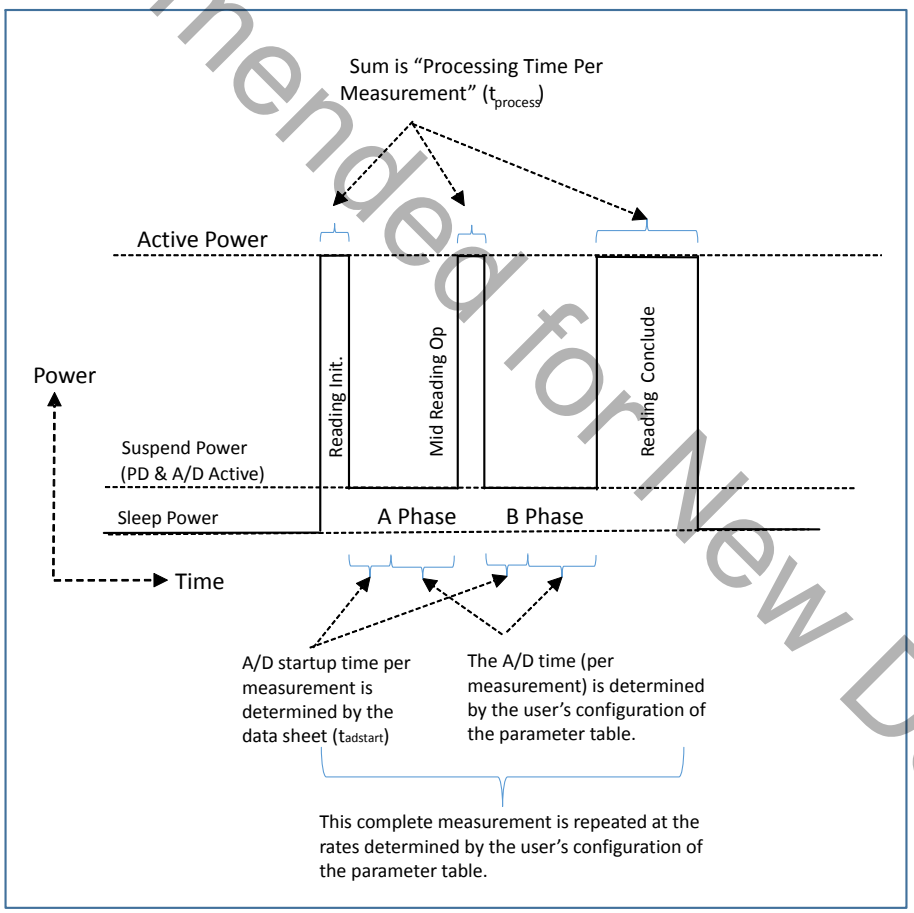


Figure 3.5. Power Consumption States During a Reading

Every A/D conversion has three periods:

155 µs at 4.5 mA	(setup time by internal controller)
48.8 µs at 525 µA	(setup time by A/D)
48.8 µs * ($2^{HW\_GAIN[3:0]}$) at 525 µA	(Actual A/D time that will vary with integration time)

3.4 Host Interface

The host interface to the Si115x consists of three pins:

- SCL
- SDA
- INT

SCL and SDA are standard open-drain pins as required for I²C operation.The Si115x asserts the INT pin to interrupt the host processor. The INT pin is an open-drain output. A pull-up resistor is needed for proper operation. As an open-drain output, it can be shared with other open-drain interrupt sources in the system.

For proper operation, the Si115x is expected to fully complete its Initialization Mode prior to any activity on the I²C.

The default I2C address of the Si115x can be changed by pulling the LED2 pin to ground. This changes the I2C address to 0x52 (the default value is 0x53).

The INT, SCL, and SDA pins are designed so that it is possible for the Si115x to be powered off without interfering with the normal operation of other I²C devices on the bus.

Conceptually, the I²C interface allows access to the Si115x internal registers.

An I²C write access always begins with a start (or restart) condition. The first byte after the start condition is the I2C address and a read-write bit. The second byte specifies the starting address of the Si115x internal register. Subsequent bytes are written to the Si115x internal register sequentially until a stop condition is encountered. An I²C write access with only two bytes is typically used to set up the Si115x internal address in preparation for an I²C read.

The I²C read access, like the I²C write access, begins with a start or restart condition. In an I²C read, the I²C master then continues to clock SCK to allow the Si115x to drive the I²C with the internal register contents.The Si115x also supports burst reads and burst writes. The burst read is useful in collecting contiguous, sequential registers. The Si115x register map was designed to optimize for burst reads for interrupt handlers, and the burst writes are designed to facilitate rapid programming of commonly used fields, such as thresholds registers.

The internal register address is a six-bit (bit 5 to bit 0) plus an Auto increment Disable (on bit 6). The Auto increment Disable is turned off by default. Disabling the auto incrementing feature allows the host to poll any single internal register repeatedly without having to keep updating the Si115x internal address every time the register is read.

It is recommended that the host should read performance measurements (in the I²C Register Map) when the Si115x asserts INT. Although the host can read any of the Si115x's I²C registers at any time, care must be taken when reading 2-byte measurements outside the context of an interrupt handler. The host could be reading part of the 2-byte measurement when the internal sequencer is updating that same measurement coincidentally. When this happens, the host could be reading a hybrid 2-byte quantity whose high byte and low byte are parts of different samples. If the host must read these 2-byte registers outside the context of an interrupt handler, the host should "double-check" a measurement if the measurement deviates significantly from a previous reading.

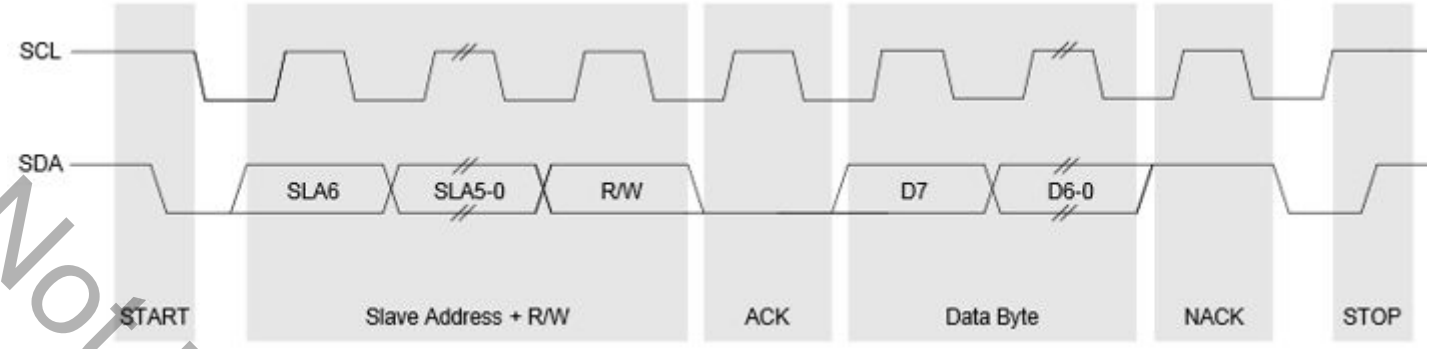


Figure 3.6. I²C Bit Timing Diagram

S	SLAVE ID	0	A	REG ADDRESS	A	DATA	A	P

Figure 3.7. Host Interface Single Write

S	SLAVE ID	1	Sr	A	DATA	N	P

Figure 3.8. Host Interface Single Read

S	SLAVE ID	0	A	REG ADDRESS	A	DATA	A	DATA	A	DATA	A	P

Figure 3.9. Host Interface Burst Write

S	SLAVE ID	0	A	REG ADDRESS	A	Sr	SLAVE ID	1	A	DATA	A	DATA	A	DATA	N	P

Figure 3.10. Host Interface Burst Read

7	6	5:0
0	AI	6 bit address 0x00 to 0x3F

Figure 3.11. Si115x REG ADDRESS Format

The following notes apply for the figures above:

1. Gray boxes are driven by the host to the Si115x.
2. White boxes are driven by the Si115x.
3. A = ACK or “acknowledge”.
4. N = NACK or “no acknowledge”.
5. S = START condition.
6. Sr = repeat START condition.
7. P = STOP condition.
8. AI = Disable Auto Increment when set.

4. Operational Modes

The Si115x can be in one of many operational modes at any time. It is important to consider the operation mode, since the mode has an impact on the overall power consumption of the Si115x. The various modes are:

- Off Mode
- Initialization Mode
- Standby Mode
- Forced Conversion Mode
- Autonomous Mode

4.1 Off Mode

The Si115x is in the Off Mode when V_{DD} is either not connected to a power supply or if the V_{DD} voltage is below the stated VDD_OFF voltage described in the electrical specifications. As long as the parameters stated in Table 8.7 Absolute Maximum Ratings on page 52 are not violated, no current will flow through the Si115x. In the Off Mode, the Si115x SCL and SDA pins do not interfere with other I^2C devices on the bus. Ensure that none of the pins have a voltage larger than the voltage on the VDD pin. If V_{DD} is grounded, for example, then current flows from system power to system ground through the SCL, SDA, and INT pull-up resistors and the ESD protection devices. Allowing V_{DD} to be less than VDD_OFF is intended to serve as a hardware method of resetting the Si115x without a dedicated reset pin.

The Si115x can also re-enter the Off Mode upon receipt of a software reset sequence. Upon entering Off Mode, the Si115x proceeds directly from the Off Mode to the Initialization Mode.

4.2 Initialization Mode

When power is applied to V_{DD} and is greater than the minimum V_{DD} Supply Voltage stated in the electrical specification table, the Si115x enters its Initialization Mode. In the Initialization Mode, the Si115x performs its initial startup sequence. Since the I^2C may not yet be active, it is recommended that no I^2C activity occur during this brief Initialization Mode period. The “Start-up time” specification in the electrical specification table is the minimum recommended time the host needs to wait before sending any I^2C accesses following a power-up sequence. After Initialization Mode has completed, the Si115x enters Standby Mode. During the Initialization mode, the I^2C address selection is made according to whether LED2 is pulled up or down.

4.3 Standby Mode

The Si115x spends most of its time in Standby Mode. After the Si115x completes the Initialization Mode sequence, it enters Standby Mode. While in Standby Mode, the Si115x does not perform any Ambient Light measurements or Proximity Detection functions. However, the I^2C interface is active and ready to accept reads and writes to the Si115x registers. The internal Digital Sequence Controller is in its sleep state and does not draw much power. In addition, the INT output retains its state until it is cleared by the host.

I^2C accesses do not necessarily cause the Si115x to exit the Standby Mode. For example, reading Si115x registers is accomplished without needing the Digital Sequence Controller to wake from its sleep state.

4.4 Forced Conversion Mode

The Si115x can operate in Forced Conversion Mode under the specific command of the host processor. The Forced Conversion Mode is entered when the FORCE command is sent. After the command is received, the Si115x performs a single measurement of all channels which are enabled in CHAN_LIST and have their COUNTER_INDEX set to 0. This is a single shot measurement whereas Autonomous Operation mode periodically triggers measurements.

Upon completion of the conversion, the Si115x can generate an interrupt to the host if the corresponding interrupt is enabled. It is possible to initiate both a proximity and ALS measurement.

4.5 Autonomous Operation Mode

The Si115x can be placed in the Autonomous Operation Mode where measurements are performed automatically without requiring an explicit host command for every measurement. The START command is used to place the Si115x in the Autonomous Operation Mode.

The measurement period is defined by the MEASRATE parameter. On each trigger, the sensor performs all channels that are enabled in CHAN_LIST, have a non-zero COUNTER_INDEX and have a non-zero MEASCOUNT.

The Si115x updates the I^2C output registers for proximity and ALS automatically. The host can also choose to be notified when these new measurements are available by enabling interrupts. The conversion frequency for autonomous operation is set up by the host prior to the START command.

The Si115x can also interrupt the host when the proximity or ALS measurement reach a pre-set threshold. For detailed threshold-based interrupt usage, see Section 6.4 Interrupt Operation. To assist in the handling of interrupts the registers are arranged so that the interrupt handler can perform an I^2C burst read operation to read the necessary registers, beginning with the interrupt status register, and cycle through the various output registers.

5. User to Sensor Communication

5.1 Basic I²C Operation

I²C operation is dependent on serial I²C reads and writes to an addressable bank of memory referred to as I²C space. The diagram below outlines the registers used, some functionality and the direction of data flow. The I²C address is initially fixed but can be programmed to a new value using the I2C_ADDR parameter register. This new value is temporary and reverts to the old value on hardware or software reset. Only 7-bit I²C addressing is supported; 10-bit I²C addressing is not supported. The Si115x responds to the I²C address of 0x53 or to an alternate address of 0x52.

5.2 Relationship Between I²C Registers and Parameter Table

Note that most of the Si115x configuration is accomplished through ‘Parameters’. The Si115x has an internal MCU with SRAM. The Parameters are stored in the Si115x Internal MCU SRAM. The I²C Registers can be viewed as mailbox registers that form an interface between the host and the internal MCU. The figure below shows the relationship between some of the key interface registers to the internal Parameters managed by the internal MCU.

- The I²C registers are directly accessible by the host.
- The parameter table is:
  - Accessible indirectly via the command register (and others).
  - Used during setup to set the operating modes of the Si115x.
  - Is read and written indirectly, one bye at a time, via the PARAM_SET command.

The data stored in the parameter table is volatile and is lost when the part is powered down or software reset command is sent to the part via the I²C part.

I2C Registers Directly Accessible by Host

Register Name	I2C Address	Direction WRT Host
PART_ID	0	IN
REV_ID	1	IN
MFR_ID	2	IN
INFO0	3	IN
INFO1	4	IN
HOSTIN3	7	IN/OUT
HOSTIN2	8	IN/OUT
HOSTIN1	9	IN/OUT
HOSTIN0	0A	IN/OUT
COMMAND	0B	IN/OUT
IRQ_ENABLE	0F	IN/OUT
RESPONSE1	10	IN
RESPONSE0	11	IN
IRQ_STATUS	12	IN
HOSTOUT0	13	IN
HOSTOUT1	14	IN
HOSTOUT2	15	IN
HOSTOUT3	16	IN
HOSTOUT4	17	IN
HOSTOUT5	18	IN
HOSTOUT6	19	IN
HOSTOUT7	1A	IN
HOSTOUT8	1B	IN
HOSTOUT9	1C	IN
HOSTOUT10	1D	IN
HOSTOUT11	1E	IN
HOSTOUT12	1F	IN
HOSTOUT13	20	IN
HOSTOUT14	21	IN
HOSTOUT15	22	IN
HOSTOUT16	23	IN
HOSTOUT17	24	IN
HOSTOUT18	25	IN
HOSTOUT19	26	IN
HOSTOUT20	27	IN
HOSTOUT21	28	IN
HOSTOUT22	29	IN
HOSTOUT23	2A	IN
HOSTOUT24	2B	IN
HOSTOUT25	2C	IN

Fields used to write to Parameter Table

Sensor Parameter Table. Indirectly Accessible by Host

Parameter Address	NAME
0x00	I2C_ADDR
0x01	CHAN_LIST
0x02	ADCCONFIG0
0x03	ADCSENS0
0x04	ADCPOST0
0x05	MEASCONFIG0
0x06	ADCCONFIG1
0x07	ADCSENS1
0x08	ADCPOST1
0x09	MEASCONFIG1
0x0A	ADCCONFIG2
0x0B	ADCSENS2
0x0C	ADCPOST2
0x0D	MEASCONFIG2
0x0E	ADCCONFIG3
0x0F	ADCSENS3
0x10	ADCPOST3
0x11	MEASCONFIG3
0x12	ADCCONFIG4
0x13	ADCSENS4
0x14	ADCPOST4
0x15	MEASCONFIG4
0x16	ADCCONFIG5
0x17	ADCSENS5
0x18	ADCPOST5
0x19	MEASCONFIG5
0x1A	MEASRATE_H
0x1B	MEASRATE_L
0x1C	MEASCOUNT0
0x1D	MEASCOUNT1
0x1E	MEASCOUNT2
0x1F	LED1_A
0x20	LED1_B
0x21	LED3_A
0x22	LED3_B
0x23	LED2_A
0x24	LED2_B
0x25	THRESHOLD0_H
0x26	THRESHOLD0_L
0x27	THRESHOLD1_H
0x28	THRESHOLD1_L
0x29	UPPER_THRESHOLD_H
0x2A	UPPER_THRESHOLD_L
0x2B	BURST
0x2C	LOWER_THRESHOLD_H
0x2D	LOWER_THRESHOLD_L

Figure 5.1. Accessing Parameters through I²C Registers

5.3 I²C Command Register Operation

Writing the codes shown below in the command summary table signals the sensor to undertake one of several complex operations.

These operations take time and all commands should be followed by a read of the RESPONSE0 register to confirm the operation is complete by examining the counter and to check for an error in the error bit. The error bit is set in the RESPONSE0 register's command counter if there is an error in the previous command (e.g., attempt to write to an illegal address beyond the parameter table, or a channel and /or burst configuration that exceeds the size of the output field (26 bytes)). If there is no such error, then the counter portion of the command counter will be incremented.

The RESPONSE0 register should be read after every command to determine completion and to check for an error. If an error is found, which should not happen except for a host software bug, the host should clear the error with a RESET_SW command or a RESET_CMD_CTR command.

One operating option is to do a RESET_CMD_CTR command before every command.

Two commands takes an input argument in either an I2C register or parameter table register. The input register should be loaded before sending the command.

- PARAM_SET command uses the value stored in the HOSTIN0 register as the data to write to the parameter address.
- SET_I2C_NEW_ADDR uses the value stored in the I2C_ADDR parameter table register as the new 7-bit I2C address. The 8th bit is ignored. The sensor will switch to the new address when the SET_I2C_NEW_ADDR is received. The address change will persist until a power reset or a software reset occurrs.

Two of the commands result in another I²C register containing return arguments (aside from incrementing RESPONSE0).

- PARAM_SET copies the data written to the parameter table to the I2C RESPONSE1 register.
- PARAM_QUERY writes the data read from the parameter table to I2C RESPONSE1 register.

Table 5.1. Command Summary

Command Register Commands	Code	Input to Sensor	Output of Sensor
RESET_CMD_CTR Resets RESPONSE0 CMD_CTR field to 0.	0x00	----------	----------
RESET_SW Forces a Reset, Resets RESPONSE0 CMD_CTR field to 0x0F.	0x01	----------	----------
SET_I2C_NEW_ADDR	0x02	I2C_ADDR (parameter table)	----------
FORCE Initiates a set of measurements specified in CHAN_LIST parameter. A FORCE command will only execute the measurements which do not have a meas counter index configured in MEASCONFIGx.	0x11	----------	----------
PAUSE Pauses autonomous measurements specified in CHAN_LIST.	0x12	----------	----------
START Starts autonomous measurements specified in CHAN_LIST. A START autonomous command will only start the measurements which has a counter index selected in MEASCONFIGx.	0x13	----------	----------
PARAM_QUERY Reads the parameter register located at PARAM_ADDRESS and store results in RESPONSE1.	0x40 | PARAM_ADDRESS	----------	RESPONSE1 = result
PARAM_SET Writes the value in INPUT0 to the parameter register located at PARAM_ADDRESS	0x80 | PARAM_ADDRESS	HOSTIN0	RESPONSE1 = HOSTIN0

Notes:

1. The successful completion of all commands except RESET_CMD_CTR and RESET_SW causes an increment of the CMD_CTR field of the RESPONSE0 register (bits [3:0].
2. 0x40 | PARAM_ADDRESS and 0x80 | PARAM_ADDRESS represent the bit-wise OR of the two values.

5.3.1 Accessing the Parameter Table (PARAM_QUERY & PARAM_SET Commands)

The parameter table is written to by writing the HOSTIN0 I2C register and the PARAM_SET command byte to the Command I²C register. The format of the PARAM_SET word is such that the 6 LSBits contain the location of the target byte in the parameter table.

Example: To transfer 0xA5 to parameter table location 0b010101.

Read RESPONSE0 (address 0x11)	and store the CMD_CTR field.
Write 0xA5 to HOSTIN0 (address 0x0A).	
Write 0b10010101 to COMMAND (address 0x0B).	
Read RESPONSE0 (address 0x11)	and check if the CMD_CTR field incremented.
If there is no increment or error, repeat the “read the RESPONSE0” step until the CMD_CTR has incremented. If there is an error send a RESET_SW or a RESET_CMD_CTR command.	
The two write commands (to HOSTIN0 and COMMAND) can be in the same I²C transaction by using the auto-increment functionality because the two registers are adjacent to each other.	

Example: To read data from the parameter table location 0b010101.

Read the RESPONSE0 (address 0x11)	and store the CMD_CTR field.
Write 0b01010101 to the COMMAND (address 0x0B).	
Read RESPONSE0 (address 0x11)	and check if the CMD_CTR field incremented.
If there is no increment or error, repeat the “read RESPONSE0” step until the CMD_CTR has incremented.	
Read RESPONSE1 (address 0x10)	this gives the read result. If there is an error send RESET_SW or a RESET_CMD_CTR command.
The last two read commands (from RESPONSE0 and RESPONSE1) should not be in the same I²C transaction.	

5.3.2 Sensor Operation Initiation Commands

The FORCE, PAUSE, and START commands make use of the information in CHAN_LIST. Configure CHAN_LIST prior to using any of these commands.

5.3.3 RESET_CMD_CTR Command

Resets RESPONSE0 CMD_CTR field to zero. This is also used to clear the CMD_ERR flag.

5.3.4 RESET_SW Command

Resets the sensor and puts it into the same state as when powering up. The parameter table and all I²C registers are reset to their default values. After sending the reset, the host should delay for the Start-Up Time as listed in the Electrical Specifications before communicating with the device.

5.4 I²C Register Summary

Table 5.2. I2C Registers

Register Name	I2C Address	Access	Function	Reset
PART_ID	0x00	R	Returns the PART_ID	PART_ID
HW_ID	0x01	R	Contains hardware ID	HW_ID
REV_ID	0x02	R	Contains revision information	REV_ID
HOSTIN0	0x0A	RW	Value to write to the parameter table when using the PARAM_SET command	0x00
COMMAND	0x0B	RW	Initiated action in Sensor when specific codes written here.	0x00
IRQENABLE	0x0F	RW	Enables interrupts for channels	0x00
RESPONSE1	0x10	R	Contains the readback value from a PARAM_QUERY or a PARAM_SET command.	0x00
RESPONSE0	0x11	R	Contains the sensor power state and command counter	0x2F
IRQ_STATUS	0x12	CR	Interrupt flag status for each channel	0x00
HOSTOUT0 to HOSTOUT25	0x13 to 0x2C	R	Sensor ADC output data	0x00

5.4.1 PART_ID

I2C Address = 0x00;

Contains the PART ID.

Part Number	PART_ID
Si1151	0x51
Si1152	0x52
Si1153	0x53

5.4.2 HW_ID

I2C Address = 0x01;

Contains the Hardware information.

BITS4:0 = Filter, LED & Module code

BITS7:5 = Hardware revision

Part Number	Features	BITS4:0 code
Si1151-AB00	1 LED driver	0x03
Si1151-AB09	940 nm filter with 1 LED driver	0x04
Si1152-AB00	2 LED drivers	0x05
Si1152-AB09	940 nm filter with 2 LED drivers	0x06
Si1153-AB00	3 LED drivers	0x00
Si1153-AB09	940 nm filter	0x01
Si1153-ABX9	Module with 940 nm filter & LED	0x02

5.4.3 REV_ID

I2C Address = 0x02;

Contains the product revision, in a 0xMN format where “M” is the major rev and “N” the minor rev.

Part Number	Major Revision	Minor Revision	REV_ID
Si115x-AAxx	1	0	0x10
Si115x-ABxx	1	1	0x11

5.4.4 HOSTIN0

I2C Address = 0x0A;

Bit	7	6	5	4	3	2	1	0
Name	HOSTIN0							
Type	R/W							
Reset	0							

Bit	Name	Function
7:0	HOSTIN0	Value to write to the parameter table when using the PARAM_SET command. Set this register before issuing the PARAM_SET.

5.4.5 COMMAND

I2C Address = 0x0B;

Commands the sensor to perform an action, such as configure the parameter table, or start a measurement. See 5.3 I²C Command Register Operation for the command list.

Bit	7	6	5	4	3	2	1	0
Name	COMMAND							
Type	R/W							
Reset	0							

Bit	Name	Function
7:0	COMMAND	Command Register. Writing a command code to this register causes the command action.

5.4.6 IRQENABLE

I2C Address = 0x0F;

Bit	7	6	5	4	3	2	1	0
Name	RSVRD		IE5	IE4	IE3	IE2	IE1	IE0
Type	RW	RW	RW	RW	RW	RW	RW	RW
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:6	RSRVD	Reserved.
5	IE5	Enables the interrupt for when the channel 5 result is ready.
4	IE4	Enables the interrupt for when the channel 4 result is ready.
3	IE3	Enables the interrupt for when the channel 3 result is ready.
2	IE2	Enables the interrupt for when the channel 2 result is ready.
1	IE1	Enables the interrupt for when the channel 1 result is ready.
0	IE0	Enables the interrupt for when the channel 0 result is ready.

5.4.7 RESPONSE1

I2C Address = 0x10;

Bit	7	6	5	4	3	2	1	0
Name	RESPONSE1[7:0]							
Type	R							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	RESPONSE1[7:0]	The sensor mirrors the data byte written to the parameter table here for the user to verify the write was successful. A parameter read command results in the byte read being available here for the host.

5.4.8 RESPONSE0

I2C Address = 0x11;

Bit	7	6	5	4	3	2	1	0
Name	RUNNING	SUSPEND	SLEEP	CMD_ERR	CMD_CTR[3:0]			
Type	R	R	R	R	R	R	R	R
Reset	N/A	N/A	N/A	0	1	1	1	1

Bit	Name	Function		
7	RUNNING	Set when the sensor is initializing or post-processing a measurement.		
6	SUSPEND	Set when the sensor is performing an ADC measurement.		
5	SLEEP	Set when the sensor is sleeping.		
4	CMD_ERR	This flag is set when the sensor encounters an error, such as trying to write to an invalid parameter table address. The error code is stored in the CMD_CTR field. The flag is cleared by a RESET_SW or a RESET_CMD_CTR command. It is cleared by a hardware reset (power up) or a RESET_SW command or a RESET_CMD_CTR.		
3:0	CMD_CTR	IF CMD_ERR = 0	This counter increments on every successful execution of a command send to the COMMAND register. It is used by the host MCU to verify command completion. The counter is reset to 0 by the RESET_CMD_CTR command. It is set to 0xF on power up or a RESET_SW command.	
		IF CMD_ERR = 1	Code	Meaning
			0x0	Invalid command.
			0x1	Parameter access to an invalid location.
			0x2	Saturation of the ADC or overflow of accumulation.
			0x3	Output buffer overflow—this can happen when Burst mode is enabled and configured for greater than 26 bytes of output.

The RESPONSE0 register will show “RUNNING” immediately after reset and then “SLEEP” after initialization is complete.

5.4.9 IRQ_STATUS

I2C Address = 0x12;

Bit	7	6	5	4	3	2	1	0
Name	RSVD		IRQ5	IRQ4	IRQ3	IRQ2	IRQ1	IRQ0
Type	R		CR	CR	CR	CR	CR	CR
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:6	RSVD	Reserved.
5	IRQ5	Indicates there is a channel 5 result available. Cleared on register read.
4	IRQ4	Indicates there is a channel 4 result available. Cleared on register read.
3	IRQ3	Indicates there is a channel 3 result available. Cleared on register read.
2	IRQ2	Indicates there is a channel 2 result available. Cleared on register read.
1	IRQ1	Indicates there is a channel 1 result available. Cleared on register read.
0	IRQ0	Indicates there is a channel 0 result available. Cleared on register read.

5.4.10 HOSTOUTx

This section covers the twenty-six I2C Host Output Registers. These registers are the output of the sensor and input to the host.

Name	I2C Address
HOSTOUT0 to HOSTOUT25	0x13 to 0x2C

Bit	7	6	5	4	3	2	1	0
Name	HOSTOUTx							
Type	R							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	HOSTOUTx	These registers are where the ADC outputs are placed for the host MCU to read. The results of the CHAN_LIST enabled “active channel” readings are located sequentially in this table. Each channel may use 2 or 3 bytes depending on the setup. The validity of the various channel outputs located in this table is determined by other factors. Data is valid when an IRQ status says that it is and remains valid until another reading happens. This is why it is imperative to service the interrupt before the next measurement cycle begins (Autonomous Mode), unless forced mode is used.

6. Measurement: Principle of Operation

Operation is based on the concept of channels. Channels are essentially tasks that have been setup by the user.

To setup these channels, the channel specific areas of the parameter table need to be loaded with the correct information as well as the global area of this table.

The channels' specific areas are described below, including:

- ADC gain
- The photodiode selected
- The counter selected to time
- How often to make a measurement
- The format of the output (16 vs. 24 bits)
- And other areas

The global area includes global information that affects all tasks, such as:

- The list of channels that are enabled.
- The setup of the two counters that can be used by the channels.
- The two light thresholds that can be selected from by the channels.
- The setup of the threshold window that can be used by the channels.

The list of channels, CHAN_LIST, in the global area determines what operations are run and how the results are packed in the output fields.

The packing of the result data in the output fields is totally determined by the enabled channels as they are packed sequentially from the lowest enabled channel to the highest in the output field (I2C space- HOSTOUT0 to HOSTOUT25). The amount of space used by each channel is determined by the 16 vs. 24 bit selection made in the channel setup.

Although space in the output buffer is reserved by the CHAN_LIST, the data validity is determined by the IRQ_STATUS register in Autonomous Mode and by elapsed time in Forced Mode. In Burst Mode, a subset of Autonomous Mode, all the expected data is valid.

6.1 Output Field Utilization

In all modes, the CHAN_LIST configuration determines how the data is stacked in the 26 byte output field. It is done on a first-come first-served basis, with the enabled lower channels taking up the lower addresses. When burst is enabled, the channel arrangement is just repeated to higher and higher addresses. See the example below.

Global Section of Parameter Table			Channel Specific Section of Parameter Table
CHAN_LIST			Output mode
0	Bit 0	Chan 0	16
1	Bit 1	Chan 1	24
0	Bit 2	Chan 2	16
1	Bit 3	Chan 3	16
1	Bit 4	Chan 4	24
1	Bit 5	Chan 5	16
X	Bit 6	X	X
X	Bit 7	X	X

I2C Register	I2C Addresss	Content
HOSTOUT0	13	Channel 1 Result: Most Significant Byte
HOSTOUT1	14	Channel 1 Result: Middle Significant Byte
HOSTOUT2	15	Channel 1 Result: Least Significant Byte
HOSTOUT3	16	Channel 3 Result: Most Significant Byte
HOSTOUT4	17	Channel 3 Result: Least Significant Byte
HOSTOUT5	13	Channel 4 Result: Most Significant Byte
HOSTOUT6	14	Channel 4 Result: Middle Significant Byte
HOSTOUT7	1A	Channel 4 Result: Least Significant Byte
HOSTOUT8	1B	Channel 5 Result: Most Significant Byte
HOSTOUT9	1C	Channel 5 Result: Least Significant Byte
HOSTOUT10	1D	Unused
HOSTOUT11	1E	Unused
HOSTOUT12	1F	Unused
HOSTOUT13	20	Unused
HOSTOUT14	21	Unused
HOSTOUT15	22	Unused
HOSTOUT16	23	Unused
HOSTOUT17	24	Unused
HOSTOUT18	25	Unused
HOSTOUT19	26	Unused
HOSTOUT20	27	Unused
HOSTOUT21	28	Unused
HOSTOUT22	29	Unused
HOSTOUT23	2A	Unused
HOSTOUT24	2B	Unused
HOSTOUT25	2C	Unused

Packing of of these four channels in the output table is determined by the four enabled channels in the CHANNEL list above. This is independent of the IRQ_ENABLE and IRQ_STATUS

Figure 6.1. Output Table Data Packing

6.2 Autonomous and Forced Modes

In Autonomous Mode, the user uses the timer fields in both the global and channels specific areas in order to set up the timing for repeated measurements. The user then sends the command to start these autonomous measurements repeatedly. When each channel's timer is tripped, the measurement for that channel is started. When the channel measurement completes, it is signaled by the IRQ_STATUS bits and by an interrupt (if the interrupt is enabled). After that signal, the sensor restarts the channel timer and waits for it to trip and signal the next measurement. The host must read the data before the next reading is generated, or risk losing the reading or getting garbage data to sample smearing (reading data in the midst of it changing).

In Forced Mode, all measurements enabled in the CHAN_LIST start as a result of a FORCE command and are only done once. If there are multiple channels enabled, then the measurements are done back-to-back starting with the lower number channel. The completion signaling is the same as for autonomous, the IRQ_STATUS and interrupt if it is enabled. The logical difference is that all the enabled channels are always shown as simultaneously ready in the IRQ_STATUS, whereas in Autonomous Mode this is not true. FORCE command only works on measurements which do not have a measurement counter selected in MEASCONFIGx.

Global Section of Parameter Table			Channel Specific Section of Parameter Table
CHAN_LIST			Output mode
0	Bit 0	Chan 0	16
1	Bit 1	Chan 1	24
0	Bit 2	Chan 2	16
1	Bit 3	Chan 3	16
1	Bit 4	Chan 4	24
1	Bit 5	Chan 5	16
X	Bit 6	X	X
X	Bit 7	X	X

I2C SPACE		
IRQ_STATUS		
Value	Bit	Meaning
0	Bit 0	Chan 0
0	Bit 1	Chan 1
0	Bit 2	Chan 2
1	Bit 3	Chan 3
0	Bit 4	Chan 4
1	Bit 5	Chan 5
X	Bit 6	X
X	Bit 7	X

I2C Register	I2C Addresss	Content
HOSTOUT0	13	Channel 1 Result: Most Significant Byte
HOSTOUT1	14	Channel 1 Result: Middle Significant Byte
HOSTOUT2	15	Channel 1 Result: Least Significant Byte
HOSTOUT3	16	Channel 3 Result: Most Significant Byte
HOSTOUT4	17	Channel 3 Result: Least Significant Byte
HOSTOUT5	13	Channel 4 Result: Most Significant Byte
HOSTOUT6	14	Channel 4 Result: Middle Significant Byte
HOSTOUT7	1A	Channel 4 Result: Least Significant Byte
HOSTOUT8	1B	Channel 5 Result: Most Significant Byte
HOSTOUT9	1C	Channel 5 Result: Least Significant Byte
HOSTOUT10	1D	Unused
HOSTOUT11	1E	Unused
HOSTOUT12	1F	Unused
HOSTOUT13	20	Unused
HOSTOUT14	21	Unused
HOSTOUT15	22	Unused
HOSTOUT16	23	Unused
HOSTOUT17	24	Unused
HOSTOUT18	25	Unused
HOSTOUT19	26	Unused
HOSTOUT20	27	Unused
HOSTOUT21	28	Unused
HOSTOUT22	29	Unused
HOSTOUT23	2A	Unused
HOSTOUT24	2B	Unused
HOSTOUT25	2C	Unused

The IRQ_STATUS bits signal which of the possible fields are updated with new information. All other fields should be considered invalid and possibly containing wrong transitory information.

This is despite the reserved space in the output table for the readings that have not yest happened.

Figure 6.2. IRQ_STATUS Shows Which Output Fields Have Valid Data

6.3 Burst Mode

Burst Mode is a subset of Autonomous Mode where BURST_COUNT measurements are performed and then measurements are stopped.

The Burst Mode is enabled by the bit 7 BURST_EN in the BURST register. The burst register is in the global area of the parameter table. Bits 6:0 of the register define the number of readings to be made as the field BURST_COUNT.

All channels set up in the CHAN_LIST operate in this mode and they operate in unison governed by the MEASRATE register in the parameter table. The individual channel MEASCONFIGx.COUNTER_INDEX [1:0] value is ignored.

The burst is started by the START command and may be paused by the PAUSE command. All measurements enabled in the CHAN_LIST are done as a quick set then repeated after the delay determined by the MEASRATE register. The number of repeats are set by the BURST register.

The measurements called for by the enabled channels are done without an intervening delay, starting with the lower number channel and ending with the highest channel number.

The burst will proceed until it is complete or until the output buffer is full, after which an interrupt may be generated if enabled and the IRQ_STATUS bit(s) associated with all the channels in the CHAN_LIST will be set. The user has the time period until the next set of reads are finished to read back the data in the output field.

The output data will be stacked in the 26 bytes output data field and will be sequential. For example, if the CHAN_LIST enables channels X, Y, and Z, then the data will be found in the output buffer as multiple sets: X1, Y1, Z1, X2, Y2, Z2... The fields X, Y, and Z are packed efficiently and are not necessarily the same length since they can be a mix of 16 and 24 bit values.

I2C SPACE		
IRQ_STATUS When Done		
Value	Bit	Meaning
0	Bit 0	Chan 0
1	Bit 1	Chan 1
0	Bit 2	Chan 2
1	Bit 3	Chan 3
1	Bit 4	Chan 4
1	Bit 5	Chan 5
X	Bit 6	X
X	Bit 7	X

Global Section of Parameter Table			Channel Specific Section of Parameter Table
CHAN_LIST			Output mode
0	Bit 0	Chan 0	16
1	Bit 1	Chan 1	24
0	Bit 2	Chan 2	16
1	Bit 3	Chan 3	16
1	Bit 4	Chan 4	24
1	Bit 5	Chan 5	16
X	Bit 6	X	X
X	Bit 7	X	X

Since The CHAN_LIST shows 4 active channels we see two sets of readings stacked one after another.

	I2C Register	I2C Addresss	Content
Reading Set 1	HOSTOUT0	13	Channel 1 Result: Most Significant Byte
	HOSTOUT1	14	Channel 1 Result: Middle Significant Byte
	HOSTOUT2	15	Channel 1 Result: Least Significant Byte
	HOSTOUT3	16	Channel 3 Result: Most Significant Byte
	HOSTOUT4	17	Channel 3 Result: Least Significant Byte
	HOSTOUT5	13	Channel 4 Result: Most Significant Byte
	HOSTOUT6	14	Channel 4 Result: Middle Significant Byte
	HOSTOUT7	1A	Channel 4 Result: Least Significant Byte
	HOSTOUT8	1B	Channel 5 Result: Most Significant Byte
	HOSTOUT9	1C	Channel 5 Result: Least Significant Byte
Reading Set 1	HOSTOUT10	1D	Channel 1 Result: Most Significant Byte
	HOSTOUT11	1E	Channel 1 Result: Middle Significant Byte
	HOSTOUT12	1F	Channel 1 Result: Least Significant Byte
	HOSTOUT13	20	Channel 3 Result: Most Significant Byte
	HOSTOUT14	21	Channel 3 Result: Least Significant Byte
	HOSTOUT15	22	Channel 4 Result: Most Significant Byte
	HOSTOUT16	23	Channel 4 Result: Middle Significant Byte
	HOSTOUT17	24	Channel 4 Result: Least Significant Byte
	HOSTOUT18	25	Channel 5 Result: Most Significant Byte
	HOSTOUT19	26	Channel 5 Result: Least Significant Byte
	HOSTOUT20	27	Unused
	HOSTOUT21	28	Unused
	HOSTOUT22	29	Unused
	HOSTOUT23	2A	Unused
	HOSTOUT24	2B	Unused
	HOSTOUT25	2C	Unused

In burst mode the I2C HOSTOUT locations are updated simultaneously when the burst is done. Only then will the IRQ_STATUS field be updates and an int generated (if the correct IRQ_ENABLE bit(s) is set).

Figure 6.3. Burst Mode Example of Two Sets of Readings

6.4 Interrupt Operation

The INT output pin is asserted by the sensor when an enabled channel in the CHAN_LIST (which has the corresponding bit in the IRQENABLE register) has finished. In Burst Mode, the interrupt is delayed until the number of readings is reached or the buffer is full.

When the host reads the IRQ_STATUS register to learn which source generated the interrupt, the IRQ_STATUS register is cleared automatically.

The most efficient method of extracting measurements from the Si115x is an I^2C Burst Read beginning at the IRQ_STATUS register.

The Si115x supports three different interrupt modes:

- Mode 1: Interrupt on every sample.
- Mode 2: Interrupt whenever the sample is larger/smaller than a set threshold.
- Mode 3. Interrupt whenever the sample enters/exits the set threshold window.

Here are the instructions on how the host should configure the sensor to operate with different interrupt modes for each channel.

- Mode 1: Set THRESH_EN field in ADCPOSTx registers to 0.
- Mode 2: Set THRESH_EN field in ADCPOSTx registers to 1 or 2. Set THRESHOLD0 or THRESHOLD1 registers to the value of the interrupt level. Use THRESH_POL bit in ADCPOSTx registers to control the polarity.
- Mode 3: Set THRESH_EN field in ADCPOSTx registers to 3. Set UPPER_THRESHOLD and LOWER_THRESHOLD registers to the value of the threshold window's upper and lower bound. Use THRESH_POL bit in ADCPOSTx registers to control the polarity.

Note: The threshold based interrupt is only available in 16-bit output mode. Do NOT set 24-bit mode when using the threshold

6.5 Timing of Channel Measurements

The timing of measurements has two aspects:

1. The length of time to take a measurement.
2. How frequently the measurement is taken.

The amount of time to take the measurement is controlled by factors like HW_GAIN (which is really the integration time), SW_GAIN, and the decimation rate setting.

Note: Each measurement is composed of two measurement times.

In an ALS measurement, two measurements are always taken and added together. In a proximity measurement, two measurements are always taken, one without the LED light and one with the LED light. The difference is then created by subtraction.

7. Parameter Table

Table 7.1. Parameter Table

Address	Name	Description	Type
0x00	I2C_ADDR	I2C Address	Global: Affects all channels
0x01	CHAN_LIST	Channel List	
0x02	ADCCONFIG0	Channel 0 Setup	Channel: Affects only the corresponding channel
0x03	ADCSENS0		
0x04	ADCPOST0		
0x05	MEASCONFIG0		
0x06	ADCCONFIG1	Channel 1 Setup	
0x07	ADCSENS1		
0x08	ADCPOST1		
0x09	MEASCONFIG1		
0x0A	ADCCONFIG2	Channel 2 Setup	
0x0B	ADCSENS2		
0x0C	ADCPOST2		
0x0D	MEASCONFIG2		
0x0E	ADCCONFIG3	Channel 3 Setup	
0x0F	ADCSENS3		
0x10	ADCPOST3		
0x11	MEASCONFIG3		
0x12	ADCCONFIG4	Channel 4 Setup	
0x13	ADCSENS4		
0x14	ADCPOST4		
0x15	MEASCONFIG4		
0x16	ADCCONFIG5	Channel 5 Setup	
0x17	ADCSENS5		
0x18	ADCPOST5		
0x19	MEASCONFIG5		

Address	Name	Description	Type
0x1A	MEASRATE_H	MEASURE RATE	Global: Affects all channels
0x1B	MEASRATE_L		
0x1C	MEASCOUNT0	MEASCOUNT	
0x1D	MEASCOUNT1		
0x1E	MEASCOUNT2		
0x1F	LED1_A	LED CURRENT	
0x20	LED1_B		
0x21	LED3_A		
0x22	LED3_B		
0x23	LED2_A		
0x24	LED2_B		
0x25	THRESHOLD0_H	THRESHOLD SETUP	
0x26	THRESHOLD0_L		
0x27	THRESHOLD1_H		
0x28	THRESHOLD1_L		
0x29	UPPER_THRESHOLD_H	THRESHOLD WINDOW SETUP	
0x2A	UPPER_THRESHOLD_L		
0x2C	LOWER_THRESHOLD_H		
0x2D	LOWER_THRESHOLD_L		
0x2B	BURST	BURST	

7.1 Global Area of the Parameter Table

The Global Area represents resources that are shared among the six channels. See the next section for specific channel properties, and for channel-specific parameter setup.

Table 7.2. Global Area of the Parameter Table

Parameter	Parameter Address	Description
I2C_ADDR	0x00	I2C Address for SET_I2C_NEW_ADDR
CHAN_LIST	0x01	Channel Enable Register
MEASRATE_H	0x1A	Measurement Rate Register
MEASRATE_L	0x1B	Measurement Rate Register continued
MEASCOUNT0	0x1C	Measurement Counter 0 Register
MEASCOUNT1	0x1D	Measurement Counter 1 Register
MEASCOUNT2	0x1E	Measurement Counter 2 Register
LED1_A	0x1F	LED Current Registers
LED1_B	0x20	
LED3_A	0x21	
LED3_B	0x22	
LED2_A	0x23	
LED2_B	0x24	
THRESHOLD0_H	0x25	Threshold 0 Register
THRESHOLD0_L	0x26	
THRESHOLD1_H	0x27	Threshold 1 Register
THRESHOLD1_L	0x28	
UPPER_THRESHOLD_H	0x29	Window Upper Threshold Register
UPPER_THRESHOLD_L	0x2A	
BURST	0x2B	Burst Control Register
LOWER_THRESHOLD_H	0x2C	Window Lower Threshold Register
LOWER_THRESHOLD_L	0x2D	

7.1.1 I2C_ADDR

Parameter Address: 0x00								
Bit	7	6	5	4	3	2	1	0
Name	RSRVD	I2C_ADDR						
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7	RSRVD	To ensure compatibility with future devices, always write bits to 0.
6:0	I2C_ADDR	The 7-bit I2C address to use. The I2C address will update once a SET_I2C_NEW_ADDR is received. The temporary I2C address persists until the next reset or power up.

7.1.2 CHAN_LIST

Parameter Address: 0x01								
Bit	7	6	5	4	3	2	1	0
Name	RSRVD	RSRVD	CHAN5_EN	CHAN4_EN	CHAN3_EN	CHAN2_EN	CHAN1_EN	CHAN0_EN
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:6	RSRVD	To ensure compatibility with future devices, always write bits to 0.
5	CHAN5_EN	Enables channel 5 for measurements.
4	CHAN4_EN	Enables channel 4 for measurements.
3	CHAN3_EN	Enables channel 3 for measurements.
2	CHAN2_EN	Enables channel 2 for measurements.
1	CHAN1_EN	Enables channel 1 for measurements.
0	CHAN0_EN	Enables channel 0 for measurements.

7.1.3 MEASRATE_H

Parameter Address: 0x1A								
Bit	7	6	5	4	3	2	1	0
Name	RSRVD	RSRVD	RSRVD	RSRVD	MEASRATE[11:8]			
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:4	RSRVD	To ensure compatibility with future devices, always write bits to 0.
3:0	MEAS-RATE[11:8]	Sets the time period between measurement groups in autonomous and burst mode. This field is joined with MEASRATE_L to form the full 12-bit MEASRATE field. Each count of MEASRATE is equivalent to 800 µs.

7.1.4 MEASRATE_L

Parameter Address: 0x1B								
Bit	7	6	5	4	3	2	1	0
Name	MEASRATE[7:0]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	MEAS-RATE[7:0]	Sets the time period between measurement groups in autonomous and burst mode. This field is joined with MEASRATE_H to form the full 12-bit MEASRATE field. Each count of MEASRATE is equivalent to 800 µs.

7.1.5 MEASCOUNTx

Parameter	Address
MEASCOUNT0	0x1C
MEASCOUNT1	0x1D
MEASCOUNT2	0x1E

Bit	7	6	5	4	3	2	1	0
Name	MEASCOUNTx							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	MEASCOUNTx	Sets the counter rollover for the corresponding MEASCOUNT counter. A value of 0 disables all channels that are using that counter. The recommended value is to set MEASCOUNTx to 1 and use the MEASRATE field to set the measurement period. See 6.5 Timing of Channel Measurements for details.

7.1.6 LEDx

Parameter	Address
LED1_A	0x1F
LED1_B	0x20
LED3_A	0x21
LED3_B	0x22
LED2_A	0x23
LED2_B	0x24

Bit	7	6	5	4	3	2	1	0
Name	LED_CURRENT							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	LED_CURRENT	Sets the LED current for the corresponding LEDx pin and LED bank selection. See Table 8.8 Typical LED Current vs. LED Code on page 53 for the code to current mapping. The LED current is not monotonic in LED_CURRENT. Channels select the LED driver and LED bank in their 7.2.4 MEASCONFIGx parameter.

7.1.7 THRESHOLDx_H

Parameter	Address
THRESHOLD0_H	0x25
THRESHOLD1_H	0x27

Bit	7	6	5	4	3	2	1	0
Name	THRESHOLDx[15:8]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	THRESH-OLDx[15:8]	Used with THRESHOLDx_L to set the 16-bit threshold for a channel. THRESHOLDx_H sets the upper 8 bits. The threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.8 THRESHOLDx_L

Parameter	Address
THRESHOLD0_L	0x26
THRESHOLD1_L	0x28

Bit	7	6	5	4	3	2	1	0
Name	THRESHOLDx[7:0]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	THRESH-OLDx[7:0]	Used with THRESHOLDx_H to set the 16-bit threshold for a channel. THRESHOLD_L sets the bottom 8 bits. The threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.9 UPPER_THRESHOLD_H

Parameter Address: 0x29								
Bit	7	6	5	4	3	2	1	0
Name	UPPER_THRESHOLD[15:8]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	UPPER_THRESHOLD[15:8]	Used with UPPER_THRESHOLD_L to set the 16-bit threshold for window thresholding. UPPER_THRESHOLD_H sets the upper 8 bits. The window threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.10 UPPER_THRESHOLD_L

Parameter Address: 0x2A								
Bit	7	6	5	4	3	2	1	0
Name	UPPER_THRESHOLD[7:0]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	UPPER_THRESHOLD[7:0]	Used with UPPER_THRESHOLD_H to set the 16-bit threshold for window thresholding. UPPER_THRESHOLD_L sets the bottom 8 bits. The window threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.11 LOWER_THRESHOLD_H

Parameter Address: 0x2C								
Bit	7	6	5	4	3	2	1	0
Name	LOWER_THRESHOLD[15:8]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	LOWER_THRESHOLD[15:8]	Used with LOWER_THRESHOLD_L to set the 16-bit threshold for window thresholding. LOWER_THRESHOLD_H sets the bottom 8 bits. The window threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.12 LOWER_THRESHOLD_L

Parameter Address: 0x2D								
Bit	7	6	5	4	3	2	1	0
Name	LOWER_THRESHOLD[7:0]							
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:0	UPPER_THRESHOLD[7:0]	Used with LOWER_THRESHOLD_H to set the 16-bit threshold for window thresholding. LOWER_THRESHOLD_L sets the bottom 8 bits. The window threshold must be enabled in ADCPOSTx.THRESH_EN. Thresholds should only be used with channels in 16-bit mode.

7.1.13 BURST

Parameter Address: 0x2B								
Bit	7	6	5	4	3	2	1	0
Name	BURST_EN	BURST_COUNT						
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7	BURST_EN	Set to 1 to enable burst mode.
6:0	BURST_COUNT	Number of readings to make before stopping.

7.2 Channel Specific Setup Areas of the Parameter Table

Below is the summary of the four-byte channel-specific area in the parameter table. There are six copies in the table corresponding to up to six tasks/channels assigned to the sensor. They are located between addresses 0x02 and 0x19 hex.

Table 7.3. Channel Specific Setup Areas of the Parameter Table

Register	7	6	5	4	3	2	1	0
ADCCONFIGx	RSRVD	DECIM_RATE[1:0]		ADCMUX[4:0]				
ADCSENSx	HSIG	SW_GAIN[2:0]			HW_GAIN[3:0]			
ADCPOSTx	RSRVD	24BIT_OUT	POSTSHIFT[2:0]			THRESH_POL	THRESH_EN[1:0]	
MEASCONFIGx	COUNTER_INDEX[1:0]		RSRVD		BANK_SEL	LED2_EN	LED3_EN	LED1_EN

The following figure illustrates how to use the channel-specific registers in the parameter table above.

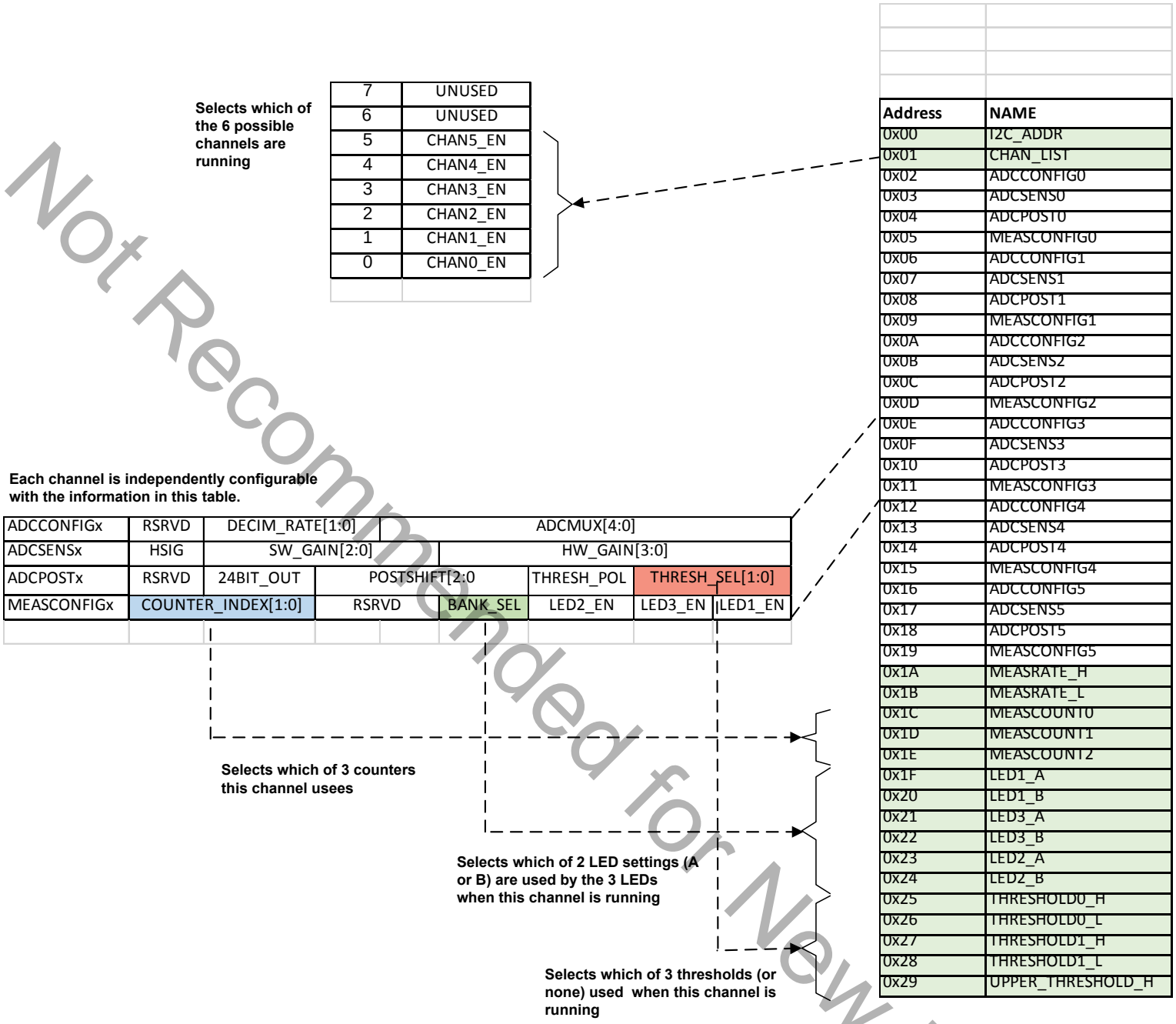


Figure 7.1. THRESH_EN, COUNTER_INDEX Fields in Each Channel Specific Register Area Points to Global Area Register THRESHOLDx and MEASCOUNTx (Respectively)

Note: In the figure above, the counter selected (1, 2, or 3) defines the number of 800 µs periods to have between readings when the channel runs. The threshold selected defines the threshold used.

7.2.1 ADCCONFIGx

Parameter Addresses: 0x02, 0x06, 0x0A, 0x0E, 0x12, 0x16								
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Name	RSRVD	DECIM_RATE[1:0]		ADCMUX[4:0]				
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7	RSRVD	To ensure compatibility with future devices, always write bits to 0.
6:5	DEC-IM_RATE[1:0]	Selects the decimations rate of A/Ds. This setting affects the number of clocks used per measurements. Decimation rate is an A/D optimization parameter. The most common decimation value is 0 for a 1024 clocks and 48.8 µs min measurement time. Consult the related application notes for more details. Increasing the reading time by using a higher decimation rate does not cause the ADC count to be larger.

Value	No of 21 MHz Clocks	Measurement time at HW_GAIN[3:0] = 0	Measurement time at HW_GAIN[3:0] = n	Usage
		Note: All measurements are repeated 2X internally for ADC offset cancellation purposes. The times below represent the integration time for one of these measurement pairs.		
0	1024	48.8 µs	48.8*(2**n) µs	Normal
1	2048	97.6 µs	97.6*(2**n) µs	Useful for longer short measurement times
2	4096	195 µs	195*(2**n) µs	Useful for longer short measurement times
3	512	24.4 µs	24.4*(2**n) µs	Useful for very short measurement times

4:0	ADCMUX[4:0]	The ADC Mux selects which photodiode(s) are connected to the ADCs for measurement. See 7.3 Photodiode Selection for more information regarding the location of the photodiodes.

ADCMUX[4:0]					Optical Functions	Relative Gain
0	0	0	0	0	Small IR	1x Small IR
0	0	0	0	1	Medium IR	2x Small IR
0	0	0	1	0	Large IR	4x Small IR
0	1	0	1	1	Visible	1x Visible
0	1	1	0	1	Large Visible	2x Visible

7.2.2 ADCSENSx

Parameter Addresses: 0x03, 0x07, 0x0B, 0x0F, 0x13, 0x17								
Bit	7	6	5	4	3	2	1	0
Name	HSIG	SW_GAIN[2:0]			HW_GAIN[2:0]			
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7	HSIG	Enables the high signal range of the ADC. The high signal range reduces the sensitivity of the ADC to allow measurement of higher light levels. The sensitivity ratio is defined in 8. Electrical Specifications
6:4	SW_GAIN[2:0]	Causes an internal accumulation of samples with no pause between readings when in FORCED Mode. In Autonomous mode the the accumulation happens at the measurement rate selected. The calculations are accumulated in 24 bits and an optional shift is applied later. See ADCPOSTx.ADC_MISC[1:0]
		Value: Number of Measurements
		0: 1
		1: 2
		2: 4
		3: 8
		4: 16
		5: 32
		6: 64
		7: 128
3:0	HW_GAIN[3:0]	Value: Nominal Measurement time for 512 decimation rate
		0: 24.4 µs
		1: 48.8 µs
		2: 97.5 µs
		……: ……
		10: 25 ms
		11: 50 ms
		12 to 15: unused

7.2.3 ADCPOSTx

Parameter Addresses: 0x04, 0x08, 0x0C, 0x10, 0x14, 0x18								
Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Name	Reserved	24BIT_OUT	POSTSHIFT[2:0]			THRESH_POL	THRESH_EN[1:0]	
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function	
7	RESERVED	To ensure compatibility with future devices, always write bits to 0.	
6	24BIT_OUT	Determines the size of the samples in the HOSTOUTx registers. 0: 16-bit unsigned integer output 1: 24-bit signed integer output	
5:3	POSTSHIFT[2:0]	The number of bits to shift right after SW accumulation. Allows the results of many additions not to overflow the output. Especially useful when the output is in 16 bit mode.	
2	THRESH_POL	Determines the polarity of the threshold based interrupt. This is only available on revision AB and above. This bit is unused on revision AA.	
		Value	Operation
		0	Interrupt is triggered when the sample is larger than the threshold (THRESH_EN is set to 1 or 2), or exits the threshold window (THRESH_EN is set to 3)
		1	Interrupt is triggered when the sample is smaller than the threshold (THRESH_EN is set to 1 or 2), or enters the threshold window (THRESH_EN is set to 3)
1:0	THRESH_EN [1:0]	Value	Operation
		0	Do not use thresholds. Interrupt on every sample when interrupts are enabled in IRQ_ENABLE.
		1	Revision AA: Interrupt when the measurement is larger than THRESHOLD1 Revision AB: Interrupt when the measurement is larger/smaller than THRESHOLD1 as defined by THRESH_POL
		2	Revision AA: Interrupt when the measurement is larger than THRESHOLD1 Revision AB: Interrupt when the measurement is larger/smaller than THRESHOLD1 as defined by THRESH_POL
		3	Revision AA: Interrupt when the measurement is larger than THRESHOLD2 Revision AB: Interrupt when the measurement exits/enters the window defined by UPPER_THRESHOLD and LOWER_THRESHOLD

7.2.4 MEASCONFIGx

Parameter Addresses: 0x05, 0x0A, 0x0D, 0x11, 0x15, 0x19								
Bit	7	6	5	4	3	2	1	0
Name	COUNTER_INDEX[1:0]		RSRVD		BANK_SEL	LED2_EN	LED3_EN	LED1_EN
Reset	0	0	0	0	0	0	0	0

Bit	Name	Function
7:6	COUNTER_INDEX[1:0]	Selects which of the three counters (MEASCOUNTx) in the global parameter list is in use by this channel. These counters control the period/frequency of measurements. When the channel uses the COUNTER_INDEX[1:0] to select a MEASCOUNT**k** register in the parameter table, then the time between measurements for this channel is = 800 us * MEASRATE * MEASCOUNT**k**. A value of zero in MEASRATE will prevent autonomous mode from working. Similarly a zero in MEASCOUNT**k** will prevent the autonomous mode from working for the concerned channel
		Value / **Results** 0 – Measurement not be performed except in BURST or Forced modes 1 – Selects MEASCOUNT0 2 – Selects MEASCOUNT1 3 – Selects MEASCOUNT2
5:4	RSRVD	Reserved. This field was previously LED_TRIM. The use of the LED_TRIM is not recommended. Set this field to 0 and adjust the LED current using LEDx.
3	BANK_SEL	Selects whether to use the LEDx_A or the LEDx_B LED current configuration. **Value** – LED current registers used to configure LED driver. 0 – LED1_A, LED2_A, LED3_A 1 – LED1_B, LED2_B, LED3_B
2	LED2_EN	Enables the LED2 driver.[1]
1	LED3_EN	Enables the LED3 driver.[2]
0	LED1_EN	Enables the LED1 driver.

Note:
1. This is only available in Si1152 and Si1153.
2. This is only available in Si1153.

7.3 Photodiode Selection

The ADCCONFIGx.ADCMUX [4:0] register controls the photodiode selection. The photodiode spectral responses are shown in the electrical specifications section.

For proximity sensing, it is best to use the large IR photodiode as this has the highest sensitivity resulting in the furthest detection range. For ambient light sensing, both the visible and IR photodiodes should be used to estimate the brightness to correct for the spectral responses.

The infrared and visible photodiodes have the same area, however the infrared photodiode is more sensitive. This can be seen in the relative optical spectral response shown in Figure 8.5 Photodiode Spectral Response Normalized to IR Maximum Response on page 56.

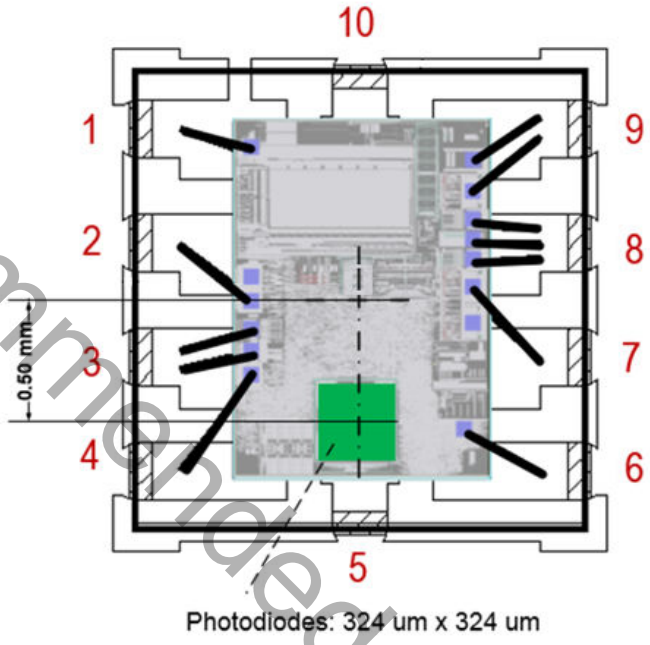


Figure 7.2. Photodiode Locations

Table 7.4. Relative Area of Photodiodes

Photodiode Selection	Relative Area
Small	1x
Medium	2x
Large	4x

8. Electrical Specifications

All electrical parameters in all tables are specified under the following conditions, unless stated otherwise.

- Typical values are based on T_{AMB}=25 °C and V_{DD}=3.3 V, by production test and/or technology characterization.
- Minimum and maximum values represent the worst conditions across supply voltage, process variation and operating temperature unless stated otherwise.
- Single channel enabled with configuration: DECIM_RATE=0, HSIG=0, HW_GAIN=0, SW_GAIN=0.
- Angle of incidence of light is 0°.

Table 8.1. Recommended Operating Conditions

Parameter	Symbol	Condition	Min	Typ	Max	Unit
V_{DD} Supply Voltage	V_{DD}		1.62	—	3.6	V
V_{DD} OFF Supply Voltage	V_{DD_OFF}	OFF mode	–0.3		0.5	V
V_{DD} Supply Ripple Voltage		V_{DD} = 3.3 V 1 kHz – 10 MHz	—	—	50	mVpp
Operating Temperature	T		–40	25	85	°C
SCL, SDA, Input High Logic Voltage	I^2C_{VIH}		V_{DD} x 0.7	—	V_{DD}	V
SCL, SDA Input Low Logic Voltage	I^2C_{VIL}		0	—	V_{DD} x 0.3	V
Start-Up Time		V_{DD} above 1.62 V	25	—	—	ms
LED Supply Voltage	VLED				5.5	V

Table 8.2. Electrical Performance Characteristics

Parameter	Symbol	Condition[1]	Min	Typ	Max	Unit
I_{DD} Standby Mode (sleep)	Isb	No ADC Conversions No I^2C Activity V_{DD} = 1.8 V	—	125	—	nA
	Isb	No ADC Conversions No I^2C Activity V_{DD} = 3.3 V	—	1.25	—	µA
I_{DD} Standby Mode (sleep) RTC On	Isb,rtc	Sleep Current during Autonomous Mode V_{DD} = 1.8 V	—	0.55	—	µA
	Isb,rtc	Sleep Current during Autonomous Mode V_{DD} = 3.3 V	—	1.8	—	µA

Parameter	Symbol	Condition[1]	Min	Typ	Max	Unit
I_{DD} Suspend Mode	Isus	ADC Conversion In Progress V_{DD} = 1.8 V	—	1.56	—	mA
	Isus	ADC Conversion In Progress V_{DD} = 3.3 V	—	1.6	—	mA
I active, but not measuring	I active	Responding to commands, Preparing and calculating results of readings. V_{DD} = 1.8 V		4.25	—	mA
	I active	Responding to commands, Preparing and calculating results of readings. V_{DD} = 3.3 V		4.5	—	mA
INT, SCL, SDA Leakage Current		V_{DD} = 3.3 V	–1	—	1	µA
Processing Time per Measurement *(During this time the current is I Active)*	$t_{process}$	ALS or Proximity		155		µs
A/D startup time *(During this time the current is I Suspend)*	$t_{adstart}$	ADC startup time prior to measurement	—	48.8	—	µs
Ratio of readings with HSIG=0 and HSIG=1 for the visible photodiode.		525 nm light, ADCMUX=0x11	—	15.2	—	
Ratio of readings with HSIG=0 and HSIG=1 for the IR photodiode.		940 nm light ADCMUX=0x0	—	15.2	—	
SCL, SDA VOL			—	—	V_{DD} * 0.2	V
INT VOL			—	—	0.4	V

Notes:

1. Unless specifically stated in the Condition column, electrical data assumes ambient light levels < 1 klx.
2. Guaranteed by design and characterization.

Test Conditions: DECIM=0, HW_GAIN=0, SW_GAIN=0, HSIG=0

Table 8.3. Optical Performance Characteristics: Si115x-AB00

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Small Visible Photodiode Response ADCMUX=0x11		460 nm (blue)	—	190	—	ADC Counts /(W/m^2)
		525 nm (green)	—	160	—	
		625 nm (red)	—	100	—	
		850 nm (IR)	—	30		
		940 nm (IR)	—	10	—	
Medium Visible Photodiode Response ADCMUX=0x13		460 nm (blue)	—	380	—	ADC Counts /(W/m^2)
		525 nm (green)	—	320	—	
		625 nm (red)	—	200	—	
		850 nm (IR)	—	60	—	
		940 nm (IR)	—	20	—	
Small Infrared Photodiode Response ADCMUX=0x0		460 nm (blue)	—	90	—	ADC Counts /(W/m^2)
		525 nm (green)	—	260	—	
		625 nm (red)	—	510	—	
		850 nm (IR)	—	690	—	
		940 nm (IR)	—	490	—	
Medium Infrared Photodiode Response Photodiode Response ADCMUX=0x1		460 nm (blue)	—	190	—	ADC Counts /(W/m^2)
		525 nm (green)	—	520	—	
		625 nm (red)	—	1000	—	
		850 nm (IR)	—	1280	—	
		940 nm (IR)	—	860	—	

Test Conditions: DECIM=0, HW_GAIN=0, SW_GAIN=0, HSIG=0

Table 8.4. Optical Performance Characteristics: Si115x-AB09 with IR optical bandpass filter

Parameter	Symbol	Condition	Min	Typ	Max	Unit
Small Visible Photodiode Response ADCMUX=0x11		460 nm (blue)	—	0	—	ADC Counts /(W/m^2)
		525 nm (green)	—	0	—	
		625 nm (red)	—	0	—	
		850 nm (IR)	—	0		
		940 nm (IR)	—	10	—	
Medium Visible Photodiode Response ADCMUX=0x13		460 nm (blue)	—	0	—	ADC Counts /(W/m^2)
		525 nm (green)	—	0	—	
		625 nm (red)	—	10	—	
		850 nm (IR)	—	0	—	
		940 nm (IR)	—	20	—	
Small Infrared Photodiode Response ADCMUX=0x0		460 nm (blue)	—	0	—	ADC Counts /(W/m^2)
		525 nm (green)	—	0	—	
		625 nm (red)	—	10	—	
		850 nm (IR)	—	40	—	
		940 nm (IR)	—	410	—	
Medium Infrared Photodiode Response Photodiode Response ADCMUX=0x1		460 nm (blue)	—	0	—	ADC Counts /(W/m^2)
		525 nm (green)	—	0	—	
		625 nm (red)	—	10	—	
		850 nm (IR)	—	80	—	
		940 nm (IR)	—	710	—	

Table 8.5. I2C Timing Specifications

Parameter	Symbol	Min	Typ	Max	Unit
Clock Frequency	f_{SCL}	—	—	400	kHz
Clock Pulse Width Low	t_{LOW}	1.3	—	—	µs
Clock Pulse Width High	t_{HIGH}	0.6	—	—	µs
Rise Time	t_R	20	—	300	ns
Fall Time	t_F	20 * (V_{DD} / 5.5)	—	300	ns
Start Condition Hold Time	$t_{HD:STA}$	0.6	—	—	µs
Start Condition Setup Time	$t_{SU:STA}$	0.6	—	—	µs
Input Data Setup Time	$t_{SU:DAT}$	100	—	—	ns
Data Hold Time	$t_{HD:DAT}$	0	—	—	ns
Output Data Valid Time	$t_{VD:DAT}$	—	—	0.9	µs
Stop Setup Time	$t_{SU:STO}$	0.6	—	—	µs
Bus Free Time	t_{BUF}	1.3	—	—	µs
Suppressed Pulse Width	t_{SP}	—	—	40	ns
Bus Capacitance	C_b	—	—	400	pF

Table 8.6. LED Optical Characteristics

Parameter	Symbol	Test Condition	Min	Typ	Max	Unit
Forward voltage	Vf1	If = 10 µA	0.8	—	—	V
Forward voltage	Vf2	If = 50 mA	—	1.4	1.8	V
Reverse current	Ir	Vr = 10 V	—	—	5.0	µA
Peak wavelength	λp	If = 50 mA	925	940	955	nm
Spectral half-width	Δλ	If = 50 mA	—	30	—	nm
Radiant flux	Po	If = 50 mA	10	—	—	mW
Radiant Intensity	Ie	If = 50 mA	17	23	30	mW/sr
Half Angle	ϕ		—	25	—	°

Note:
1. All specifications measured at 25 °C.

Table 8.7. Absolute Maximum Ratings

Parameter	Condition	Min	Typ	Max	Unit
V_{DD} Supply Voltage		–0.3	—	4	V
Operating Temperature		–40	—	85	°C
Storage Temperature		–65	—	85	°C
INT, SCL, SDA Voltage	at V_{DD} = 0 V, T_A < 85 °C	–0.5	—	3.6	V
ESD Rating	Human Body Model	—	—	2	kV
	Machine Model	—	—	225	V
	Charged-Device Model	—	—	2	kV

Table 8.8. Typical LED Current vs. LED Code

Order No.	LED Code	Current
0	0x00	5.5
1	0x08	11
2	0x10	17
3	0x18	22
4	0x20	28
5	0x28	33
6	0x30	39
7	0x38	44
8	0x12	50
9	0x21	55
10	0x29	66
11	0x31	77
12	0x22	83
13	0x39	88
14	0x2A	100
15	0x23	111
16	0x32	116
17	0x3A	133
18	0x24	138
19	0x33	155
20	0x2C	166
21	0x3B	177
22	0x34	194
23	0x2D	199
24	0x3C	221
25	0x35	232
26	0x3D	265
27	0x36	271
28	0x3E	310
29	0x3F	354

Note:

1. At trim bit = 0.
2. The LED current is not monotonic in the LED code. This list is sorted

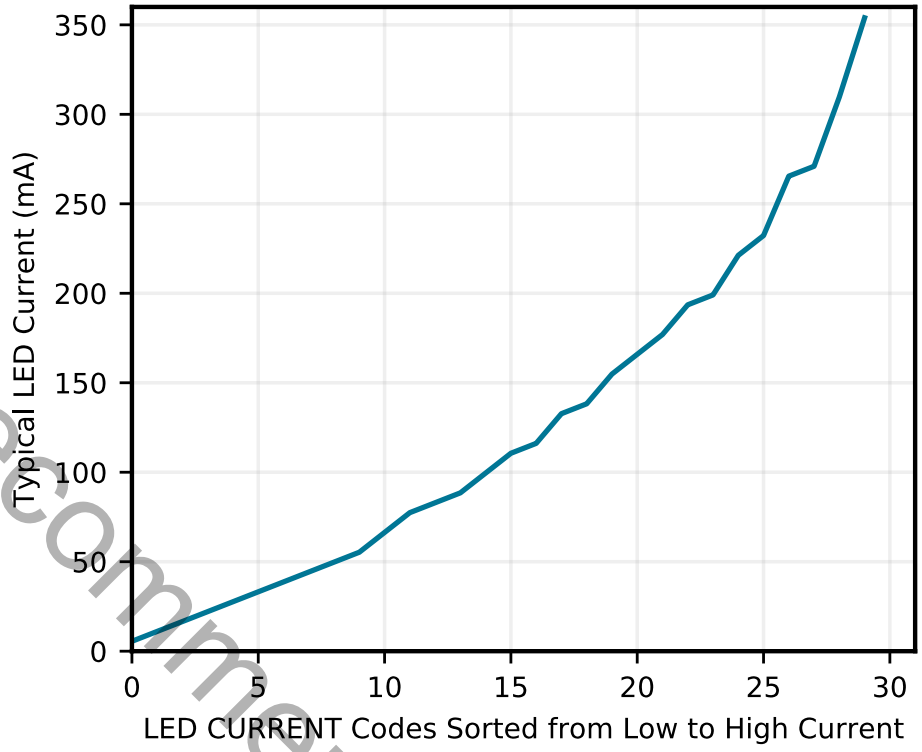


Figure 8.1. Typical LED Currents as a Function of LED Code

Note: In the figure above, the LED configuration happens in the Global Area registers, LED[1,2,3]_[A,B], and in the MEASCONFIGx register of the channel-specific registers.

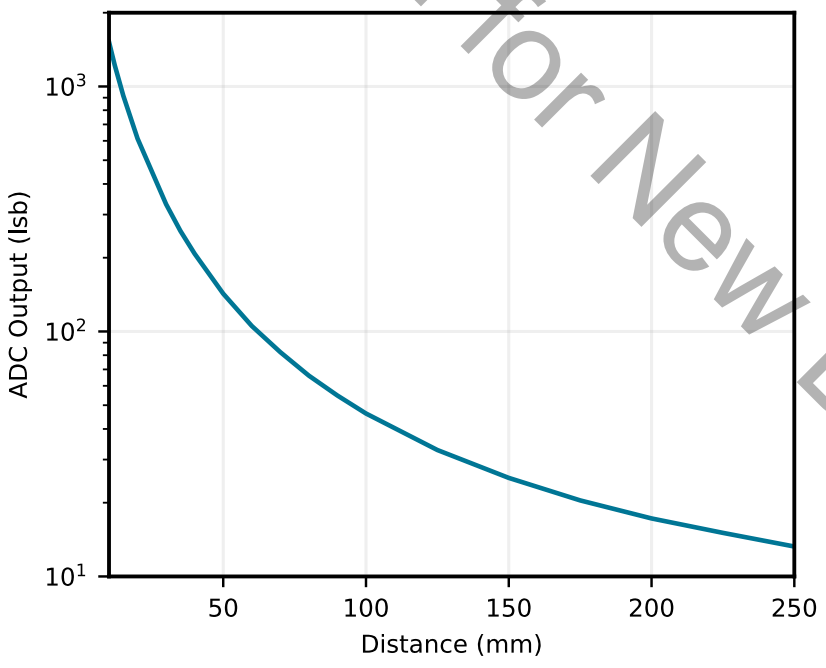


Figure 8.2. ADC Out as a Function of Distance

Note: The above graph is created under the following conditions: (LED1 = 16.6 mA, t = 24.4 µs, HSIG =0). Grey 18% reflector target. Medium IR photodiode. LED beam ½ power is ±30 °C. Output is 5 mW total.

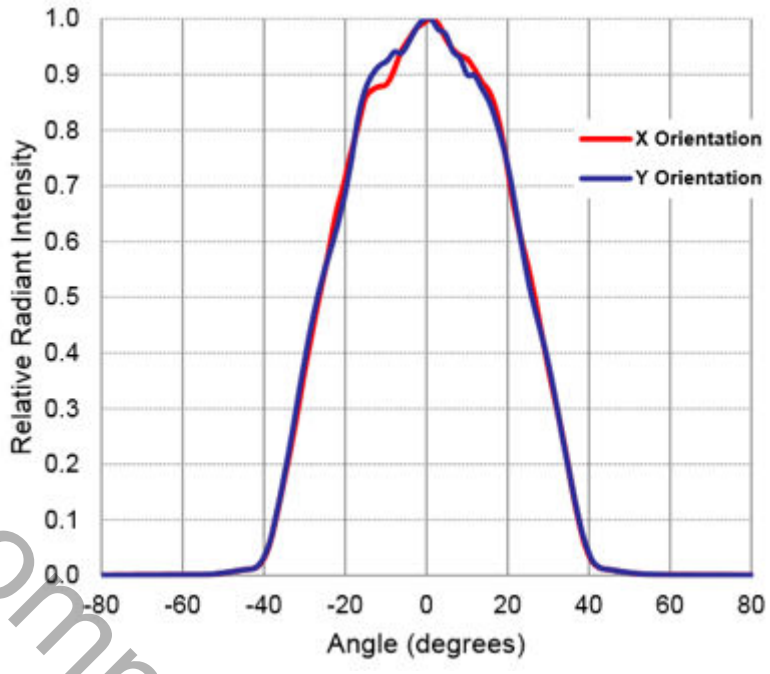


Figure 8.3. Si115x-AB9X LED Radiant Intensity vs. Angle (Indicative)

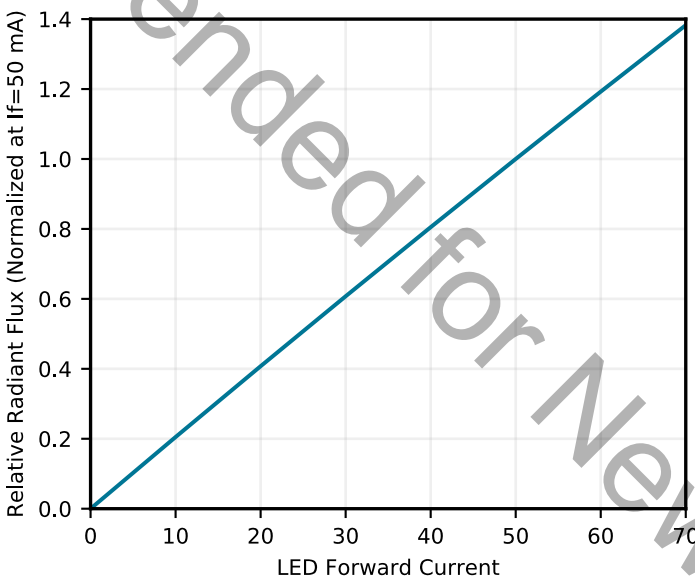


Figure 8.4. Si115x-AB9X LED Radiant Intensity vs. Forward Current (Indicative)

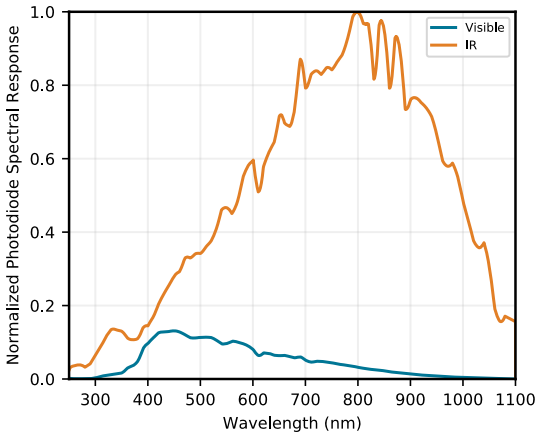


Figure 8.5. Photodiode Spectral Response Normalized to IR Maximum Response

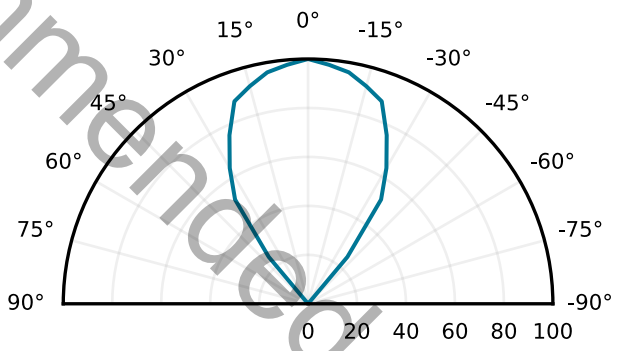


Figure 8.6. Typical Angular Sensitivity of the Photodiodes (%)

9. Pin Descriptions

9.1 DFN Pin Description

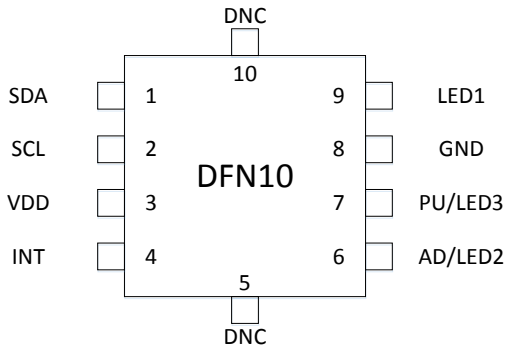


Figure 9.1. 10-Pin DFN

Table 9.1. Pin Descriptions

Pin	Name	Type	Description
1	SDA	Bidirectional	I^2C Data.
2	SCL	Input	I^2C Clock.
3	VDD	Power	Power Supply. Voltage source.
4	INT	Bidirectional	Interrupt Output. Open-drain interrupt output pin.
5	DNC		Do Not Connect. This pin is electrically connected to an internal Si115x node. It should remain unconnected.
6	AD / LED2	Bidirectional	LED2 output. It is sensed during startup. Pull up to VDD with 47 kΩ resistor for default I^2C address (0x53). Pull down with 47 kΩ resistor to select alternate I^2C address (0x52) and do not use it as an LED driver in that case.
7	PU / LED3	Bidirectional	LED3 output (Si1153 only) Connect to V_{DD} through pull up resistor (mandatory for Si1151 and Si1152, mandatory for Si1153 if no LED is used)
8	GND	Power	Ground.
9	LED1	Output	LED1 output. Connect to V_{DD} through a pull-up resistor when not in use.
10	DNC		Do Not Connect. This pin is electrically connected to an internal Si115x node. It should remain unconnected.

9.2 LGA Module Pin Description

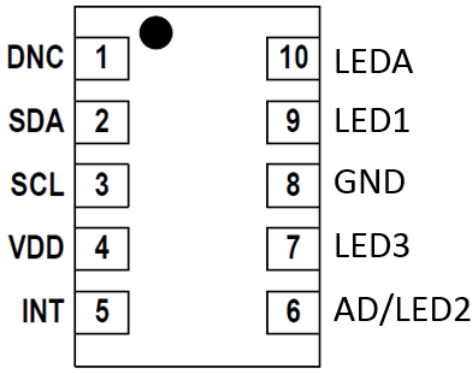


Figure 9.2. 2.85 x 4.9 mm LGA Module

Table 9.2. Pin Descriptions

Pin	Name	Type	Description
1	DNC		Do Not Connect. This pin is electrically connected to an internal Si115x node. It should remain unconnected.
2	SDA	Bidirectional	I^2C Data.
3	SCL	Input	I^2C Clock.
4	VDD	Power	Power Supply. Voltage source.
5	INT	Bidirectional	Interrupt Output. Open-drain interrupt output pin.
6	AD / LED2	Bidirectional	LED2 output. Connect to V_{DD} through pull up resistor (mandatory for Si1151 and Si1152, mandatory for Si1153 if no LED is used)
7	PU / LED3	Bidirectional	LED3 output. Always connect to V_{DD} through a pull-up resistor. Connect to an LED cathode if that output is used. Must be at logic level high during power-up sequence to allow normal operation.
8	GND	Power	Ground.
9	LED1	Output	LED1 output. Connect to V_{DD} through a pull-up resistor when not in use.
10	LEDA	Power	LED Anode Supply. Connect to VLED.

10. Package Outline

10.1 10-Pin 2x2 mm DFN

DFN Package Diagram Dimensions illustrates the package details for the Si115x DFN package lists the values for the dimensions shown in the illustration.

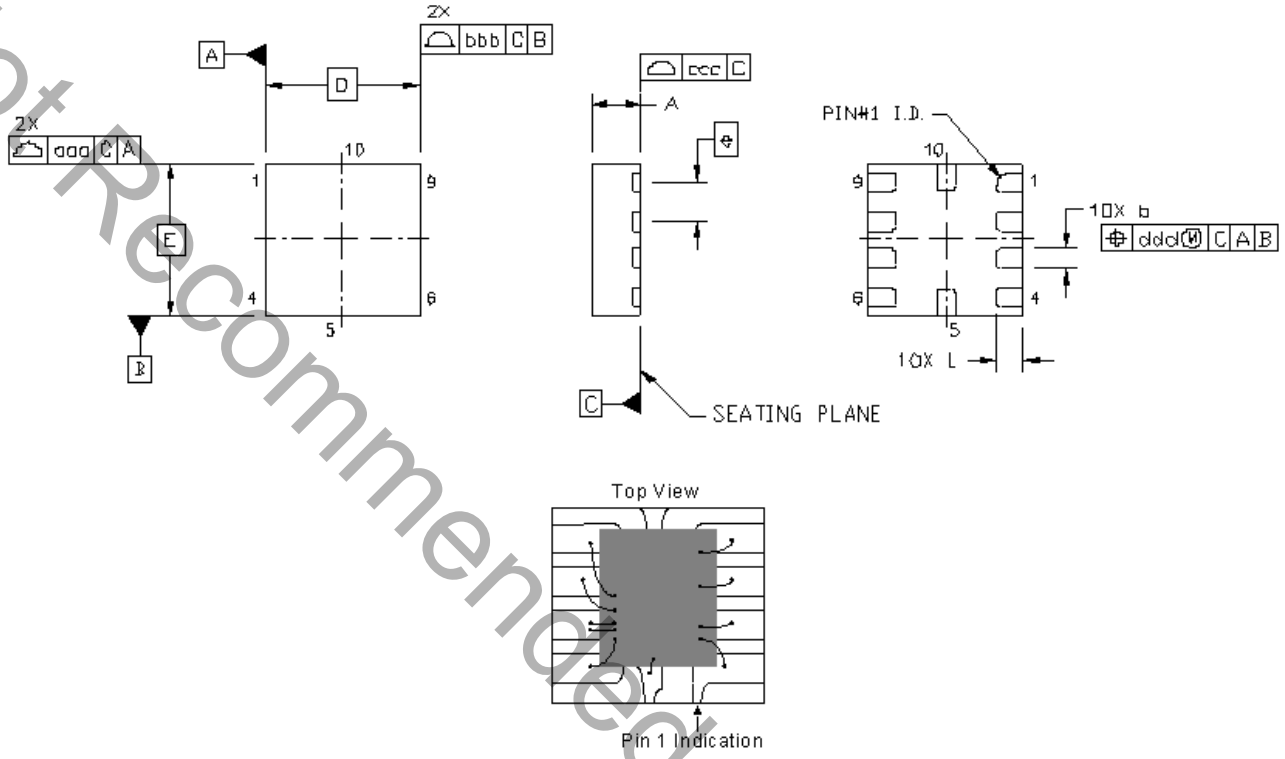


Figure 10.1. DFN Package Diagram Dimensions

Table 10.1. Package Diagram Dimensions

Dimension	Min	Nom	Max
A	0.55	0.65	0.75
b	0.20	0.25	0.30
D		2.00 BSC.	
e		0.50 BSC.	
E		2.00 BSC.	
L	0.30	0.35	0.40
aaa		0.10	
bbb		0.10	
ccc		0.08	
ddd		0.10	

Notes:
1. All dimensions shown are in millimeters (mm).
2. Dimensioning and Tolerance per ANSI Y14.5M-1994.

10.2 10-Pin LGA Module

The figure below illustrates the package details for the Si115x LGA package while the table lists the values for the dimensions shown in the illustration.

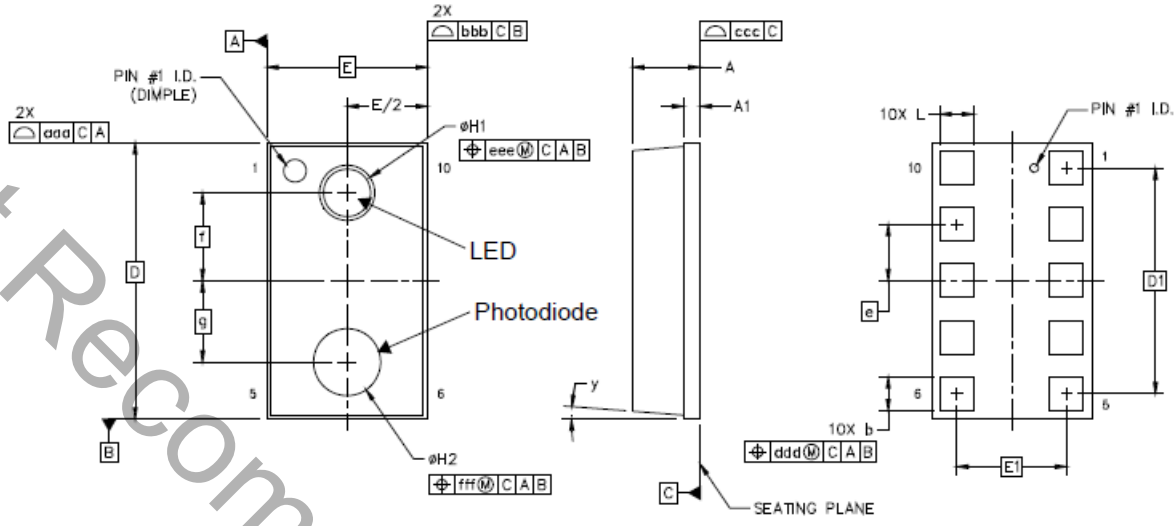


Figure 10.2. LGA Package Diagram Dimensions

Table 10.2. 10-Pin LGA Module Package Diagram Dimensions

Dimension	Min	Nom	Max
A	1.10	1.20	1.30
A1	0.28	0.30	0.32
b	0.55	0.60	0.65
D		4.90 BSC	
D1		4.00 BSC	
e		1.00 BSC	
E		2.85 BSC	
E1		1.95 BSC	
f		1.56 BSC	
g		1.44 BSC	
H1	0.98	1.03	1.08
H2	1.19	1.24	1.29
L	0.55	0.60	0.65
y		3° REF	
aaa		0.10	
bbb		0.10	
ccc		0.08	
ddd		0.10	
eee		0.10	
fff		0.10	

Notes:

1. All dimensions shown are in millimeters (mm) unless otherwise noted.
2. Dimensioning and tolerancing per ANSI Y14.5M-1994.
3. Recommended card reflow profile is per the JEDEC/IPC J-STD-020 specification for Small Body Components.

11. Land Patterns

11.1 2x2 mm DFN Land Pattern

See the figure and table below for the suggested 2 x 2 mm DFN PCB land pattern.

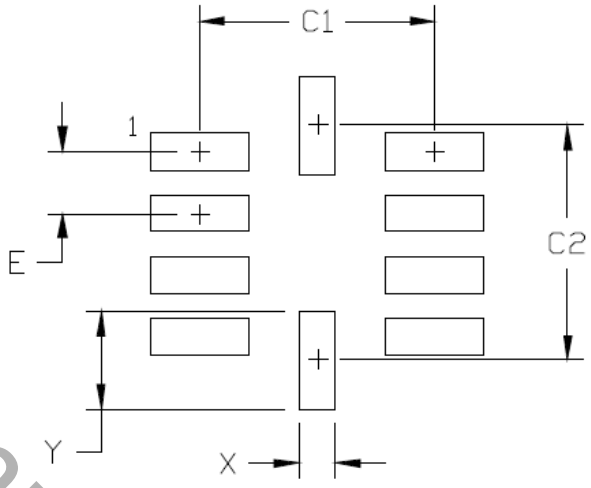


Figure 11.1. 2 x 2 mm DFN PCB Land Pattern

Table 11.1. Land Pattern Dimensions

Dimension	mm
C1	1.90
C2	1.90
E	0.50
X	0.30
Y	0.80

Notes:

General

1. All dimensions shown are in millimeters (mm).
2. This Land Pattern Design is based on the IPC-7351 guidelines.
3. All dimensions shown are at Maximum Material Condition (MMC). Least Material Condition (LMC) is calculated based on a Fabrication Allowance of 0.05 mm.

Solder Mask Design

4. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 mm minimum, all the way around the pad.

Stencil Design

5. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
6. The stencil thickness should be 0.125 mm (5 mils).
7. The ratio of stencil aperture to land pad size should be 1:1 for all pads.

Card Assembly

8. A No-Clean, Type-3 solder paste is recommended.
9. The recommended card reflow profile is per the JEDEC/IPC J-STD-020D specification for Small Body Components.

11.2 10-Pin LGA Module

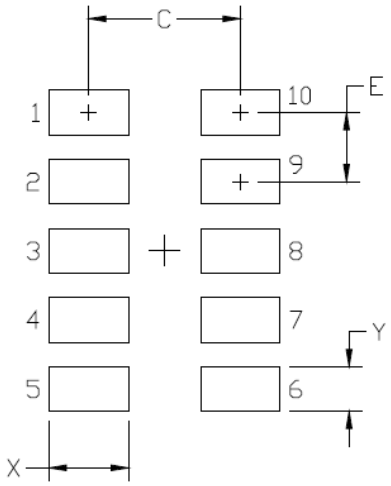


Figure 11.2. 10-Pin LGA Module Land Pattern

Table 11.2. Land Pattern Dimensions

Dimension	mm
C	2.20
E	1.00
X	1.15
Y	0.65

Notes:

General

1. All dimensions shown are in millimeters (mm).
2. This Land Pattern Design is based on the IPC-7351 guidelines.
3. All dimensions shown are at Maximum Material Condition (MMC). Least Material Condition (LMC) is calculated based on a Fabrication Allowance of 0.05 mm.

Solder Mask Design

4. All metal pads are to be non-solder mask defined (NSMD). Clearance between the solder mask and the metal pad is to be 60 mm minimum, all the way around the pad.

Stencil Design

5. A stainless steel, laser-cut and electro-polished stencil with trapezoidal walls should be used to assure good solder paste release.
6. The stencil thickness should be 0.125 mm (5 mils).
7. The ratio of stencil aperture to land pad size should be 1:1 for all pads.

Card Assembly

8. A No-Clean, Type-3 solder paste is recommended.
9. The recommended card reflow profile is per the JEDEC/IPC J-STD-020D specification for Small Body Components.

12. Revision History

Revision 1.5

February, 2024

- Updated Table 2.1 Ordering Guide on page 5 to note NRND and EOL OPNs.

Revision 1.4

August, 2022

- Updated Ordering Guide.
- Fixed MEASRATE field from 16-bit to 12-bit.
- Added restrictions on MEASCOUNT field.
- Removed the LED_TRIM field and marked as reserved.
- Fixed I_suspend electrical specification to include the ADC on current.
- Added I_sleep,rtc specification for IDD calculations during autonomous mode in sleep.
- Added detailed register descriptions for global parameter table.
- Clarified theory of operation throughout document.

Revision 1.3

January, 2019

- Updated data sheet to include content for Si1151 and Si1152.

Revision 1.2

September, 2018

- Added interrupt modes to use threshold window.
- Updated the parameter table to the latest firmware.

Revision 1.1

October 5, 2017

- Added OPN Si1153-AA09-AMR.

Revision 1.0

September 29, 2016

- Updated Register in Table 8.2 Electrical Performance Characteristics on page 47 from Reset to IRQENABLE.
- Swapped position on LED2_EN and LED_3 EN.
- Added Max VLED voltage to 5.5 V.

Revision 0.9

December 4, 2015

- Initial release.

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