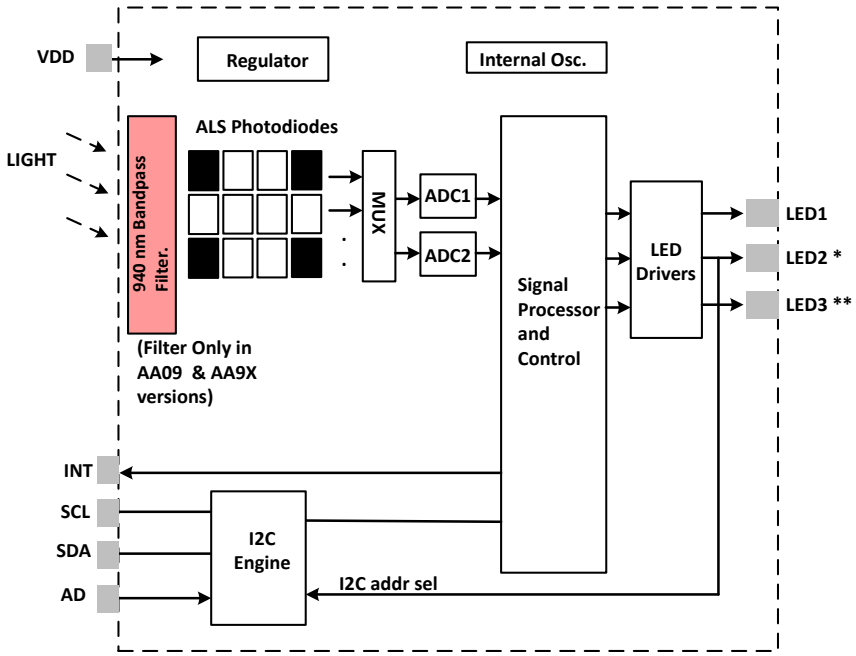
# Si1153 Data Sheet

## Proximity/Ambient Light Sensor IC with I²C Interface

The Si1153-AA00/AA09/AA9x 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 three integrated LED drivers with programmable drive levels. The Si1153 offers excellent performance under a wide dynamic range and a variety of light sources, including direct sunlight. The Si1153 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 Si1153 is capable of supporting multiple-axis proximity motion detection. The Si1153 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.

** Pull up to VDD with 47 kOhm resistor

### 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 (Si1153-AA09/AA9X).
- 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 25.6 µs every 800 ms at 180 mA plus 3 µA Si1153 supply).
  - <500 nA standby current.
  - 25.6 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

# 1. Feature List

- 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).
  - 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 (Si1153- AA09/ AA9X).
- 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 25.6 µs every 800 ms at 180 mA plus 3 µA Si1153 supply).
  - <500 nA standby current.
  - 25.6 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.
- Trim-able internal oscillator with typical 1% accuracy.
- $I^2C$ Serial communications
  - Up to 3.4 Mbps 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 | DFN OPNs | Package | ALS | 940 nm Filter | Proximity (# of LED Drivers) | # of LEDs Included |
|---|---|---|---|---|---|---|
| Si1153 | Si1153-AA00-GMR | 2 x 2 mm DFN | Y | | 3 | 0 |
| Si1153 | Si1153-AA09-GMR | 2 x 2 mm DFN | | Y | 3 | 0 |
| Si1153 | Si1153-AA9x-GMR | 2.85 x 4.9 mm LGA Module | | Y | 3 | 1 |

# 3. Functional Description

The Si1153 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 Si1153 to initiate on-demand Ambient Light or proximity measurements. The host can also place the Si1153 in an autonomous operational state where it performs measurements at set intervals and interrupts the host either after each measurement is completed or whenever a set threshold has been crossed. This results in overall system power saving, allowing the host controller to operate longer in its sleep state instead of polling the Si1153.

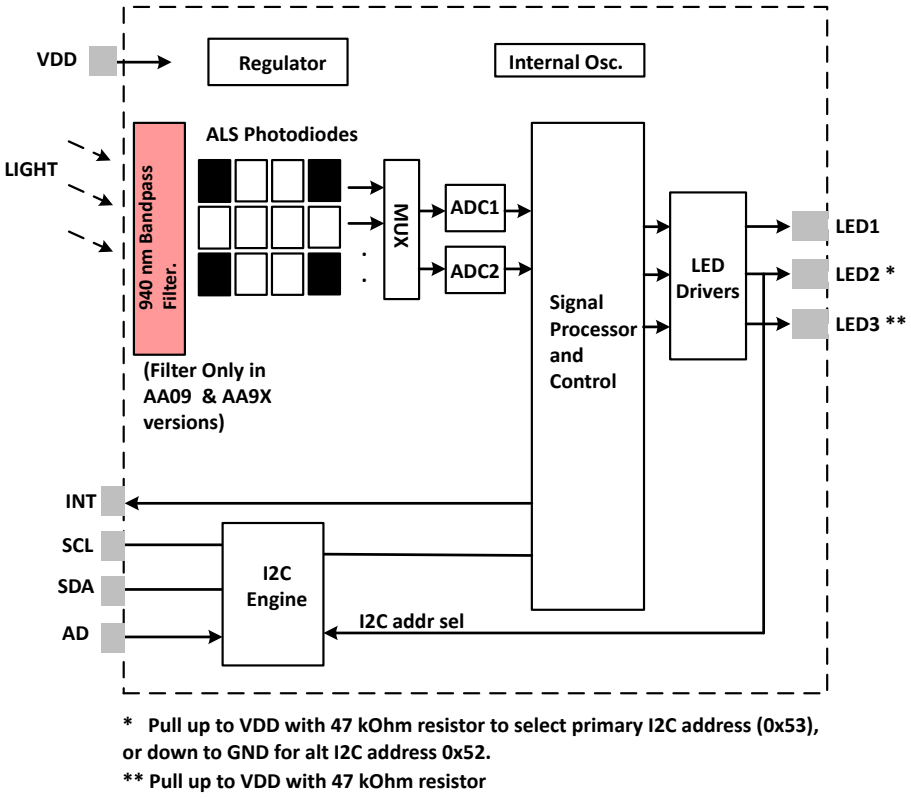



**Figure 3.1. Functional Block Diagram**

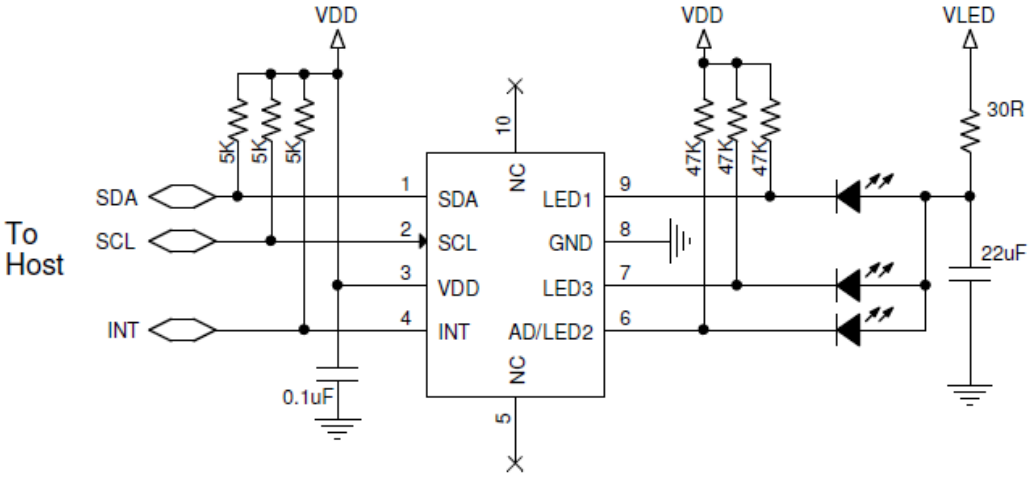



**Figure 3.2. Si1153 DFN Package Basic Application**

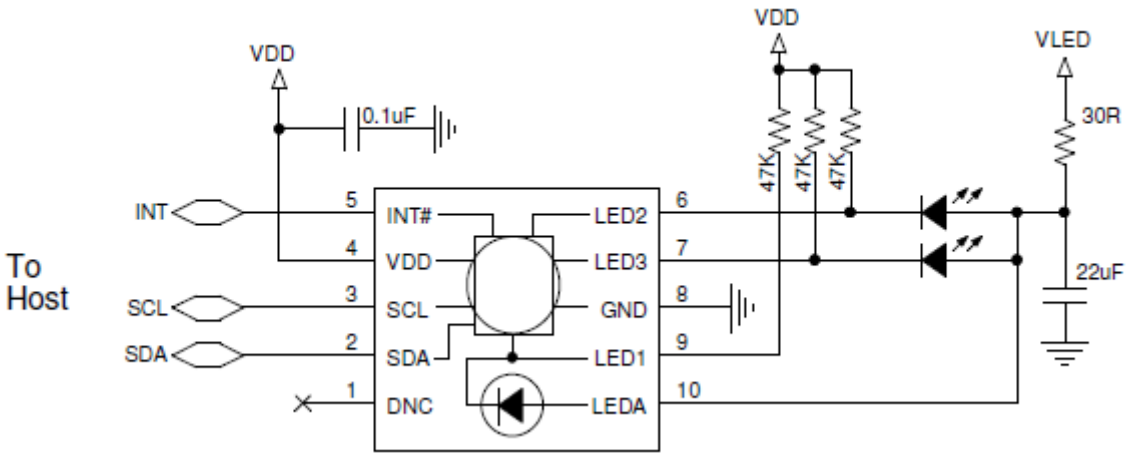



**Figure 3.3. Si1153 LGA Module Basic Application**

### 3.1 Ambient Light Sensing

The Si1153 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 Si1153 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. Si1153 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 Si1153 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 Si1153 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 Si1153 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 Si1153 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 Si1153 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 Si1153 can initiate proximity sense measurements when explicitly commanded by the host or periodically through an autonomous process.

Whenever it is time to make a PS measurement, the Si1153 makes up to six measurements, depending on what is enabled in the CHLIST 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 PS channel, it is also possible for the Si1153 to notify the host whenever the threshold has been crossed. This reduces the number of interrupts to the host, aiding in efficient software algorithms.

The Si1153 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 44.) 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 Si1153 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 Si1153-AA09 version of the Si1153 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.

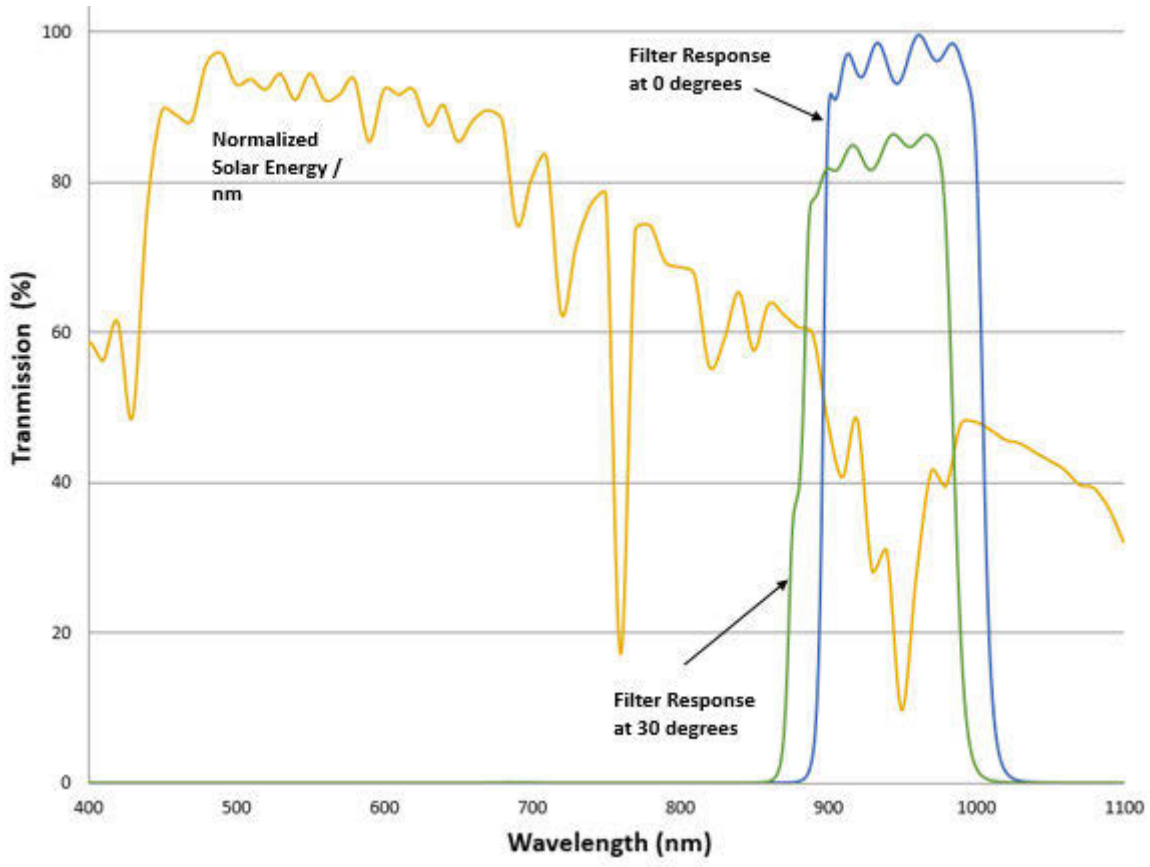



**Figure 3.4. Typical Si1153-AA09 Filter Response Compared to the Sunlight Energy Spectrum**

### 3.3 Power Consumption

The Si1153 alternates between three power consumption states: Active, Suspend, and Sleep. (See the diagram below for an illustration of each of these states.) The total power consumed by the part depends heavily on the measurement rate, measurement mode, and measurement gain for the various channels enabled. The power levels for the three modes, as well as the Active Power time per reading, are provided in this document. The Suspend time (where the A/D and PD are operating) has two parts. One is determined by the user setup and can be determined by the DECIM_RATE and HW_GAIN setup information in Section 7.2 Channel Specific Setup Areas of the Parameter Table, while the other (A/D Startup time) is determined by tadstart, shown in Table 8.2 Electrical Performance Characteristics on page 38.

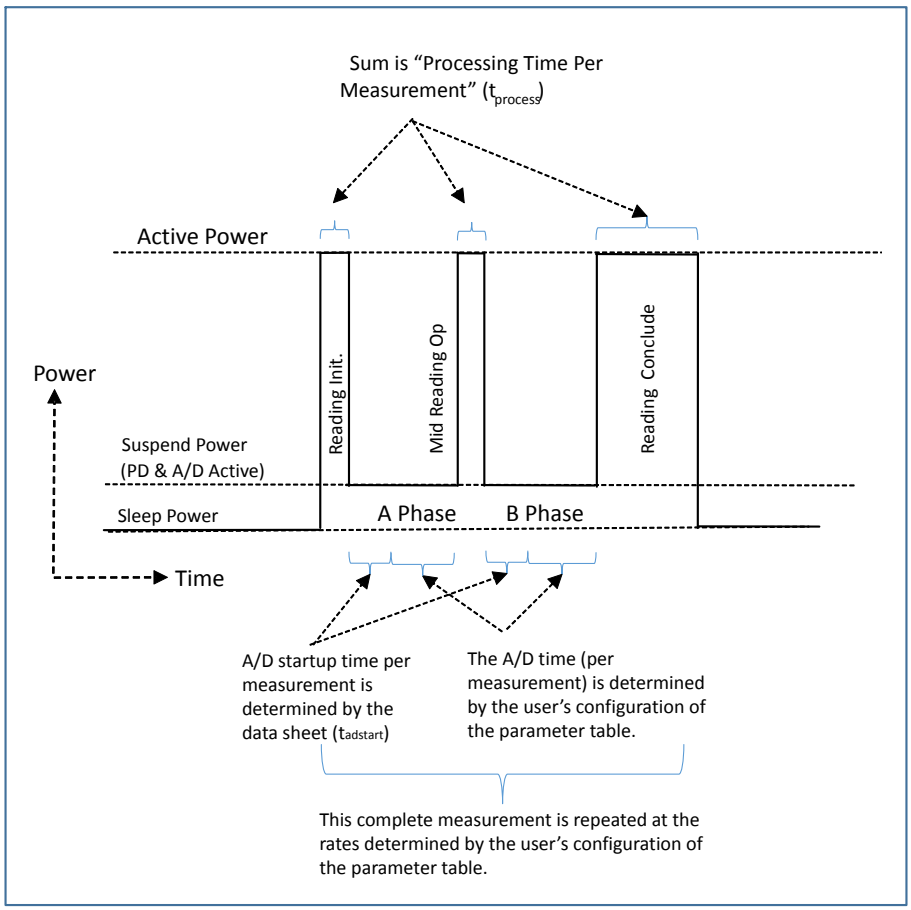



**Figure 3.5. Power Consumption States During a Reading**

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 Si1153 consists of three pins:

- SCL
- SDA
- INT

SCL and SDA are standard open-drain pins as required for $I^2C$ operation.The Si1153 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 Si1153 is expected to fully complete its Initialization Mode prior to any activity on the $I^2C$.

The default I2C address of the Si1153 can be changed by pulling the LED 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 Si1153 to enter the Off Mode by software command without interfering with normal operation of other $I^2C$ devices on the bus.

Conceptually, the $I^2C$ interface allows access to the Si1153 internal registers.

An $I^2C$ 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 Si1153 internal register. Subsequent bytes are written to the Si1153 internal register sequentially until a stop condition is encountered. An $I^2C$ write access with only two bytes is typically used to set up the Si1153 internal address in preparation for an $I^2C$ read.

The $I^2C$ read access, like the $I^2C$ write access, begins with a start or restart condition. In an $I^2C$ read, the $I^2C$ master then continues to clock SCK to allow the Si1153 to drive the $I^2C$ with the internal register contents.The Si1153 also supports burst reads and burst writes. The burst read is useful in collecting contiguous, sequential registers. The Si1153 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 Si1153 internal address every time the register is read.

It is recommended that the host should read performance measurements (in the $I^2C$ Register Map) when the Si1153 asserts INT. Although the host can read any of the Si1153's $I^2C$ 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.

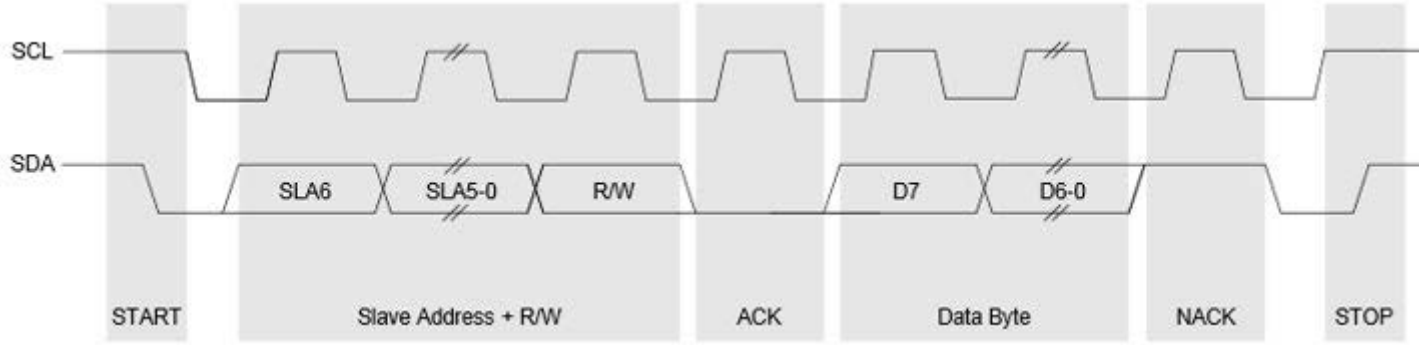



**Figure 3.6. I²C Bit Timing Diagram**

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

**Figure 3.7. Host Interface Single Write**

| S | SLAVE ID | 1 | A | DATA | N | STOP |
|---|---|---|---|---|---|---|

**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 | STOP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

**Figure 3.10. Host Interface Burst Read**

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

**Figure 3.11. Si1153 REG ADDRESS Format**

The following notes apply for the figures above:

1. Gray boxes are driven by the host to the Si1153.
2. White boxes are driven by the Si1153.
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 Si1153 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 Si1153. The various modes are:

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

## 4.1 Off Mode

The Si1153 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 43 are not violated, no current will flow through the Si1153. In the Off Mode, the Si1153 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 Si1153 without a dedicated reset pin.

The Si1153 can also re-enter the Off Mode upon receipt of a software reset sequence. Upon entering Off Mode, the Si1153 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 Si1153 enters its Initialization Mode. In the Initialization Mode, the Si1153 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 Si1153 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 Si1153 spends most of its time in Standby Mode. After the Si1153 completes the Initialization Mode sequence, it enters Standby Mode. While in Standby Mode, the Si1153 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 Si1153 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 Si1153 to exit the Standby Mode. For example, reading Si1153 registers is accomplished without needing the Digital Sequence Controller to wake from its sleep state.

## 4.4 Forced Conversion Mode

The Si1153 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. Upon completion of the conversion, the Si1153 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 Automated Operation Mode

The Si1153 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 Si1153 in the Autonomous Operation Mode.

The Si1153 updates the $I^2C$ 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 Si1153 can also interrupt the host when the proximity or ALS measurement reach a pre-set threshold. 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. This new value is volatile 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 Si1153 responds to the I²C address of 0x53 or to an alternate address of 0x52.

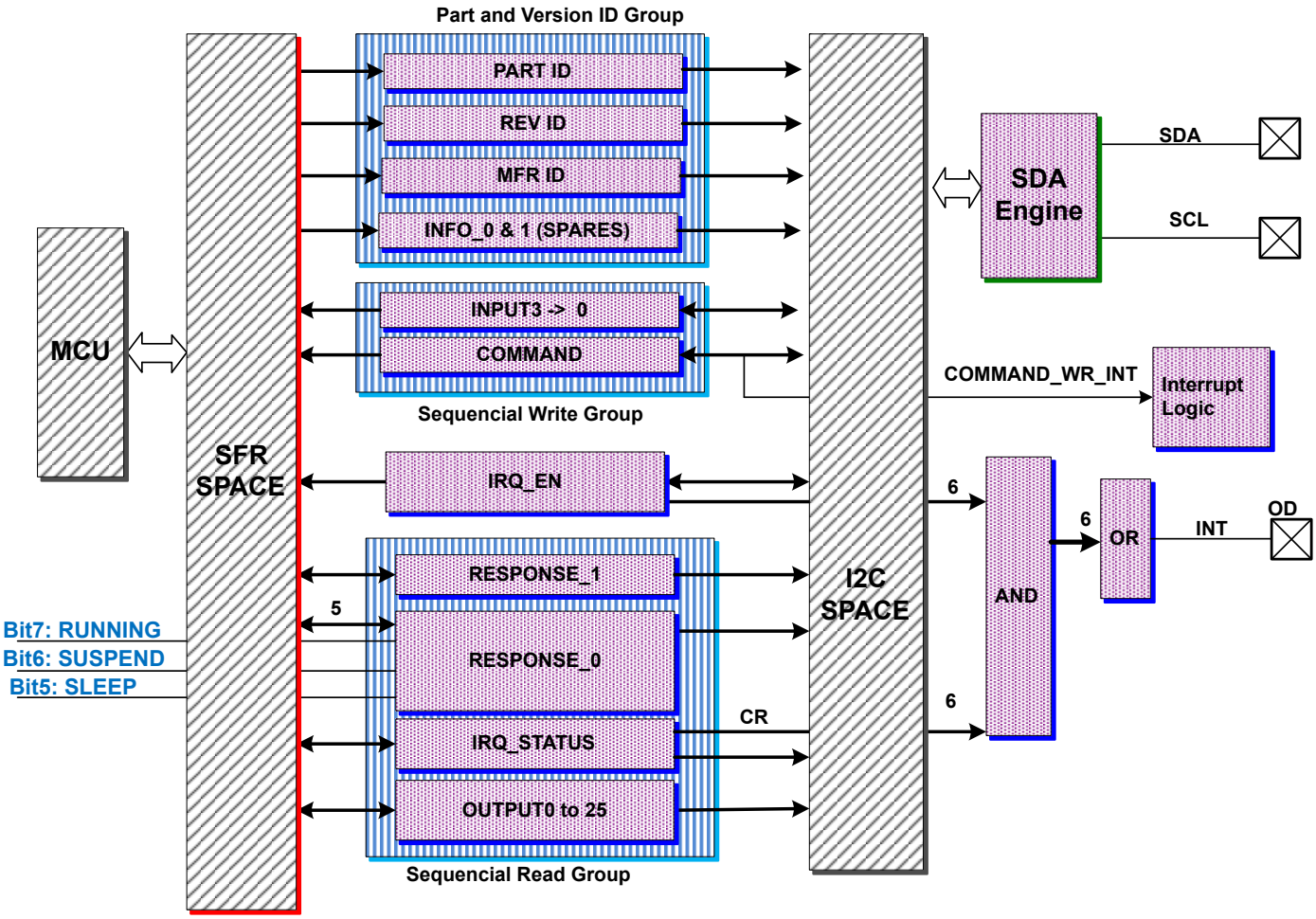



**Figure 5.1. I²C Interface Block Diagram**

### 5.2 Relationship Between I²C Registers and Parameter Table

Note that most of the Si1153 configuration is accomplished through ‘Parameters’. The Si1153 has an internal MCU with SRAM. The Parameters are stored in the Si1153 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 fix the operating modes of the Si1153.
  - 0x2C bytes long and is read and written indirectly, one bye at a time, via the command register.

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 | LED2_A |
| 0x22 | LED2_B |
| 0x23 | LED3_A |
| 0x24 | LED3_B |
| 0x25 | THRESHOLD0_H |
| 0x26 | THRESHOLD0_L |
| 0x27 | THRESHOLD1_H |
| 0x28 | THRESHOLD1_L |
| 0x29 | THRESHOLD2_H |
| 0x2A | THRESHOLD2_L |
| 0x2B | BURST |

**Figure 5.2. 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 RESPONSE_0 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 SW bug, the host should clear the error with a RESET command or a RESET_CMD_CTR command.

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

Two of the commands imply another I²C register contains an argument.

- STORE_NEW_I2C ADDR command implies a new address has been loaded in the parameter table location I2CID PARAMETER.
- PARAM_SET command implies a byte has been stuffed into INPUT0 register.
- The three CHAN_LIST commands imply the CHAN_LIST location in the parameter table has been configured. A valid CHAN_LIST implies other configuration areas in the parameter table are correctly setup as well.

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

- PARAM_SET results in the write data being copied in to I2C RESPONSE1 register.
- PARAM_QUERY results in read data in the I2C RESPONSE1 register.

**Table 5.1. Command Summary**

| Command Register Commands | Code | Input to Sensor | Output of Sensor |
|---|---|---|---|
| RESET_CMD_CTR<br><br>Resets RESPONSE0 CMMND_CTR field to 0. | 0x00 | ---------- | ---------- |
| RESET_SW<br><br>Forces a Reset, Resets RESPONSE0 CMMND_CTR field to 0xXXX01111. | 0x01 | ---------- | ---------- |
| FORCE<br><br>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 MEAS-CONFIGx. | 0x11 | ---------- | ---------- |
| PAUSE<br><br>Pauses autonomous measurements specified in CHAN_LIST. | 0x12 | ---------- | ---------- |
| START<br><br>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<br><br>Reads Parameter xxxxxx and store results in RE-SPONSE1.xxxxxx is a 6 bit Address Field (64 bytes). | 0b01xxxxxx | | RESPONSE1 = result |
| PARAM_SET<br><br>Writes INPUT0 to the Parameter xxxxxx.xxxxxx is a 6 bit Address Field (64 bytes). | 0b10xxxxxx | INPUT0 | RESPONSE1 = INPUT0 |

**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. Resets RESPONSE0 CMMND_CTR field to 0.
3. Forces a Reset, Resets RESPONSE0 CMMND_CTR field to 0xXXX01111.
4. Uses CHAN_LIST in Parameter Space.
5. "xxxxxx" is a 6-bit Address Field (64 bytes).

### 5.3.1 Accessing the Parameter Table (PARAM_QUERY & PARAM_SET Commands)

The parameter table is written to by writing the INPUT_0 I2C register and the PARAM_SET command byte to the Command $I^2C$ 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 CMMND_CTR field. |
| Write 0xA5 to INPUT0 (address 0x0A). | |
| Write 0b10010101 to COMMAND (address 0x0B). | |
| Read RESPONSE0 (address 0x11) | and check if the CMMND_CTR field incremented. |
| If there is no increment or error, repeat the “read the RESPONSE0” step until the CMMND_CTR has incremented. If there is an error send a RESET or a RESET_CMD_CTR command. | |
| The two write commands (to INPUT0 and COMMAND) can be in the same $I^2C$ transaction. | |

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

| | |
|---|---|
| Read the RESPONSE0 (address 0x11) | and store the CMMND_CTR field. |
| Write 0b01010101 to the COMMAND (address 0x0B). | |
| Read RESPONSE0 (address 0x11) | and check if the CMMND_CTR field incremented. |
| If there is no increment or error, repeat the “read RESPONSE0” step until the CMMND_CTR has incremented. | |
| Read RESPONSE1 (address 0x10) | this gives the read result. If there is an error send RESET or a RESET_CMD_CTR command. |
| The last two read commands (from RESPONSE0 and RESPONSE1) should not be in the same $I^2C$ 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 CMMND_CTR field and does nothing else.

### 5.3.4 RESET Command

Resets the sensor and puts it into the same state as when powering up. The parameter table and all $I^2C$ registers are reset to their default values.

### 5.4 I²C Register Summary

The content of the three MSBits of Response0 after reset will depend on the running state (see the Response0 write up).

**Table 5.2. I2C Registers**

| Register Name | I2C Address | Direction WRT Host | Function | Value after Reset (Hard or Soft) | Direction WRT Sensor |
|---|---|---|---|---|---|
| PART_ID | 0x00 | IN | Returns DEVID (0x53 for the Si1153). | PART_ID | OUT |
| HW_ID | 0x01 | IN | Returns Hardware ID. | HW_ID | OUT |
| REV_ID | 0x02 | IN | Hardware Rev (0xMN). | REV_ID | OUT |
| HOSTIN0 | 0x0A | IN/OUT | Data for parameter table on PARAM_SET write to COMMAND register. | 0x00 | IN |
| COMMAND | 0x0B | IN/OUT | Initiated action in Sensor when specific codes written here. | 0x00 | IN |
| IRQENABLE | 0x0F | IN/OUT | The six least significant bits enable Interrupt Operation. | 0x00 | IN |
| RESPONSE1 | 0x10 | IN | Contains the readback value from a param query or a param set command. | 0x00 | IN/OUT |
| RESPONSE0 | 0x11 | IN | The 5th MSB of the counter is an error indicator, with the 4 LSBits indicating the error code when the MSB is set. | 0xXXXX1111 | IN/OUT |
| IRQ_STATUS | 0x12 | IN | The six least significant bits show the interrupt status. | 0x00 | IN/OUT |
| HOSTOUT0 to HOSTOUT25 | 0x13 to 0x2C | IN | Captured Sensor Data. | 0x00 | IN/OUT |

#### 5.4.1 PART_ID

**I2C Address = 0x00;**

Contains Part ID, e.g., 0x53 for Si1153.

### 5.4.2 HW_ID

**I2C Address = 0x01;**

Contains the Hardware information.

BITS4:0 = Filter, LED & Module code

BITS7:5 = Silicon HW rev (Steps with silicon mask change)

| Part Number | Features | BITS4:0 code |
|---|---|---|
| Si1153-AA00 | — | 0x00 |
| Si1153-AA09 | 940 nm filter | 0x01 |
| Si1153-AAX9 | 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.

### 5.4.4 INFO0

**I2C Address = 3;**

Contains 0 after a hard reset or a RESET Command.

### 5.4.5 INFO1

**I2C Address = 4;**

Contains 0 after a hard reset or a RESET Command.

### 5.4.6 HOSTIN0

| Name | I2C Address |
|---|---|
| HOSTIN0 | 0x0A |

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

| Bit | Name | Function |
|---|---|---|
| 7:0 | HOSTIN0 | This Register is the Input to the Sensor and Output of the Host. |

Contain 0 after a hard reset or a RESET Command.

### 5.4.7 COMMAND

**I2C Address = 0x0B;**

Contains 0 after a hard reset or a RESET Command.

### 5.4.8 IRQENABLE

**I2C Address = 0x0F;**

Contains 0 after a hard reset or a RESET Command.

### 5.4.9 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.<br><br>A parameter read command results in the byte read being available here for the host. |

### 5.4.10 RESPONSE0

**I2C Address = 0x11;**

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

<table>
<tr><th>Bit</th><th>Name</th><th colspan="3">Function</th></tr>
<tr><td>7</td><td>RUNNING</td><td colspan="3">Indicator of MCU state.</td></tr>
<tr><td>6</td><td>SUSPEND</td><td colspan="3">Indicator of MCU state.</td></tr>
<tr><td>5</td><td>SLEEP</td><td colspan="3">Indicator of MCU state.</td></tr>
<tr><td>4</td><td>CMD_ERR</td><td colspan="3">It is cleared by a hardware reset (power up) or a RESET command or a RESET_CMD_CTR.<br><br>It is set by a bad command. E.g., an attempt to write beyond the parameter table.<br><br>If it is set, the CMMND_CTR field is the error code.</td></tr>
<tr><td rowspan="6">3:0</td><td rowspan="6">CMMND_CTR</td><td>IF CMD_ERR = 0</td><td colspan="2">A counter that increments on every GOOD command (successful I<sup>2</sup>C Command Register write and sensor execution of the command).<br><br>It is reset to 0 by the RESET_CMD_CTR command.<br><br>It is set to 0b1111 on Power Up or a RESET command. This is how a user can detect a fresh SW reset or a power up event.</td></tr>
<tr><td rowspan="5">IF CMD_ERR = 1</td><td>Code</td><td>Meaning</td></tr>
<tr><td>0x10</td><td>Invalid command.</td></tr>
<tr><td>0x11</td><td>Parameter access to an invalid location.</td></tr>
<tr><td>0x12</td><td>Saturation of the ADC or overflow of accumulation.</td></tr>
<tr><td>0x13</td><td>Output buffer overflow—this can happen when Burst mode is enabled and configured for greater than 26 bytes of output.</td></tr>
</table>

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

### 5.4.11 IRQ_STATUS

**I2C Address = 0x12;**

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

| Bit | Name | Function |
|---|---|---|
| 7:6 | UNUSED | Unused. Read = 00b; Write = Don't Care. |
| 5 | IRQ5 | Enables an IRQ for channel 5 result being ready. |
| 4 | IRQ4 | Enables an IRQ for channel 4 result being ready. |
| 3 | IRQ3 | Enables an IRQ for channel 3 result being ready. |
| 2 | IRQ2 | Enables an IRQ for channel 2 result being ready. |
| 1 | IRQ1 | Enables an IRQ for channel 1 result being ready |
| 0 | IRQ0 | Enables an IRQ for channel 0 result being ready. |

### 5.4.12 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<br>to<br>HOSTOUT25 | 0x13<br>to<br>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 the output of the MCU and input to the host. 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.<br><br>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 affect 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 three light thresholds that can be selected from 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 Address | 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 Address | 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 |

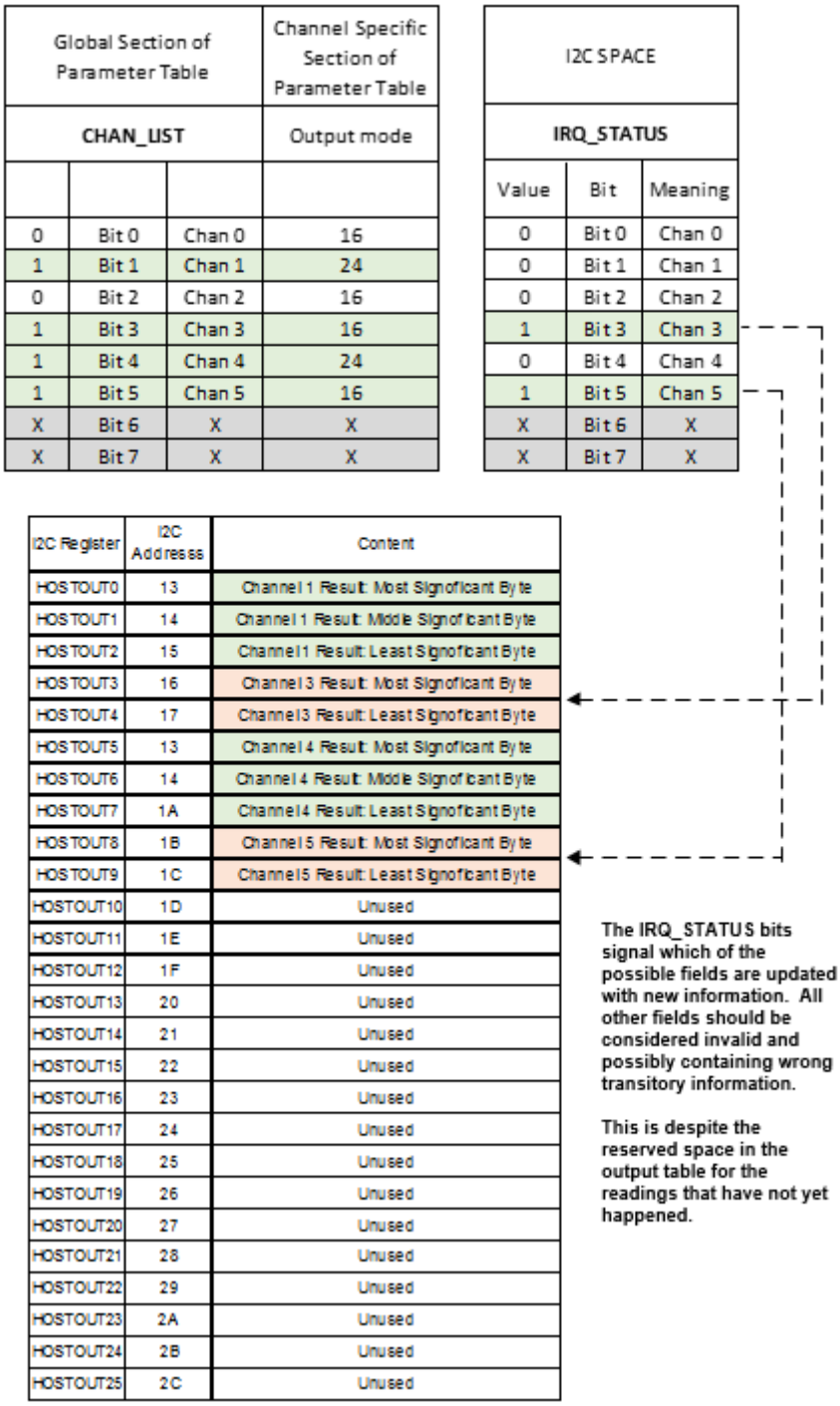



**Figure 6.2. IRQ_STATUS Shows Which Output Fields Have Valid Data**

### 6.3 Burst Mode

Burst Mode is always used in Autonomous Mode.

The Burst Mode is enabled by the BURST register's bit 7. 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.

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 Signoficant Byte |
| | HOSTOUT1 | 14 | Channel 1 Result: Middle Signoficant Byte |
| | HOSTOUT2 | 15 | Channel 1 Result: Least Signoficant Byte |
| | HOSTOUT3 | 16 | Channel 3 Result: Most Signoficant Byte |
| | HOSTOUT4 | 17 | Channel 3 Result: Least Signoficant Byte |
| | HOSTOUT5 | 13 | Channel 4 Result: Most Signoficant Byte |
| | HOSTOUT6 | 14 | Channel 4 Result: Middle Signoficant Byte |
| | HOSTOUT7 | 1A | Channel 4 Result: Least Signoficant Byte |
| | HOSTOUT8 | 1B | Channel 5 Result: Most Signoficant Byte |
| | HOSTOUT9 | 1C | Channel 5 Result: Least Signoficant Byte |
| Reading Set 1 | HOSTOUT10 | 1D | Channel 1 Result: Most Signoficant Byte |
| | HOSTOUT11 | 1E | Channel 1 Result: Middle Signoficant Byte |
| | HOSTOUT12 | 1F | Channel 1 Result: Least Signoficant Byte |
| | HOSTOUT13 | 20 | Channel 3 Result: Most Signoficant Byte |
| | HOSTOUT14 | 21 | Channel 3 Result: Least Signoficant Byte |
| | HOSTOUT15 | 22 | Channel 4 Result: Most Signoficant Byte |
| | HOSTOUT16 | 23 | Channel 4 Result: Middle Signoficant Byte |
| | HOSTOUT17 | 24 | Channel 4 Result: Least Signoficant Byte |
| | HOSTOUT18 | 25 | Channel 5 Result: Most Signoficant Byte |
| | HOSTOUT19 | 26 | Channel 5 Result: Least Signoficant 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 RESET 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 Si1153 is an $I^2C$ Burst Read beginning at the IRQ_STATUS register.

### 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. See the timing diagram below for an example of ALS and proximity measurement timing.

Global Parameter Table's
Timing Paramters

| |
|---|
| MEASRATE_H = 0 |
| MEASRATE_L = 1 |
| MEASCOUNT1 = 5 |
| MEASCOUNT2 = 10 |
| MEASCOUNT3 = X |

MEASRATE is 1 for a base period of 800 us

MEASCONFIG1.COUNTER_INDEX[1:0] selects MEASCOUNT1 which is 5. This makes Chan1 meas. period equal to 4ms

MEASCONFIG3.COUNTER_INDEX[1:0] selects MEASCOUNT2 which is 10. This makes Chan3 meas. period equal to 8 ms

CHANNEL 1 Setup

| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| ADCCONFIGx | RSRVD | DECIM_RATE[1:0] = 0 | | ADCMUX[4:0] | | | | |
| ADCSENSx | HSIG | SW_GAIN[2:0] = 0 | | | HW_GAIN[3:0] = 2 | | | |
| ADCPOSTx | RSRVD | 24BIT_OUT | POSTSHIFT[2:0 | | | UNUSED | THRESH_SEL[1:0] | |
| MEASCONFIGx | COUNTER_INDEX[1:0] = 1 | | LED_TRIM[1:0] | | BANK_SEL | Led 2 En. | Led 3 En. | LED1 En. |

CHANNEL 3 Setup

| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|---|---|
| ADCCONFIGx | RSRVD | DECIM_RATE[1:0] = 0 | | ADCMUX[4:0] | | | | |
| ADCSENSx | HSIG | SW_GAIN[2:0] = 0 | | | HW_GAIN[3:0] = 3 | | | |
| ADCPOSTx | RSRVD | 24BIT_OUT | POSTSHIFT[2:0 | | | UNUSED | THRESH_SEL[1:0] | |
| MEASCONFIGx | COUNTER_INDEX[1:0] = 2 | | LED_TRIM[1:0] | | BANK_SEL | LED3 En. | LED2 En. | LED1 En. |

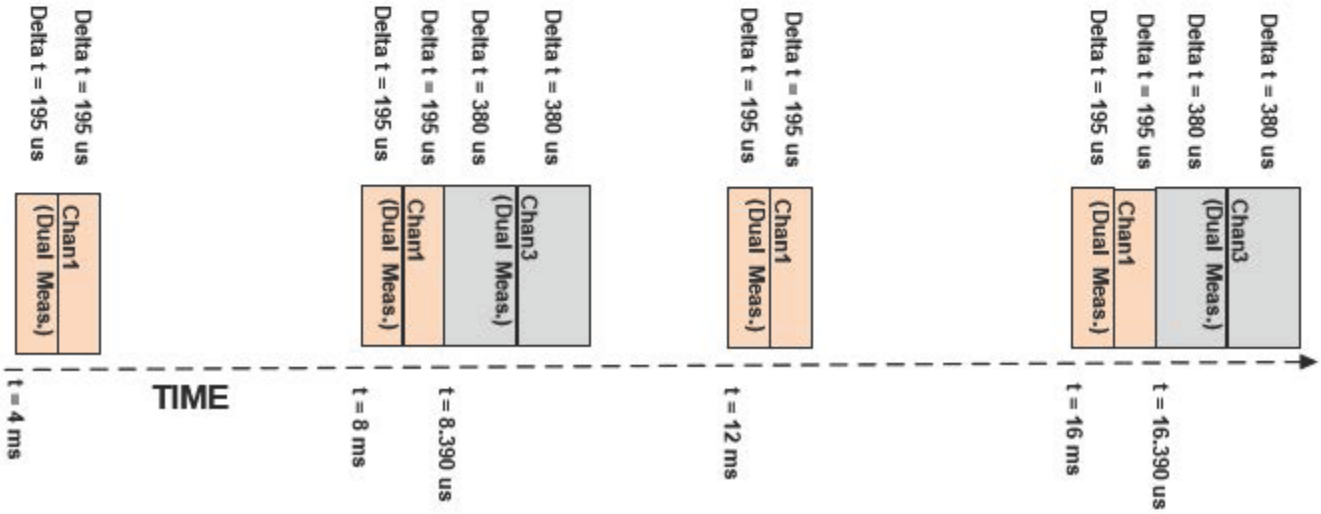



**Figure 6.4. Example of Measurement Timing**

# 7. Parameter Table

**Table 7.1. Parameter Table**

| Address | Name | Description | |
|---|---|---|---|
| 0x00 | I2C_ADDR | I2C Address (Temp) | Global Area: Affects all Channels |
| 0x01 | CHAN_LIST | Channel List | |
| 0x02 | ADCCONFIG0 | Channel 0 Setup | Channel Areas: Specific Channel Setup |
| 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 | |
|---|---|---|---|
| 0x1A | MEASRATE_H | MEASURE RATE | Global Area: Affects all Channels |
| 0x1B | MEASRATE_L | | |
| 0x1C | MEASCOUNT0 | MEASCOUNT | |
| 0x1D | MEASCOUNT1 | | |
| 0x1E | MEASCOUNT2 | | |
| 0x25 | THRESHOLD0_H | THRESHOLD SETUP | |
| 0x26 | THRESHOLD0_L | | |
| 0x27 | THRESHOLD1_H | | |
| 0x28 | THRESHOLD1_L | | |
| 0x29 | THRESHOLD2_H | | |
| 0x2A | THRESHOLD2_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 | | | |
|---|---|---|---|---|
| MEASRATE[1] | 0x1A | MEASRATE[15:8] | Main Measurement Rate Counter | Governs how much time between measurement groups. One count represents an 800 µs time period. |
| MEASRATE[0] | 0x1B | MEASRATE[7:0] | | |
| MEASCOUNT0 | 0x1C | MEASCOUNT0[7:0] | Three Measurement Rate extension counters available for setting the rate. | Each of 6 channel setups selected which of these counters to use via the MEASCONFIG::COUNTER_INDEX[1:0] bits: |
| MEASCOUNT1 | 0x1D | MEASCOUNT1[7:0] | | |
| MEASCOUNT2 | 0x1E | MEASCOUNT2[7:0] | | |
| THRESHOLD0[1] | 0x25 | THRESHOLD0[15:8] | THRESHOLD0 | One of these three (or none) us Chosen by MEASCONFIGx.THRESH_SEL[1:0] |
| THRESHOLD0[0] | 0x26 | THRESHOLD0[7:0] | | |
| THRESHOLD1[1] | 0x27 | THRESHOLD1[15:8] | THRESHOLD1 | |
| THRESHOLD1[0] | 0x28 | THRESHOLD1[7:0] | | |
| THRESHOLD2[1] | 0x29 | THRESHOLD2[15:8] | THRESHOLD2 | |
| THRESHOLD2[0] | 0x2A | THRESHOLD2[7:0] | | |
| BURST | 0x2B | BURST[7:0] | | Bit 7 is Burst Enable while BURST_COUNT[6:0] are the count |
| CHAN_LIST | 0x01 | CHAN_LIST[5:0] | | The six least significant bits enable the 6 possible channels. |

### 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 0x18 hex.

**Table 7.3. Channel Specific Setup Areas of the Parameter Table**

| | 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] | | | UNUSED | THRESH_SEL[1:0] | |
| MEASCONFIGx | COUNTER_INDEX[1:0] | | LED_TRIM[1:0] | | BANK_SEL | LED2 En. | LED3 En. | LED1 En. |

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

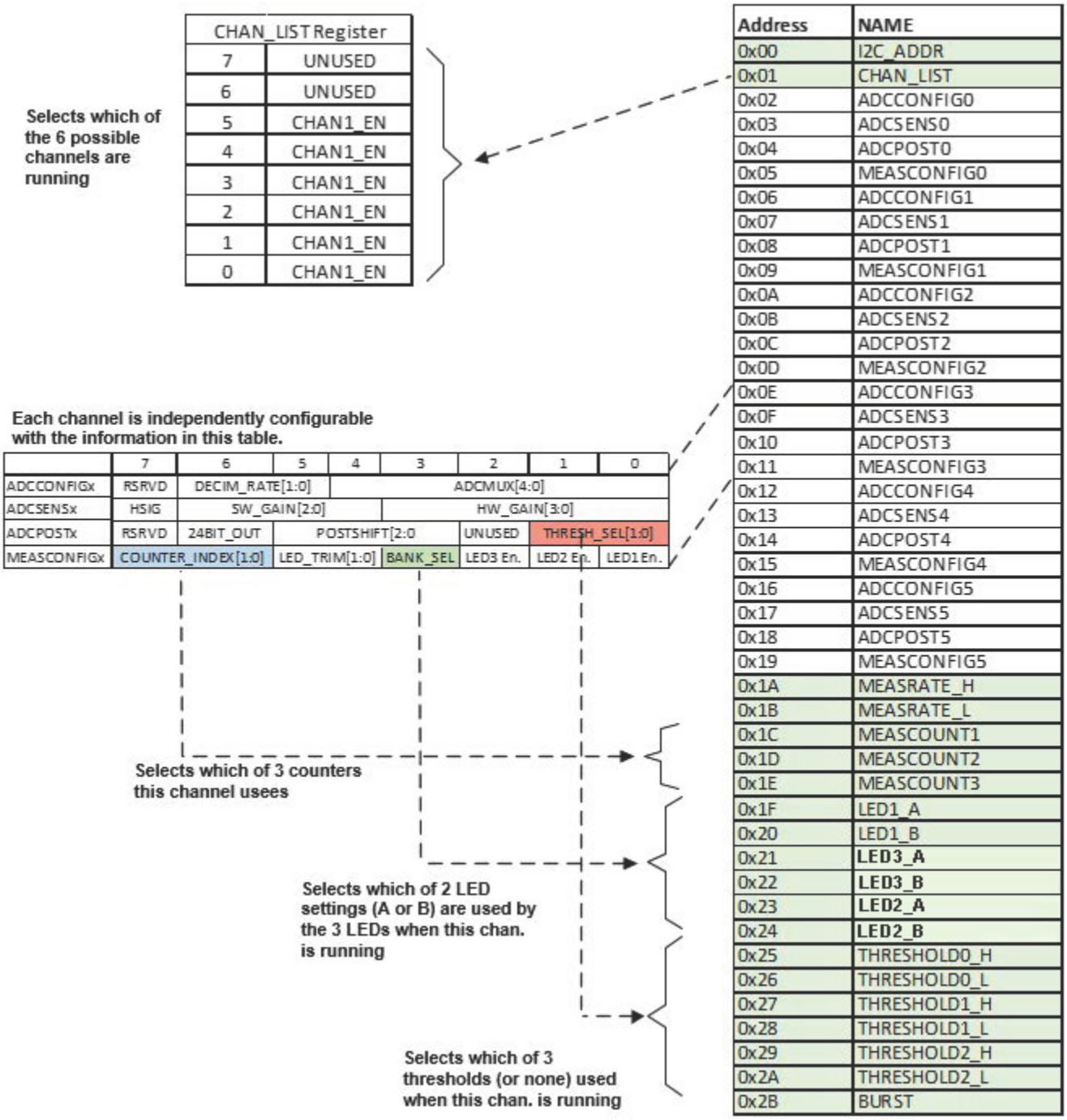



**Figure 7.1. THRESH_SEL, COUNTER_INDEX Fields in Each Channel Specific Register Area Points to Global Area Register THRESHOLDx and MEASCOUNTx (Respectively)**

**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 (0, 1, or 2) 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 | Reserved | DECIM_RATE[1:0] | | ADCMUX[4:0] | | | | |
| Reset | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Bit | Name | Function |
|---|---|---|
| 7 | RESERVED | Must remain at 0. |
| 6:5 | DEC-IM_RATE[1:0] | Selects 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.<br><br>Increasing the reading time by using more clocks 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.<br><br>See Photodiode Section for more information regarding the location of the photodiodes. |
|---|---|---|

| ADCMUX[4:0] | | | | | Optical Functions | Operation | Comments |
|---|---|---|---|---|---|---|---|
| 0 | 0 | 0 | 0 | 0 | Small IR | D1b | |
| 0 | 0 | 0 | 0 | 1 | Medium IR | D1b + D2b | |
| 0 | 0 | 0 | 1 | 0 | Large IR | D1b + D2b + D3b + D4b | |
| 0 | 1 | 0 | 1 | 1 | White | D1 | |
| 0 | 1 | 1 | 0 | 1 | Large White | D1 + D4 | |

### 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 | This is the Ranging bit for the A/D. Normal gain at 0 and High range (sensitivity is divided by 14.5) when set to 1. | |
| 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.<br><br>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 clocks |
| | | 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] | | | UNUSED | THRESH_EN[1:0] | |
| Reset | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| Bit | Name | Function | | |
|---|---|---|---|---|
| 7 | RESERVED | Must be set to 0 | | |
| 6 | 24BIT_OUT | Determines the size of the fields in the output registers. | | |
| | | Value | Bits/Result | Output |
| | | 0 | 16 | Unsigned integer |
| | | 1 | 24 | Signed Integer |
| | | | | |
| 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 | UNUSED | | | |
| 1:0 | THRESH_EN [1:0] | Value | Operation | |
| | | 0 | Do not use THRESHOLDs | |
| | | 1 | Interrupt when the measurement is larger than the THRESHOLD0 Global Parameters | |
| | | 2 | Interrupt when the measurement is larger than the THRESHOLD1 Global Parameters | |
| | | 3 | Interrupt when the measurement is larger than the THRESHOLD2 Global Parameters | |

### 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] | | LED_TRIM[1:0] | | 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**.<br><br>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 | LED_TRIM[1:0] | **Value** | **Results** |
| | | 0 | Nominal LED Currents |
| | | 1 | UNDEFINED |
| | | 2 | LED Currents Increased by 9% |
| | | 3 | LED Currents decreased by 10% |
| 3 | BANK_SEL | **Value** | LED Current Registers Selected in Global Register Area |
| | | 0 | LED1_A, LED2_A, LED3_A |
| | | 1 | LED1_B, LED2_B, LED3_B |
| 2 | LED2_EN | One value enables the LED | |
| 1 | LED3_EN | One value enables the LED | |
| 0 | LED1_EN | One value enables the LED | |

### 7.3 Photodiode Selection

The ADCCONFIGx.ADCMUX [4:0] Register controls the photodiode selection.

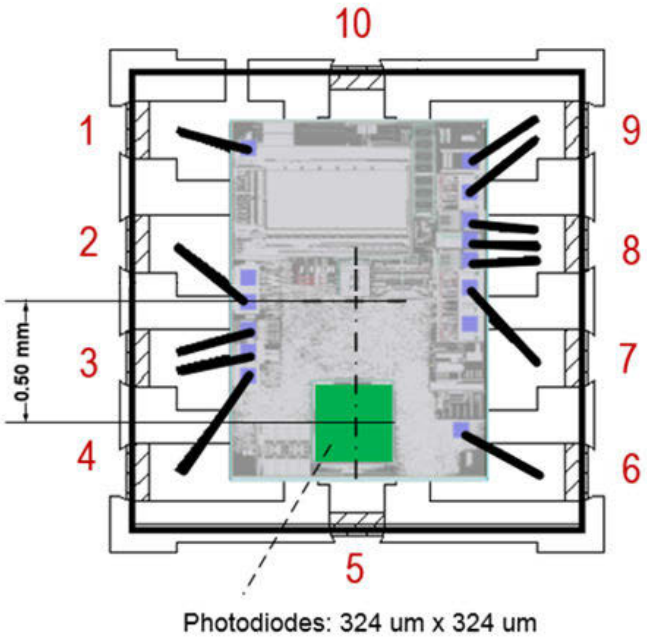



**Figure 7.2. Photodiode Locations**

# 8. Electrical Specifications

**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 | | 1.0 | V |
| $V_{DD}$ Supply Ripple Voltage | | $V_{DD}$ = 3.3 V<br>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<br>No $I^2C$ Activity<br>$V_{DD}$ = 1.8 V | — | 125 | — | nA |
| | Isb | No ADC Conversions<br>No $I^2C$ Activity<br>$V_{DD}$ = 3.3 V | — | 1.25 | — | µA |
| $I_{DD}$ Suspend Mode | Isus | Autonomous Operation (RTC On)<br>ADC conversion in Progress<br>No $I^2C$ Activity<br>$V_{DD}$ = 1.8 V | — | 0.550 | — | mA |
| | Isus | Autonomous Operation (RTC On)<br>ADC conversion in Progress<br>No $I^2C$ Activity<br>$V_{DD}$ = 3.3 V | — | 0.525 | — | mA |

| Parameter | Symbol | Condition[1] | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| 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 Prox | | 155 | | µs |
| A/D startup time per measurement *(During this time the current is I Suspend)* | $t_{adstart}$ | ALS or Prox | — | 48.8 | — | µs |
| Ratio of readings with HSIG=0 and HSIG=1 for the shallow PD. | | 525 nm, Internal ADCMUX=11, ADC_GAIN=0 | — | 15.2 | — | units |
| Ratio of readings with HSIG=0 and HSIG=1 for the deep PD. | | 940 nm ADCMUX=0, ADC_GAIN=0 | — | 15.2 | — | units |
| 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.

**Table 8.3. Optical Performance Characteristics: Si1153-AA00**

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| White minus Dark Shallow Photodiode Response<br><br>ADCMUX=11<br>DECIM=0<br>ADC_RANGE=0<br>HSIG=0 | | 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 | — | |
| Dual White minus Dual Dark Photodiode Response<br><br>ADCMUX=13<br>DECIM=0<br>ADC_GAIN = 0<br>HSIG=0 | | 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 | — | |
| Deep minus Dark<br><br>Photodiode Response<br><br>ADCMUX=0<br>DECIM=0<br>ADC_GAIN =0<br>HSIG=0 | | 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 | — | |
| Dual Deep Photodiode minus Dual Dark<br><br>Photodiode Response<br><br>ADCMUX=1<br>DECIM=0<br>ADC_GAIN =0<br>HSIG=0 | | 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 | — | |

**Table 8.4. Optical Performance Characteristics: Si1153-AA09**

| Parameter | Symbol | Condition | Min | Typ | Max | Unit |
|---|---|---|---|---|---|---|
| White minus Dark Shallow Photodiode Response<br><br>ADCMUX=11<br>DECIM=0<br>ADC_RANGE=0<br>HSIG=0 | | 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 | — | |
| Dual White minus Dual Dark Photodiode Response<br><br>ADCMUX=13<br>DECIM=0<br>ADC_GAIN = 0<br>HSIG=0 | | 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 | — | |
| Deep minus Dark<br>Photodiode Response<br><br>ADCMUX=0<br>DECIM=0<br>ADC_GAIN =0<br>HSIG=0 | | 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 | — | |
| Dual Deep Photodiode minus Dual Dark<br>Photodiode Response<br>ADCMUX=1<br>DECIM=0<br>ADC_GAIN =0<br>HSIG=0 | | 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 | — | °C |

**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.

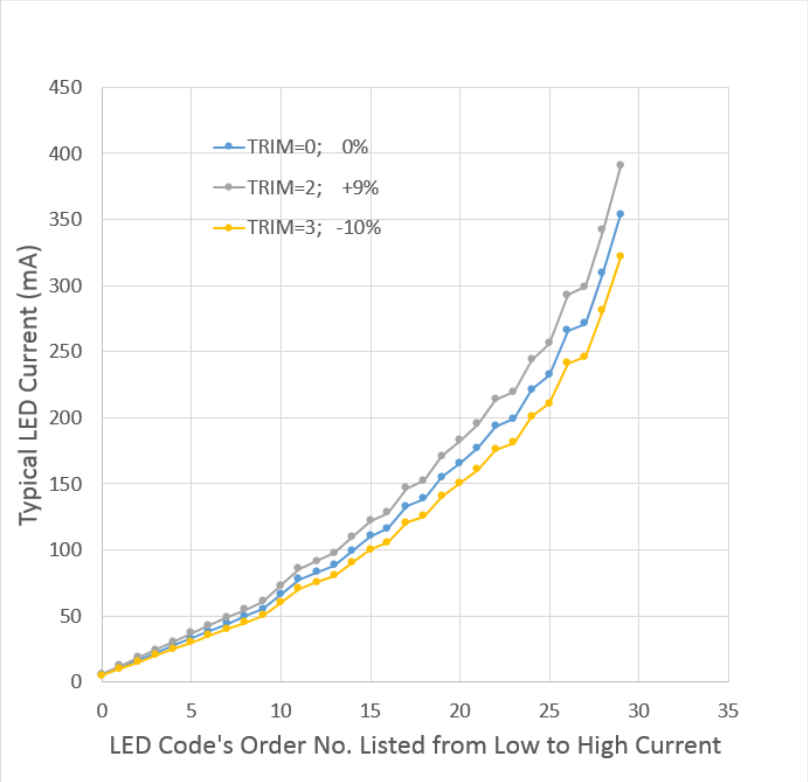



**Figure 8.1. Typical LED Currents as a Function of LED Code and the Trim Bit**

**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.

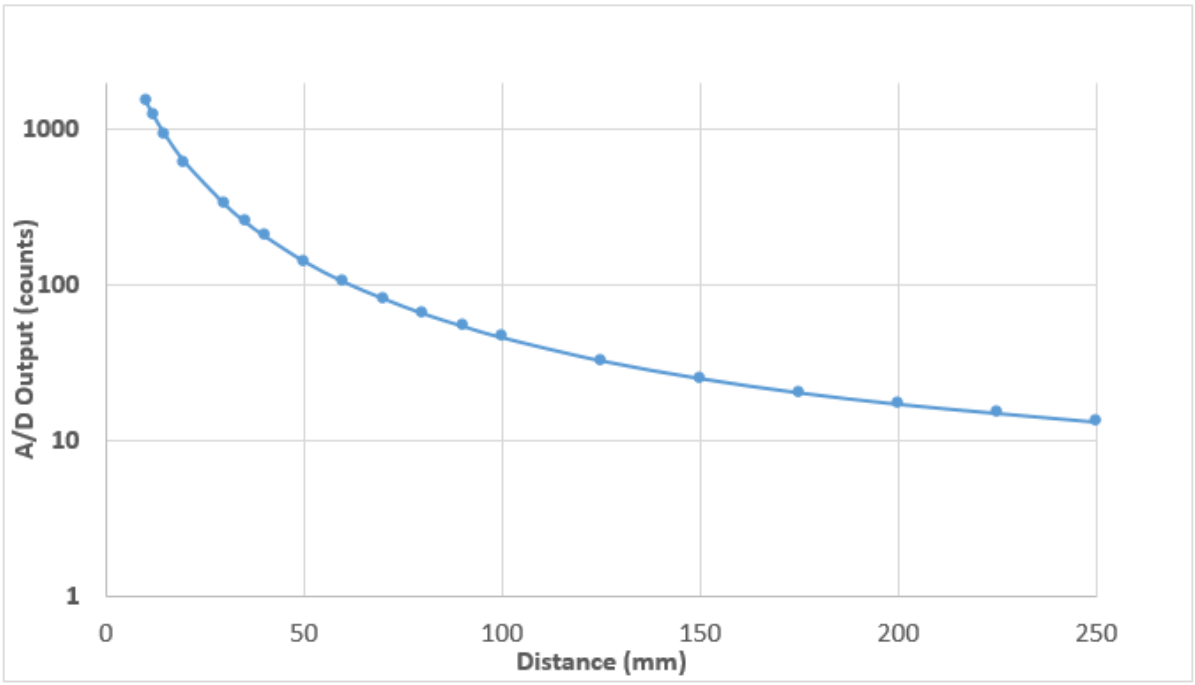



**Figure 8.2. ADC Out as a Function of Distance**

**Note:** The above graph is created under the following conditions: (LED I = 16.6 mA, t = 24.4 µs, Range = low). Grey 18% reflector. Dual Section photodiode. LED beam ½ power is at ±30 °C. Output is 5 mW total.

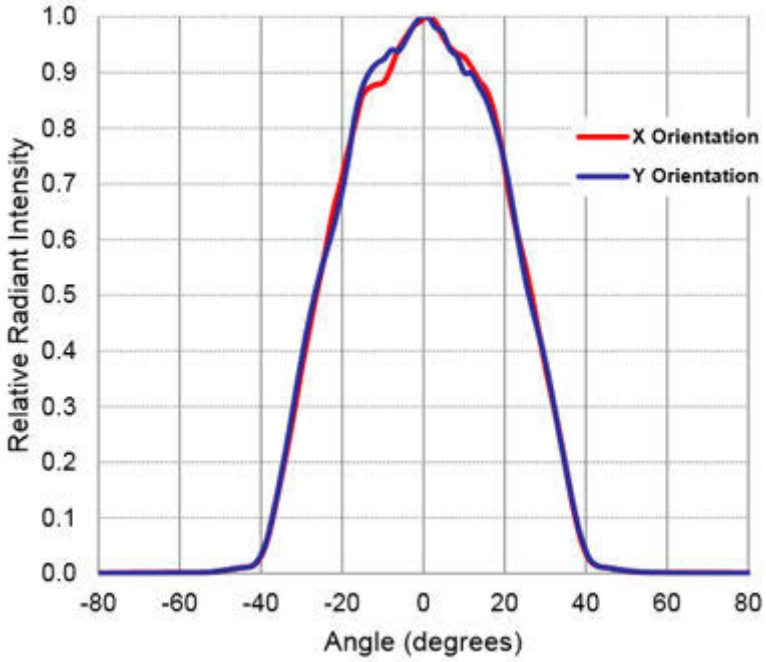



**Figure 8.3. Si115-AA9X LED Radiant Intensity vs. Angle (Indicative)**

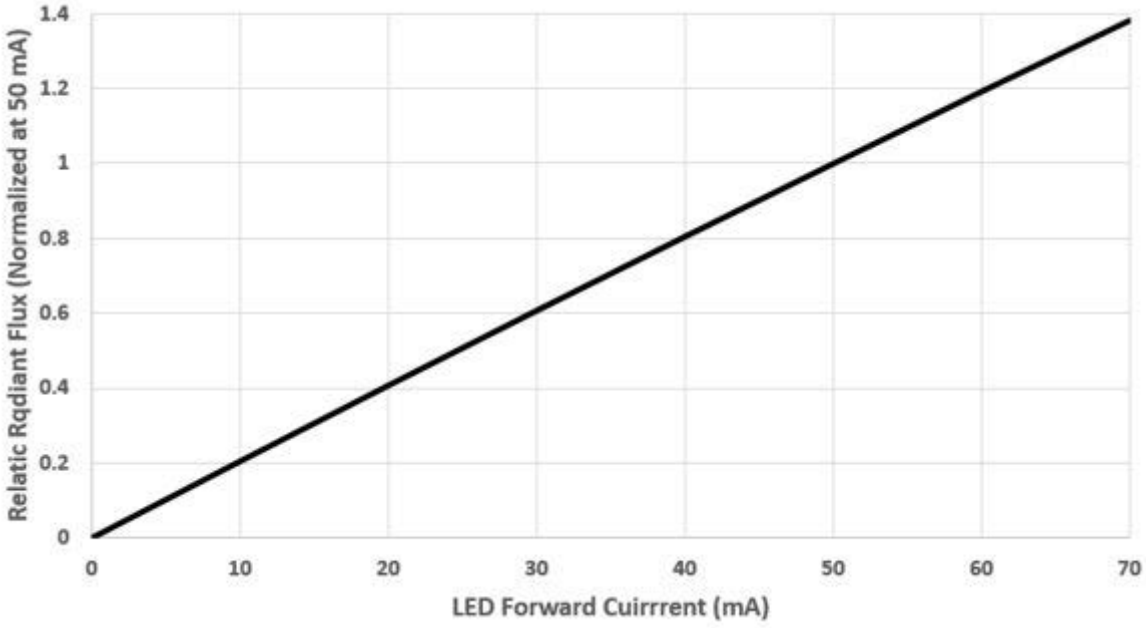



**Figure 8.4. Si115-AA9X LED Radiant Intensity vs. Forward Current (Indicative)**

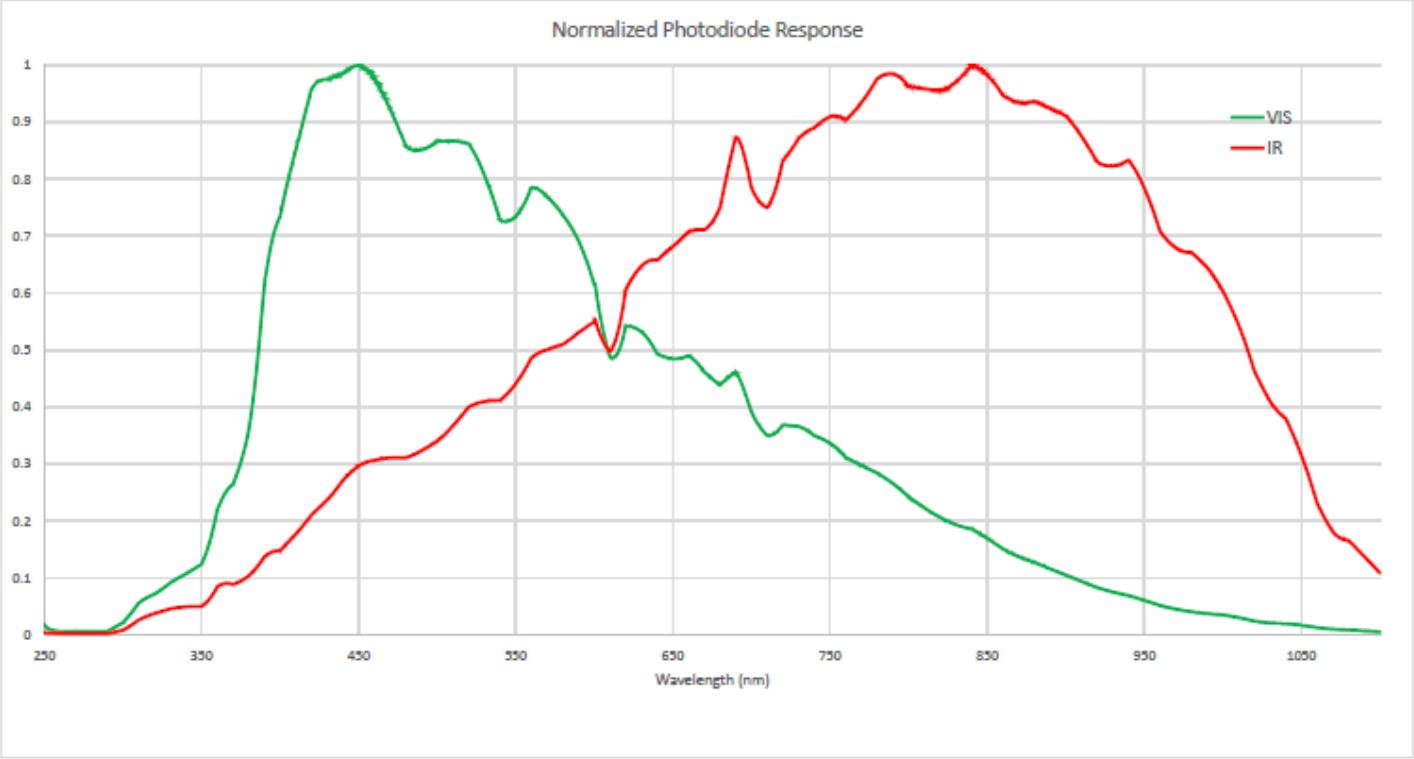



**Figure 8.5. Si1153-AA00 Shallow and Deep Photodiode Spectral Response (Indicative)**

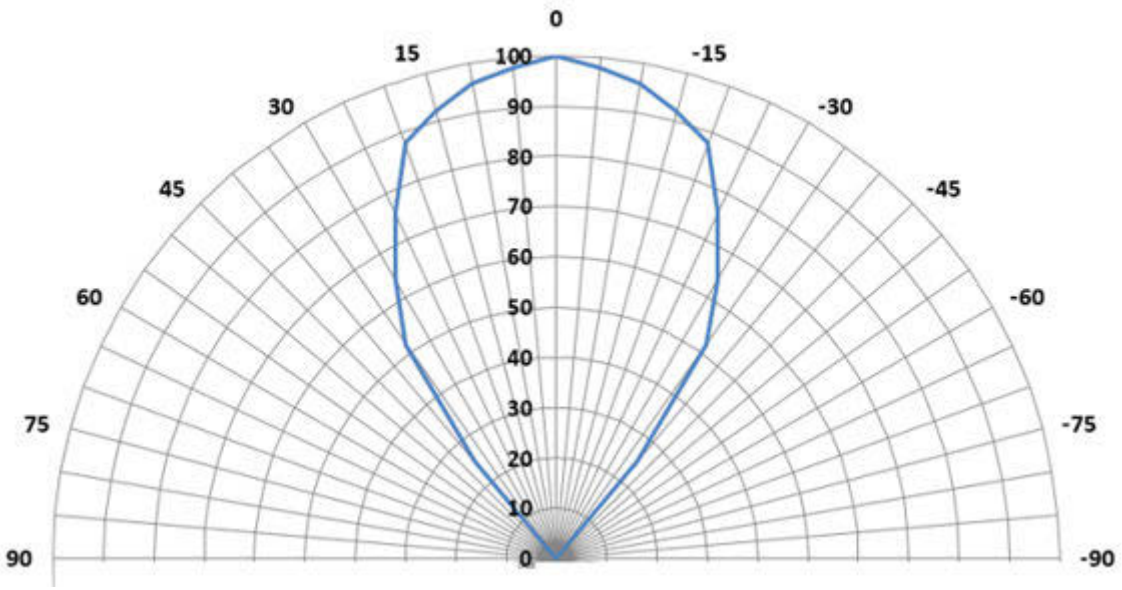



**Figure 8.6. Typical Angular Sensitivity of the Photodiodes (%)**

# 9. Pin Descriptions

## 9.1 DFN Pin Description

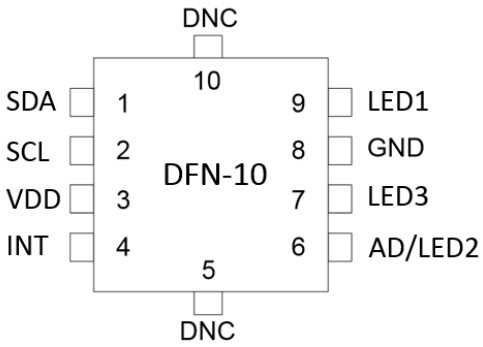



**Figure 9.1. 10-Pin DFN**

**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.<br>Voltage source. |
| 4 | INT | Bidirectional | Interrupt Output.<br>Open-drain interrupt output pin. Must be at logic level high during power-up sequence to enable low power operation. |
| 5 | DNC | | Do Not Connect.<br>This pin is electrically connected to an internal Si1153 node. It should remain unconnected. |
| 6 | AD / LED2 | Bidirectional | LED2 output.<br>It is sensed during startup. Pull up to VDD with 47 k Resistor for default $I^2C$ address (0x53). Pull down with 47 k Resistor to select alternate $I^2C$ address (0c52) and do not use it as an LED driver in that case. |
| 7 | LED3 | Bidirectional | LED3 output.<br>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.<br>Reference voltage. |
| 9 | LED1 | Output | Connect to $V_{DD}$.<br>Connect to $V_{DD}$ through a pull-up resistor when not in use. |
| 10 | DNC | | Do Not Connect.<br>This pin is electrically connected to an internal Si1153 node. It should remain unconnected. |

### 9.2 Module Pin Description

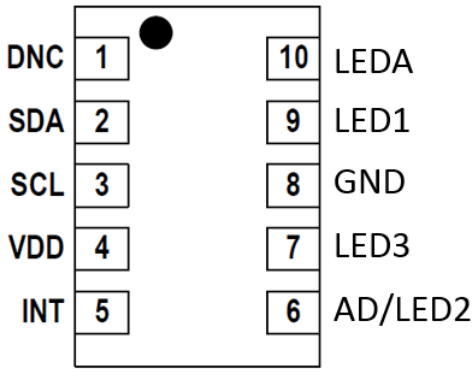



**Figure 9.2. 2 x 2 mm QFN**

**Table 9.2. Pin Descriptions**

| Pin | Name | Type | Description |
|---|---|---|---|
| 1 | DNC | | Do Not Connect.<br><br>This pin is electrically connected to an internal Si1153 node. It should remain unconnected. |
| 2 | SDA | Bidirectional | $I^2C$ Data. |
| 3 | SCL | Input | $I^2C$ Clock. |
| 4 | VDD | Power | Power Supply.<br><br>Voltage source. |
| 5 | INT | Bidirectional | Interrupt Output.<br><br>Open-drain interrupt output pin. Must be at logic level high during power-up sequence to enable low power operation. |
| 6 | AD / LED2 | Bidirectional | LED2 output.<br><br>It is sensed during startup. Pull up to VDD with 47 k Resistor for default I2C address (0x53). Pull down with 47 k Resistor to select alternate I2C address (0c52) and do not use it as an LED driver in that case. |
| 7 | LED3 | Bidirectional | LED3 output.<br><br>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.<br><br>Reference voltage. |
| 9 | LED1 | Output | Connect to $V_{DD}$.<br><br>Connect to $V_{DD}$ through a pull-up resistor when not in use. |
| 10 | LEDA | | LED Anode Supply. Connect to VLED. |

# 10. Modules Outline

## 10.1 10-Pin 2x2 mm DFN

DFN Package Diagram Dimensions illustrates the package details for the Si1153 DFN package lists the values for the dimensions shown in the illustration.

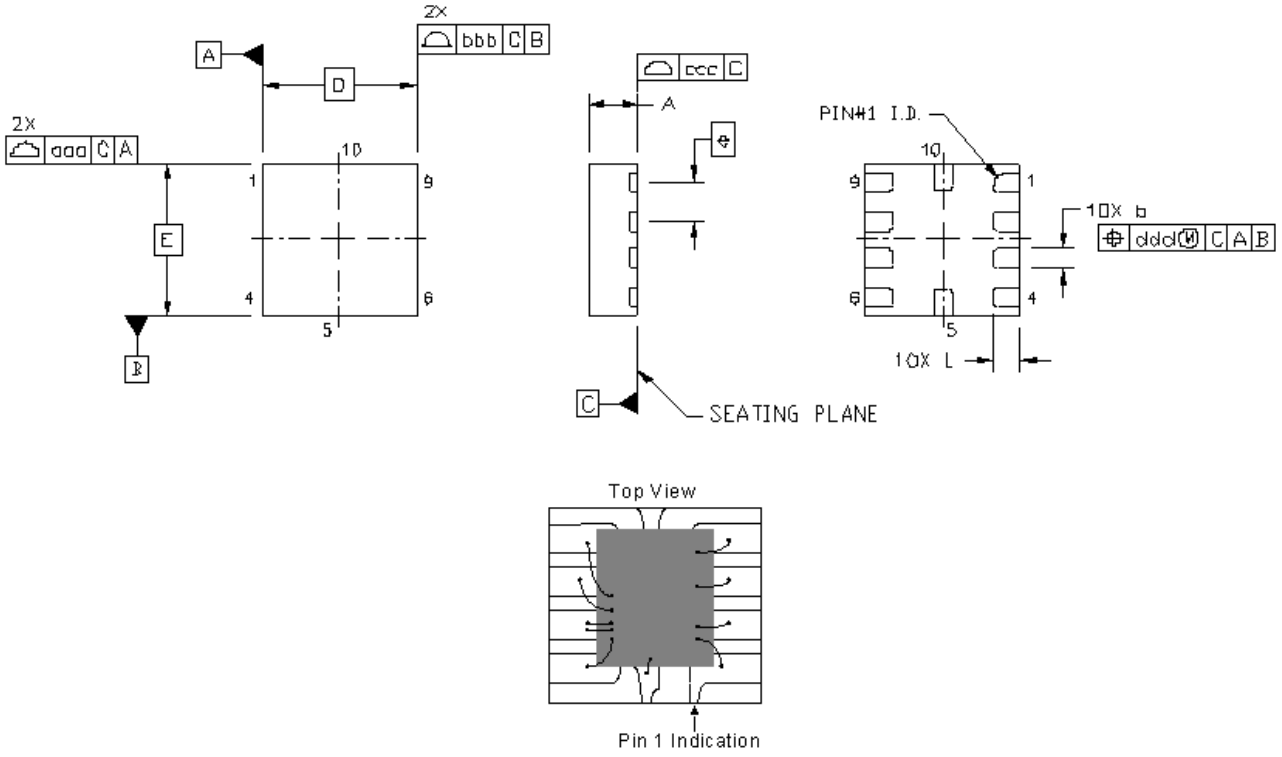



**Figure 10.1. DFN Package Diagram Dimensions**

**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 Si1153 DFN package while the table lists the values for the dimensions shown in the illustration.

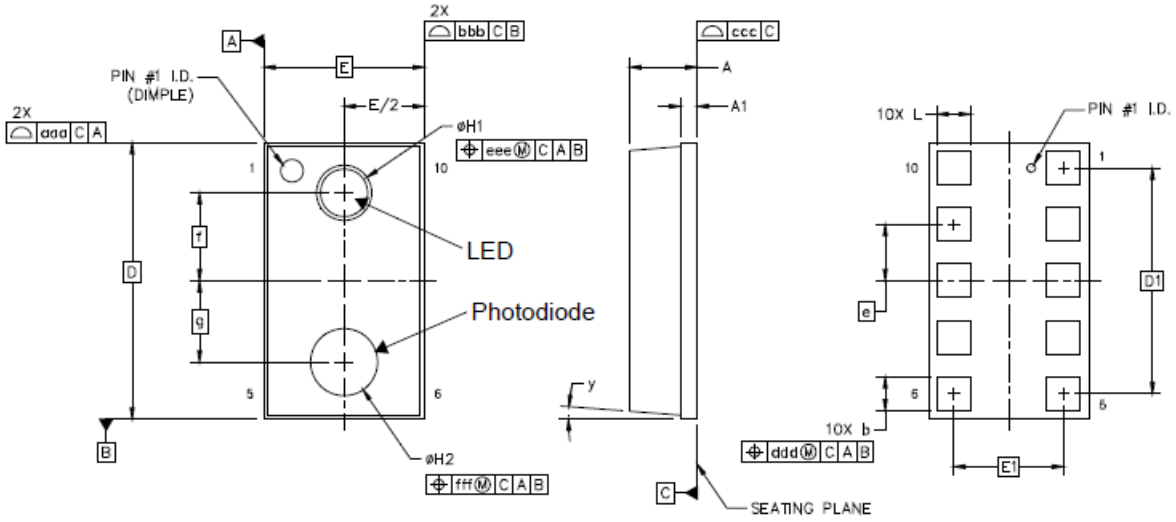



**Figure 10.2. DFN Package Diagram Dimensions**

**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.

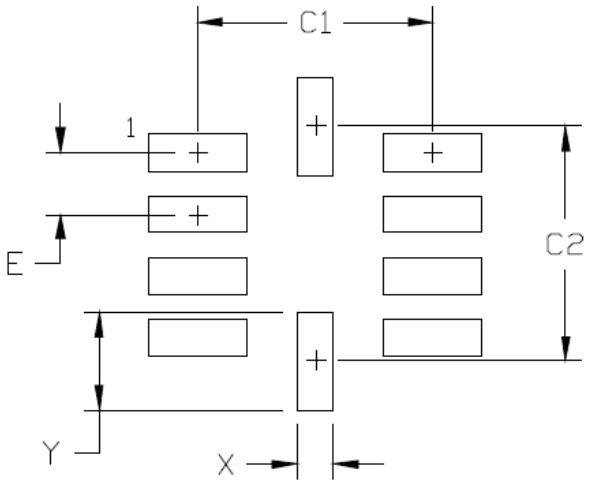



**Figure 11.1. 2 x 2 mm DFN PCB Land Pattern**

**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

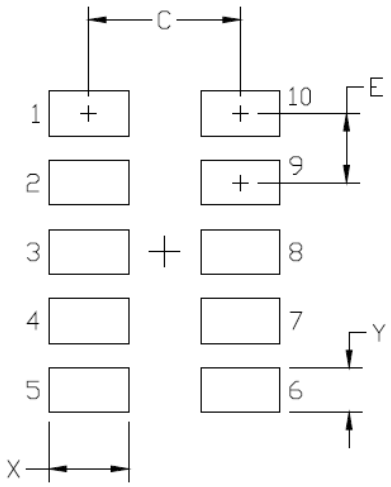



**Figure 11.2. 10-Pin LGA Module Land Pattern**

**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. Document Change List

## 12.1 Revision 0.9

December 4, 2015

- Initial release.

## 12.2 Revision 1.0

September 29, 2016

- Updated Register in Table 8.2 Electrical Performance Characteristics on page 38 from Reset to IRQENABLE.
- Swapped position on LED2_EN and LED_3 EN.
- Updated Max VLED voltage to 5.5 V.

# Table of Contents


**1. Feature List . . . . . 1**

**2. Ordering Guide . . . . . 2**

**3. Functional Description . . . . . 3**

3.1 Ambient Light Sensing . . . . . 4

3.2 Proximity Sensing . . . . . 5

3.3 Power Consumption . . . . . 7

3.4 Host Interface . . . . . 8

**4. Operational Modes . . . . . 10**

4.1 Off Mode . . . . . 10

4.2 Initialization Mode . . . . . 10

4.3 Standby Mode . . . . . 10

4.4 Forced Conversion Mode . . . . . 10

4.5 Automated Operation Mode . . . . . 10

**5. User to Sensor Communication . . . . . 11**

5.1 Basic $I^2C$ Operation . . . . . 11

5.2 Relationship Between $I^2C$ Registers and Parameter Table . . . . . 12

5.3 $I^2C$ Command Register Operation . . . . . 14

5.3.1 Accessing the Parameter Table (PARAM_QUERY & PARAM_SET Commands) . . . . . 16

5.3.2 Sensor Operation Initiation Commands . . . . . 16

5.3.3 RESET_CMD_CTR Command . . . . . 16

5.3.4 RESET Command . . . . . 16

5.4 $I^2C$ Register Summary . . . . . 17

5.4.1 PART_ID . . . . . 17

5.4.2 HW_ID . . . . . 18

5.4.3 REV_ID . . . . . 18

5.4.4 INFO0 . . . . . 18

5.4.5 INFO1 . . . . . 18

5.4.6 HOSTIN0 . . . . . 18

5.4.7 COMMAND . . . . . 18

5.4.8 IRQENABLE . . . . . 18

5.4.9 RESPONSE1 . . . . . 19

5.4.10 RESPONSE0 . . . . . 19

5.4.11 IRQ_STATUS . . . . . 20

5.4.12 HOSTOUTx . . . . . 20

**6. Measurement: Principle of Operation . . . . . 21**

6.1 Output Field Utilization . . . . . 21

6.2 Autonomous and Forced Modes . . . . . 23

6.3 Burst Mode . . . . . 25

6.4 Interrupt Operation . . . . . 27

6.5 Timing of Channel Measurements . . . . . .27

**7. Parameter Table . . . . . 29**

7.1 Global Area of the Parameter Table . . . . . .30

7.2 Channel Specific Setup Areas of the Parameter Table . . . . . .31

7.2.1 ADCCONFIGx . . . . . .33

7.2.2 ADCSENSx . . . . . .34

7.2.3 ADCPOSTx . . . . . .35

7.2.4 MEASCONFIGx . . . . . .36

7.3 Photodiode Selection . . . . . .37

**8. Electrical Specifications . . . . . 38**

**9. Pin Descriptions . . . . . 48**

9.1 DFN Pin Description . . . . . .48

9.2 Module Pin Description . . . . . .49

**10. Modules Outline . . . . . 50**

10.1 10-Pin 2x2 mm DFN . . . . . .50

10.2 10-Pin LGA Module . . . . . .51

**11. Land Patterns. . . . . 53**

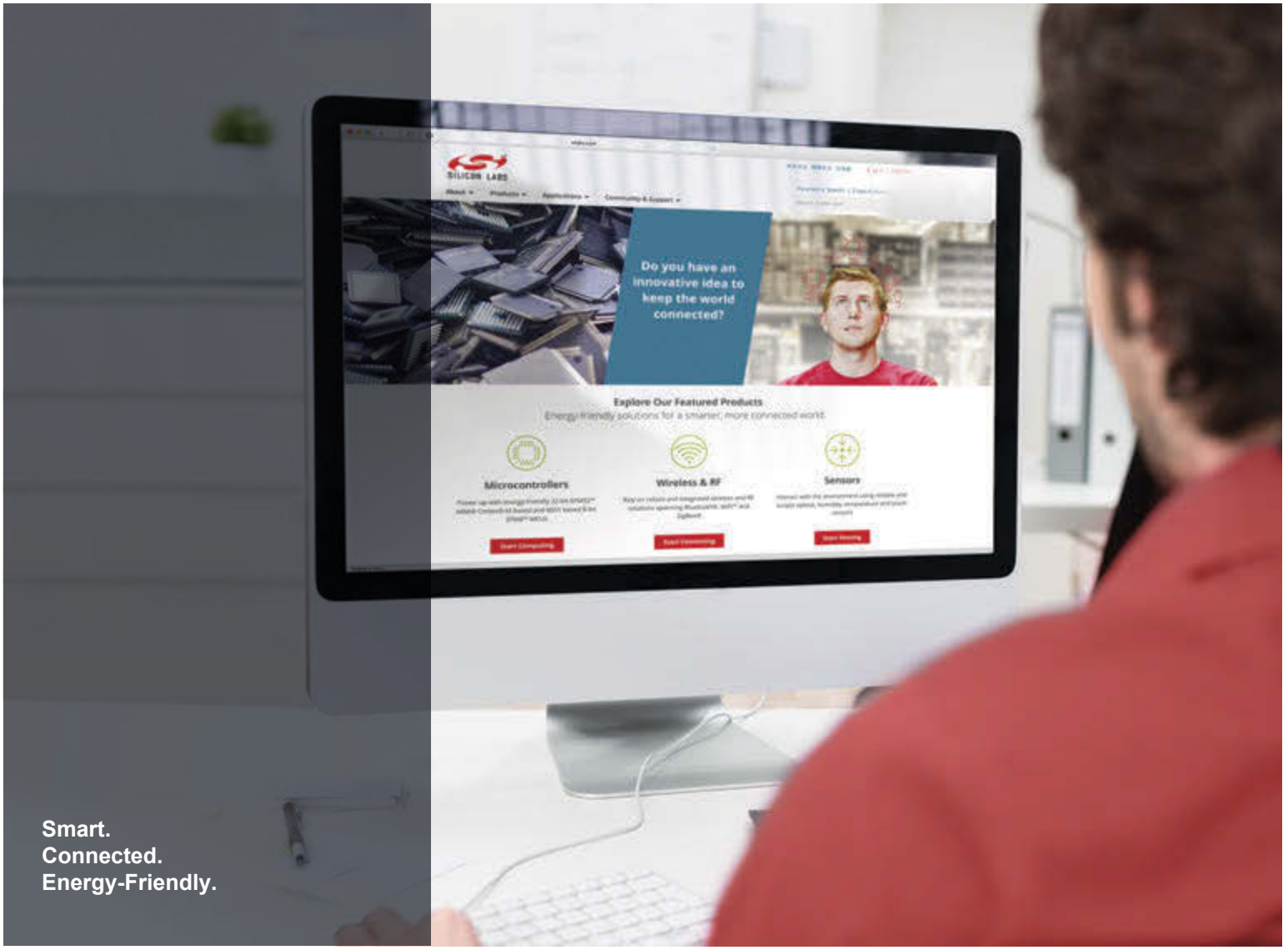
11.1 2x2 mm DFN Land Pattern . . . . . .53

11.2 10-Pin LGA Module . . . . . .54

**12. Document Change List . . . . . 55**

12.1 Revision 0.9 . . . . . .55

12.2 Revision 1.0 . . . . . .55




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