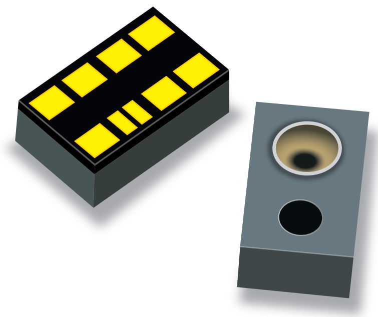
HS3000A

Digital Ambient Light & Proximity Sensor with built-in IR LED



Description

The HS3000A combines an advanced digital proximity sensor, IR LED and LED driver with dual ambient light sensors (ALS) and tri-mode I^2C interface with interrupt capability in an integrated monolithic device. Multiple power management features and very low active sensing power consumption directly address the power requirements of battery operated mobile phones and mobile internet devices. The proximity sensor measures reflected light intensity with a high degree of precision and excellent ambient light rejection. The HS3000A enables a proximity sensor system with a 32:1 programmable LED drive current range and a 30dB overall proximity detection range. The dual ambient light sensors include one with a photopic light filter and one with no filter. Both have dark current compensation and high sensitivity eliminating inaccurate light level detection and insuring proper backlight control even in the presence of dark cover glass. The HS3000A is ideal for improving the user experience by enhancing the screen interface with the ability to measure distance for near/far detection in real time and the ability to respond to ambient lighting conditions to control display backlight intensity.

Features

- Proximity sensor, IR LED, LED driver and dual ALS in one device
- Very low power consumption
  - Stand-by current 5μA (monitoring I^2C interface only, V_{DD}=3V)
  - ALS average operational current 40μA (both sensors active)
  - Proximity sensing average operational current 100μA
  - Average LED sink current 600μA

Proximity Sensing

- Proximity detection distance threshold I^2C programmable with 12- bit resolution and eight integration time ranges (16-bit effective resolution)
- Effective for measuring distances up to 100mm and beyond
- Excellent IR and ambient light rejection including sunlight (over 100K lux) and CFL interference
- Programmable LED drive current from 10mA to 160mA in 5mA steps, no external resistor required
- User programmable LED pulse frequency

Ambient Light Sensing

- Dual ALS senses ambient light and provides 16-bit output counts on the I^2C bus directly proportional to the ambient light intensity
- Photopic spectral response of ALS1 nearly matches human eye
- Broadband response of ALS2 supports compensation for spectral shifts encountered with different types of cover glass
- Dynamic dark current compensation
- Linear response over the full operating range
- Senses intensity of ambient light from 0.05 lux to 52k lux with 21- bit effective resolution (16-bit converter)
- Continuously programmable integration times (6.25ms, 12.5ms, 25ms… to 800ms)
- Precision on-chip oscillator (counts equal 0.1 lux at 100ms integration time)

Additional Features

- Programmable interrupt function including independent upper and lower threshold detection or threshold based hysteresis for proximity and or ALS
- Level or Edge Triggered interrupts
- Proximity persistence feature reduces interrupts by providing hysteresis to filter fast transients such as camera flash
- Automatic power down after single measurement or continuous measurements with programmable interval time for both ALS and PS functions
- Wide operating voltage range (2.3V to 3.6V)
- Wide operating temperature range (-40°C to 80°C)
- I²C serial communication port
  - Standard mode – 100 kHz
  - Fast mode – 400 kHz
  - High speed mode – 3.4 MHz
- No external components required except power supply decoupling caps
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant

Applications

- Senses human presence in terms of distance and senses ambient light conditions, saving display power in applications such as:
  - Smart phones, mobile internet devices, MP3 players, GPS
  - Mobile device displays and backlit keypads

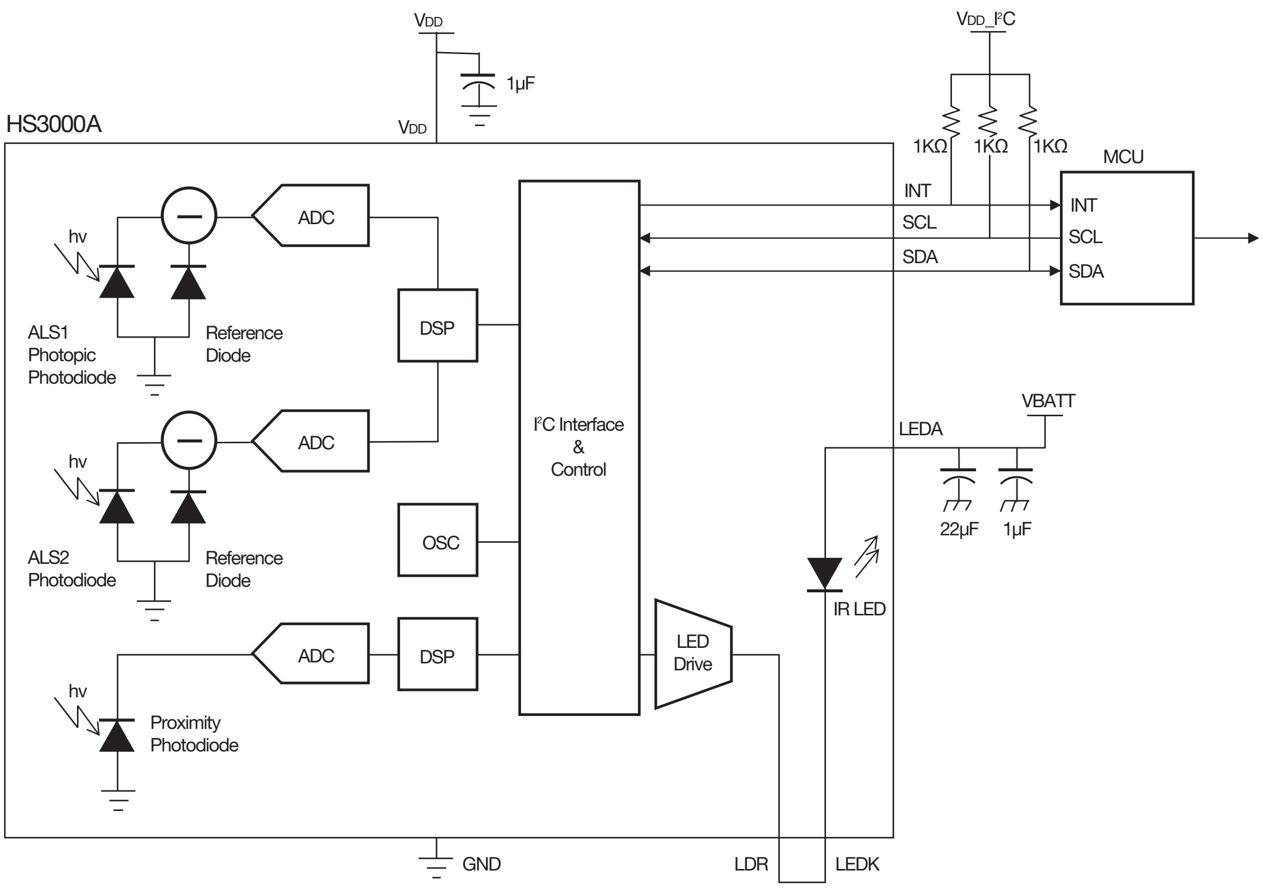


Figure 1. HS3000A Application Block Diagram

Table 1. Terminal Function (Pins Configuration)

HS3000A

PIN	NAME	TYPE	DESCRIPTION
1	SDA	I/O	I^2C serial data I/O terminal – serial data I/O for I^2C.
2	INT	O	Interrupt – open drain.
3	LDR	I	LED driver for proximity emitter – up to 100 mA, open drain.
4	LEDK	O	LED Cathode, connect to LDR pin in most systems to use internal LED driver circuit
5	LEDA	I	LED Anode, connect to VBATT on PCB
6	GND		Power supply ground. All voltages are referenced to GND.
7	SCL	I	I^2C serial clock input terminal – clock signal for I^2C serial data.
8	V_{DD}		Power Supply voltage.

Ordering Information

Part Number	Pin Count	Packaging	Quantity
HS3000A	8	Tape & Reel	2500 per reel

Pin Definition

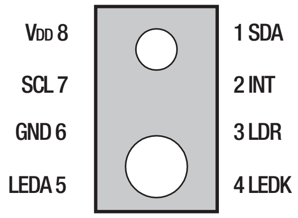


Table 2. ABSOLUTE MAXIMUM RATINGS

Rating	Symbol	Value	Unit
Input power supply	V_{DD}	4.0	V
Input voltage range	V_{in}	-0.3 to V_{DD} + 0.2	V
Output voltage range	V_{out}	-0.3 to V_{DD} + 0.2	V
Maximum Junction Temperature	$TJ_{(max)}$	100	°C
Storage Temperature	T_{STG}	-40 to 80	°C
ESD Capability, Human Body Model (Note1)	ESD_{HBM}	2	kV
ESD Capability, Charged Device Model (Note 1)	ESD_{CDM}	500	V
ESD Capability, Machine Model (Note 1)	ESD_{MM}	200	V

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. This device incorporates ESD protection and is tested by the following methods:
   ESD Human Body Model tested per EIA/JESD22-A114
   ESD Charged Device Model tested per ESD-STM5.3.1-1999
   ESD Machine Model tested per EIA/JESD22-A115
   Latchup Current Maximum Rating: ≤ 100 mA per JEDEC standard: JESD78

Table 3. OPERATING RANGES

Rating	Symbol	Min	Typ	Max	Unit
Power supply voltage	V_{DD}	2.3		3.6	V
Power supply current, stand-by mode (V_{DD} = 3.0V)	$IDD_{STBY\_3.0}$			5	μA
Power supply current, stand-by mode (V_{DD} = 3.6V)	$IDD_{STBY\_3.6}$			10	μA
Power supply average current, ALS1 operating 100ms integration time and 500ms intervals, 1000 lux white LED illumination	IDD_{ALS1}			30	μA
Power supply average current, ALS2 operating 100ms integration time and 500ms intervals, 1000 lux white LED illumination	IDD_{ALS2}			50	μA
Power supply average current, ALS1+ALS2 operating 100ms integration time and 500ms intervals, 1000 lux white LED Illumination	$IDD_{ALS1+ALS2}$			40	μA
Power supply average current, ALS1+ALS2 operating 100ms integration time and 100ms intervals (100% Duty Cycle), 1000 lux White LED Illumination	$IDD_{ALS1+ALS2\_MAX}$			200	μA
Power supply average current, PS operating 1200μs integration time and 50ms intervals	IDD_{PS}			100	μA
LED average sink current, PS operating at 1200μs integration time and 50ms intervals and LED current set at 50mA	I_{LED}		600	-	μA
I^2C signal voltage (Note 2)	$V_{DD}\_I^2C$	1.6	1.8	2.0	V
Low level input voltage ($V_{DD}\_I^2C$ related input levels)	V_{IL}	-0.3		0.3 $V_{DD}\_I^2C$	V
High level input voltage ($V_{DD}\_I^2C$ related input levels)	V_{IH}	0.7 $V_{DD}\_I^2C$		$V_{DD}\_I^2C$ + 0.2	V
Hysteresis of Schmitt trigger inputs	V_{hys}	0.1 $V_{DD}\_I^2C$			V
Low level output voltage (open drain) at 3 mA sink current (INTB)	V_{OL}			0.2 $V_{DD}\_I^2C$	V
Input current of IO pin with an input voltage between 0.1 V_{DD} and 0.9 V_{DD}	I_I	-10		10	μA
Output low current (INTB)	I_{OL}	3		-	mA
Operating free-air temperature range	T_A	-40		80	°C

2. The I^2C interface is functional to 3.0V, but timing is only guaranteed up to 2.0V. High Speed mode is guaranteed to be functional to 2.0V.

Table 4. ELECTRICAL CHARACTERISTICS

(Unless otherwise specified, these specifications apply over 2.3v < V_{DD} < 3.3V, 1.7v < V_{DD}_I^2C < 1.9v, -40°C < T_A < 80°C, 10pF < Cb < 100pF) (See Note 3)

Parameter	Symbol	Min	Typ	Max	Unit
LED pulse current	I_{LED_pulse}	10		160	mA
LED pulse current step size	$I_{LED\_pulse\_step}$		5		mA
LED pulse current accuracy	I_{LED_acc}	-20		+20	%
Interval Timer Tolerance	Tol_{f_timer}	-35		+35	%
Edge Triggered Interrupt Pulse Width	PW_{INT}		50		μS
SCL clock frequency	f_{SCL_std}	10		100	kHz
	f_{SCL_fast}	100		400	
	f_{SCL_hs}	100		3400	
Hold time for START condition. After this period, the first clock pulse is generated.	$T_{HD;STA\_std}$	4.0		-	μS
	$t_{HD;STA\_fast}$	0.6		-	
	$t_{HD;STA\_hs}$	0.160		-	
Low period of SCL clock	t_{LOW_std}	4.7		-	μS
	t_{LOW_fast}	1.3		-	
	t_{LOW_hs}	0.160		-	
High period of SCL clock	t_{HIGH_std}	4.0		-	μS
	t_{HIGH_fast}	0.6		-	
	t_{HIGH_hs}	0.060		-	
SDA Data hold time	$t_{HD;DAT\_d\_std}$	0		3.45	μS
	$t_{HD;DAT\_d\_fast}$	0		0.9	
	$t_{HD;DAT\_d\_hs}$	0		0.070	
SDA Data set-up time	$t_{SU;DAT\_std}$	250		-	nS
	$t_{SU;DAT\_fast}$	100		-	
	$t_{SU;DAT\_hs}$	10			
Rise time of both SDA and SCL (input signals) (Note 4)	$t_{r\_INPUT\_std}$	20		1000	nS
	$t_{r\_INPUT\_fast}$	20		300	
	$t_{r\_INPUT\_hs}$	10		40	
Fall time of both SDA and SCL (input signals) (Note 4)	$t_{f\_INPUT\_std}$	20		300	nS
	$t_{f\_INPUT\_fast}$	20		300	
	$t_{f\_INPUT\_hs}$	10		40	
Rise time of SDA output signal (Note 4)	$t_{r\_OUT\_std}$	20		300	nS
	$t_{r\_OUT\_fast}$	20 + 0.1 Cb		300	
	$t_{r\_OUT\_hs}$	10		80	
Fall time of SDA output signal (Note 4)	$t_{f\_OUT\_std}$	20		300	nS
	$t_{f\_OUT\_fast}$	20 + 0.1 Cb		300	
	$t_{f\_OUT\_hs}$	10		80	
Set-up time for STOP condition	$t_{SU;STO\_std}$	4.0		-	μS
	$t_{SU;STO\_fast}$	0.6		-	
	$t_{SU;STO\_hs}$	0.160		-	
Bus free time between STOP and START condition	t_{BUF_std}	4.7		-	μS
	t_{BUF_fast}	1.3		-	
	t_{BUF_hs}	0.160		-	
Capacitive load for each bus line (including all parasitic capacitance) (Note 5)	C_b	10		100	pF
Noise margin at the low level (for each connected device - including hysteresis)	V_{nL}	0.1 V_{DD}		-	V
Noise margin at the high level (for each connected device - including hysteresis)	V_{nH}	0.2 V_{DD}		-	V

3. Refer to Figure 2 and Figure 3 for more information on AC characteristics.
4. The rise time and fall time are dependent on both the bus capacitance (Cb) and the bus pull-up resistor R_p. Max and min pull-up resistor values are determined as follows: $R_{p(max)} = t_{r\,(max)}/(0.8473 \times Cb)$ and $R_{p(min)} = (V_{DD}\_I^2C - V_{ol(max)})/I_{ol}$.
5. Cb = capacitance of one bus line, maximum value of which including all parasitic capacitances should be less than 100 pF. Bus capacitance up to 400pF is supported, but at relaxed timing.

Table 5. OPTICAL CHARACTERISTICS
(Unless otherwise specified, these specifications are for V_{DD} = 3.3V, TA = 25°C)

Parameter	Symbol	Min	Typ	Max	Unit
Ambient Light Sensor 1					
Spectral response, peak (Note 6)	λ_p		560		nm
Spectral response, low -3dB	λ_{c_low}		510		nm
Spectral response, high -3dB	λ_{c_high}		610		nm
Dynamic range	DR_{ALS}	0.05		52k	lux
Maximum Illumination (ALS operational but saturated)	E_{v_MAX}			1M	lux
Resolution, Counts per lux, Tint=800ms	CR_{800}		80		counts
Resolution, Counts per lux, Tint=100ms	CR_{100}		10		counts
Resolution, Counts per lux, Tint=6.25ms	$CR_{6.25}$		0.625		counts
Illuminance responsivity, green 560nm LED, Ev = 100 lux, Tint = 100ms	R_{v_g100}		1000		counts
Illuminance responsivity, green 560nm LED, Ev = 1000 lux, Tint = 100ms	R_{v_g1000}		10000		counts
Dark current, Ev = 0 lux, Tint = 100ms	R_{vd}	0	0	3	counts
Proximity Sensor					
Detection range, Tint = 4800μs, I_{LED} = 40mA, White Reflector	$D_{PS\_4800\_WHITE}$		100		mm
Detection range, Tint = 3600μs, ILED = 50mA, White Reflector	$D_{PS\_3600\_WHITE}$		100		mm
Detection range, Tint = 2400μs, ILED = 70mA, White Reflector	$D_{PS\_2400\_WHITE}$		100		mm
Detection range, Tint = 1800μs, ILED = 80mA, White Reflector	$D_{PS\_1800\_WHITE}$		100		mm
Detection range, Tint = 1200μs, ILED = 100mA, White Reflector	$D_{PS\_1200\_WHITE}$		100		mm
Detection range, Tint = 600μs, ILED = 100mA, White Reflector	$D_{PS\_600\_WHITE}$		75		mm
Detection range, Tint = 300μs, ILED = 100mA, White Reflector	$D_{PS\_300\_WHITE}$		60		mm
Detection range, Tint = 150μs, ILED = 100mA, White Reflector	$D_{PS\_150\_WHITE}$		50		mm
Detection range, Tint = 1200μs, ILED = 100mA, Grey Reflector	$D_{PS\_1200\_GREY}$		70		mm
Detection range, Tint = 1200μs, ILED = 100mA,, Black Reflector	$D_{PS\_1200\_BLACK}$		35		mm
Saturation power level	P_{DMAX}		1		mW/cm^2
Measurement resolution, Tint = 150μs	MR_{150}		12		bits
Measurement resolution, Tint = 300μs	MR_{300}		13		bits
Measurement resolution, Tint = 600μs	MR_{600}		14		bits
Measurement resolution, Tint = 1200μs	MR_{1200}		15		bits
Measurement resolution, Tint = 1800μs	MR_{1800}		16		bits
Measurement resolution, Tint = 2400μs	MR_{2400}		16		bits
Measurement resolution, Tint = 3600μs	MR_{3600}		16		bits
Measurement resolution, Tint = 4800μs	MR_{4800}		16		bits

6. Refer to Figure 4 for more information on spectral response.

Parameter	Test Conditions	Symbol	Min	Typ	Max	Unit
IR LED						
Forward Voltage	I_F = 20 mA	V_F		1.45		V
Reverse Voltage	I_R = 10 µA	V_R	5.0			V
Radiated Power	I_F = 20 mA	P_O	4.5			mW
Peak Wavelength	I_F = 20 mA	λ_P		850		nm
Spectral Radiation Bandwidth	I_F = 20 mA	$\Delta\lambda$		40		nm

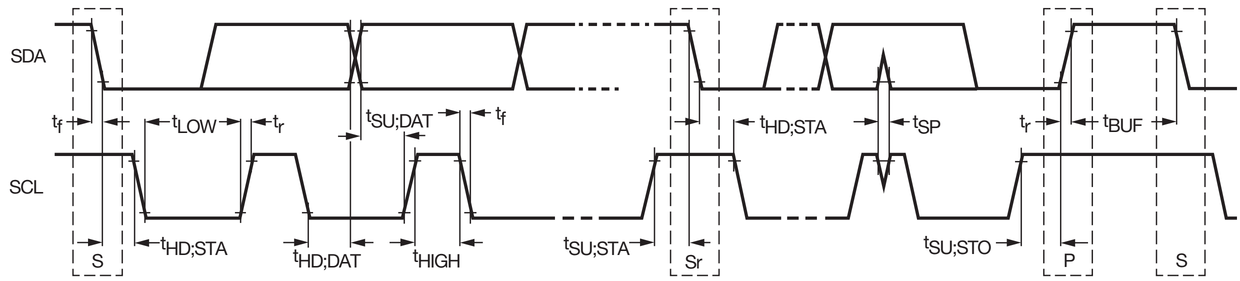


Figure 2. AC Characteristics, Standard and Fast Modes

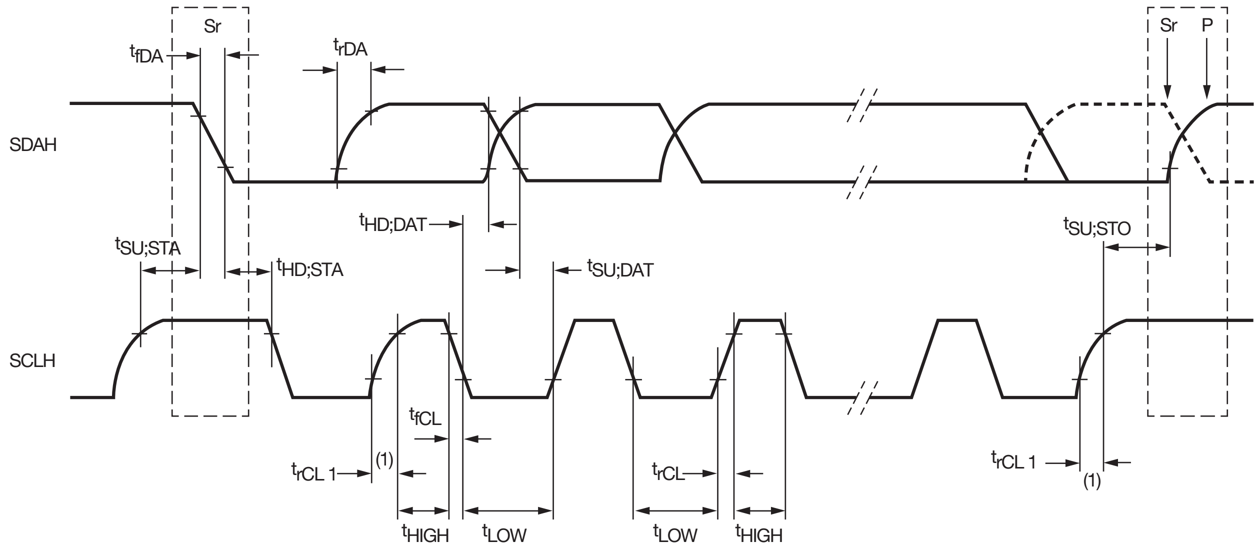


Figure 3. AC Characteristics, High Speed Mode

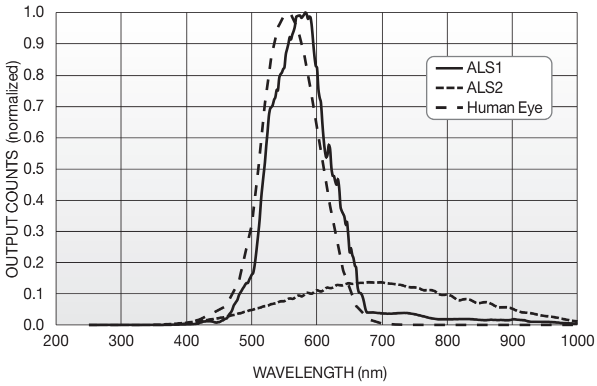


Figure 4: ALS Spectral Response (Normalized)

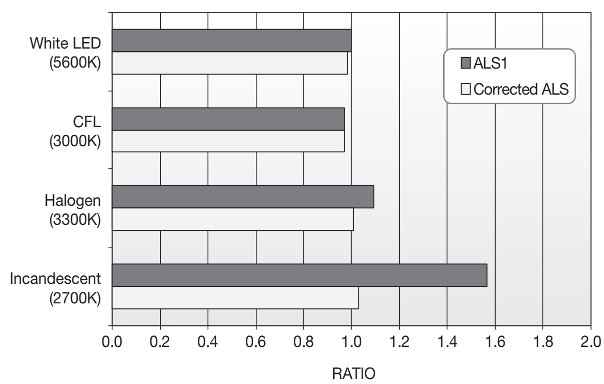


Figure 5: ALS Light Source Dependency Before and After Software Correction Based on ALS1/ALS2 Ratio (Normalized to White Light, No Correction)

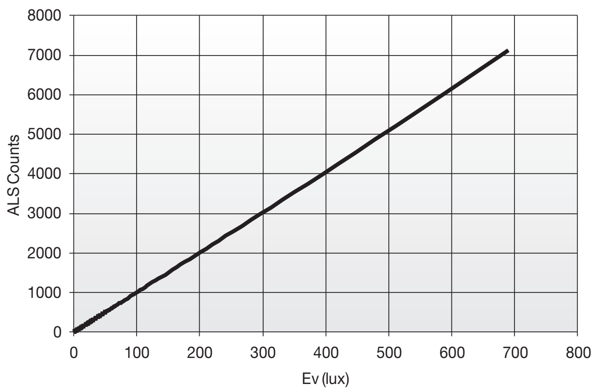


Figure 6: ALS1 Linearity 0-700 lux

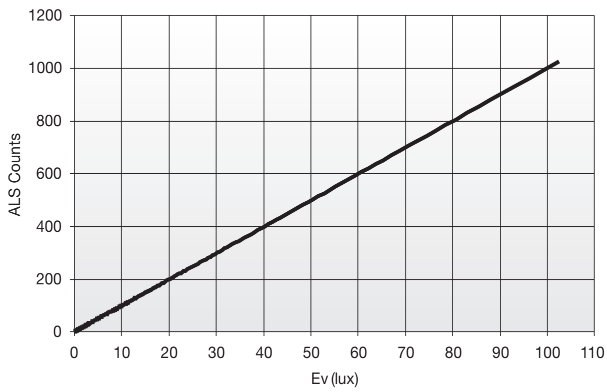


Figure 7: ALS1 Linearity 0-100 lux

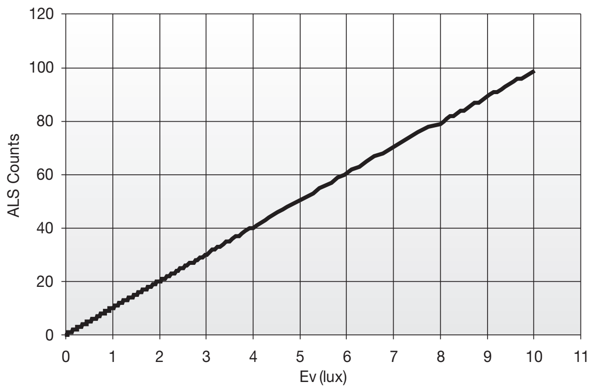


Figure 8: ALS1 Linearity 0-10 lux

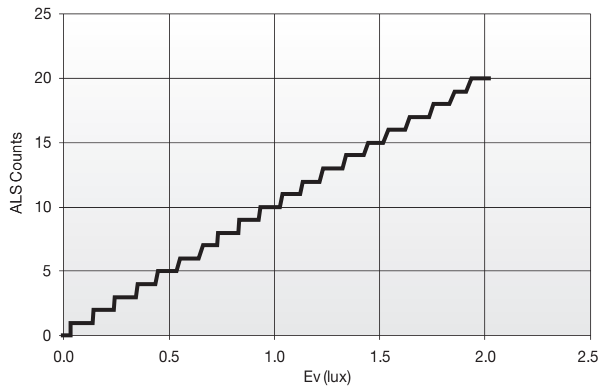


Figure 9: ALS1 Linearity 0-2 lux

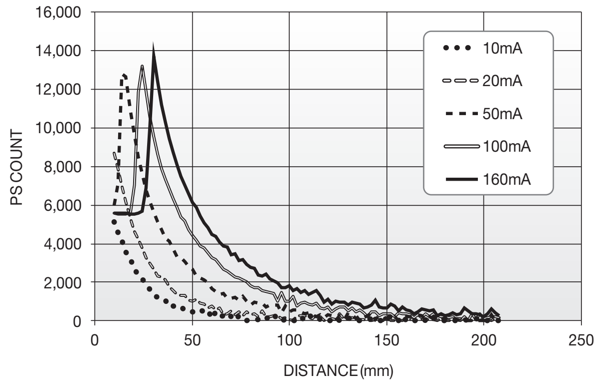


Figure 10: PS Response vs. Distance and LED Current T_{INT}=300 us, White Reflector

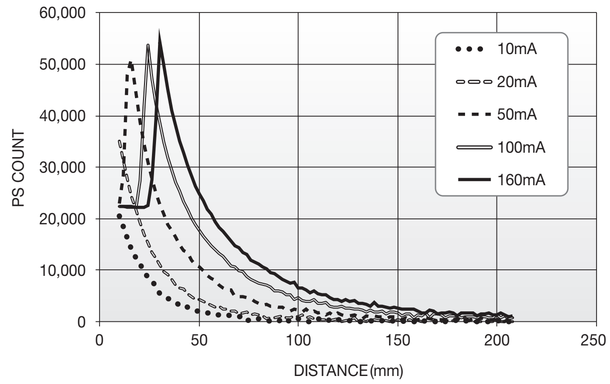


Figure 11: PS Response vs. Distance and LED Current T_{INT}=1200 us, White Reflector

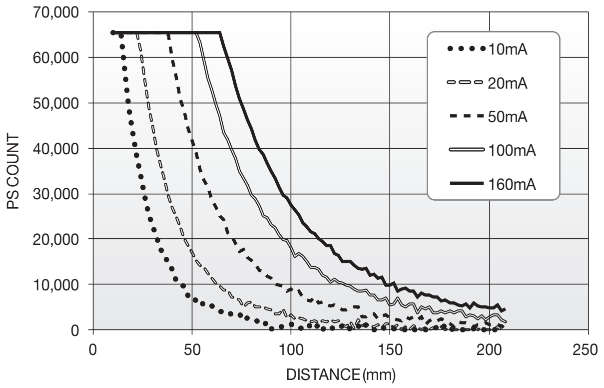


Figure 12: PS Response vs. Distance and LED Current T_{INT}=4800 us, White Reflector

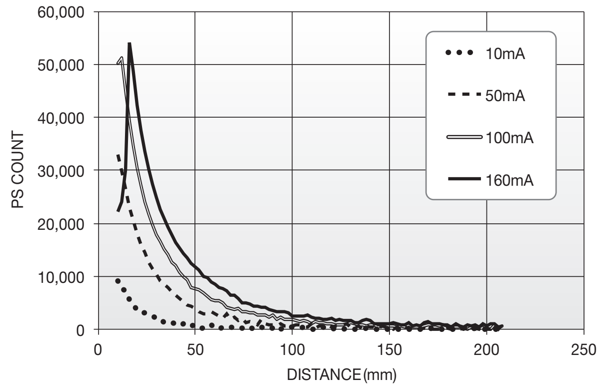


Figure 13: PS Response vs. Distance and LED Current T_{INT}=1200 us, Grey Reflector

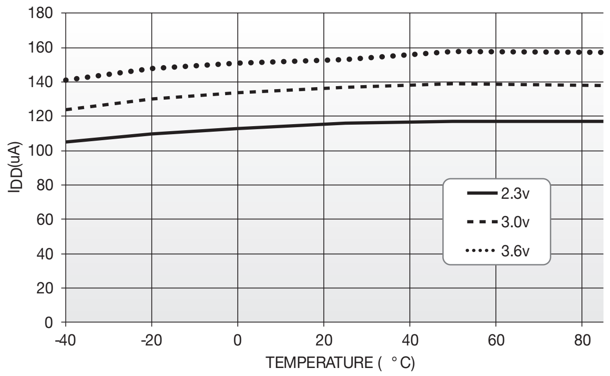


Figure 14: ALS1 + ALS2 Supply Current vs. Temperature and Supply Voltage; ALS1 & ALS2 T_{INT}=100 ms, T_R=100 ms (100% Duty Cycle) 100 lux Illumination

Description of Operation

Proximity Sensor Architecture

HS3000A combines an advanced digital proximity sensor, LED driver, IR LED, dual ambient light sensors and a tri-mode I^2C interface as shown in Figure 1. The LED driver draws a modulated current through the IR LED to illuminate the target. The LED current is programmable over a wide range. The infrared light reflected from the target is detected by the proximity sensor photo diode. The proximity sensor employs a sensitive photo diode fabricated in ON Semiconductor's standard CMOS process technology. The modulated light received by the on-chip photodiode is converted to a digital signal using a variable slope integrating ADC with a default resolution (at 1200us) of 15-bits, unsigned. The signal is processed to remove all unwanted signals resulting in a highly selective response to the generated light signal. The final value is stored in the PS_DATA register where it can be read by the I^2C interface.

Proximity Sensor LED Frequency and Delay Settings

The LED current modulation frequency is user selectable from approximately 128KHz to 2MHz using the PS_LED_FREQUENCY register. An internal precision 4MHz oscillator provides the frequency reference. The 4MHz clock is divided by the value in register 0x0D to determine the pulse rate. The default is 0x10 (16) which results in an LED pulse frequency of 250KHz. Values below 200KHz and above 1MHz are not recommended.
Switching high LED currents can result in noise injected into the proximity sensor receiver causing inaccurate readings. The PS receiver has a user programmable delay from the LED edge to when the receiver samples the data (PS_SAMPLE_DELAY – register 0x0E). Longer delays may reduce the effect of switching noise but also reduce the sensitivity.
Since the value of the delay is dependent on the pulse frequency, its value must be carefully computed. The value obviously cannot exceed the LED pulse width or there would be no sampling of the data when the LED is illuminated. There is also a minimum step size of 250ns as determined by the 4MHz clock.
To determine the correct value for the PS_SAMPLE_DELAY register, a series of steps are needed. Below is an example for a 210KHz (approx) LED pulse frequency – which is a divide by 19 of the 4MHz clock - and a 250ns sample delay.

1. Determine the LED pulse width resulting from the value in register 0x0D (ClkDiv). Since the LED driver has a 50% duty cycle, for 210KHz this would be 2.375us:
   PulseWidth = 250nsxClkDiv/2 = 2.375us

2. Determine the desired delay. In this case, 250ns.

3. Subtract the delay from the pulse width to get the sample width: SampleWidth=PulseWidth-delay = 2.125us

4. Divide the resulting sample width by the LED pulse width then multiply by the decimal value of register 0x0D and add 1. Then round to nearest integer:
   RV=(SampleWidth/PulseWidth)xClkDiv+1 (2.125us/2.375us)x19 + 1 = 18

5. If RV = 0, set register 0x0E to 0x01.

6. If RV = 1, set register 0x0E to 0x02.

7. If RV>1 and odd:
   a. If RV > ClkDiv-1, set register 0x0E to ClkDiv-1 b. If RV <= ClkDiv-1, set register 0x0E to RV.

8. If RV>1 and even
   a. If RV > ClkDiv+1, set register 0x0E to ClkDiv+1 b. If RV <= ClkDiv+1, set register 0x0E to RV
   This is the valid case for the example. Set register 0x0E to 18 (0x12)
   Table 6 shows some common LED pulse frequencies and sample delays and the resulting register values.

Table 6. Common LED Pulse Frequency Settings

LED Pulse Frequency (KHz)	Sample Delay (ns)	PS_LED_ FREQUENCY Register (0x0D) Value	PS_SAMPLE_ DELAY Register (0x0E) Value
200	250	0x14	0x13
200	500	0x14	0x11
200	750	0x14	0x0F
250	250	0x10	0x0F
250	500	0x10	0x0D
500	250	0x08	0x07
500	500	0x08	0x05
1000	250	0x04	0x03

Ambient Light Sensor Architecture

The HS3000A contains two ambient light sensors. The first ambient light sensor employs a photo diode with its own proprietary photopic filter limiting extraneous photons, and thus performing as a band pass filter on the incident wave front. The filter only transmits photons in the visible spectrum which are primarily detected by the human eye. The photo response of this sensor is as shown in Figure4. The second ambient light sensor employs a similar photo diode but without a light filter. Either or both ALS can be enabled. When disabled, an ALS is put in power down mode.

The ambient light signal detected by each photo diode is converted to a digital signal using a variable slope integrating ADC with a resolution of 16-bits, unsigned. The ADC values are stored in the ALS_DATA1 and ALS_DATA2 registers where they can be read by the I^2C interface. ALS1 nominally produces 10 counts per lux when illuminated by a white LED. ALS2 produces 2 counts per lux under the same conditions. Response to other types of lighting are shown in Figure5.

ALS Spectral Response Correction

The ALS1 photopic filter has some IR leakage which results in higher ALS readings for light sources with higher IR content, such as incandescent lighting (see Figure 5). For purely photopic light, ALS1 is very accurate and correction is not needed. For other light sources, or if the spectral response of the light is shifted by cover glass, etc., the ALS reading can be corrected by reading both ALS1 and ALS2 and applying an equation in the system software such as

$$ALS = ALS1x(0.1x(ALS1/ALS2)+0.5)$$

The equation shown does not work well for very low ALS1 and/or ALS2 values (a single count introduces a large correction factor),lighting conditions to control display backlight intensity.

thus it is recommended that the correction not be applied if the ALS1 value is below 5 counts and/or the ALS2 value is 0. Likewise if ALS1 reaches 65535 counts, the equation will begin to be incorrect and thus should not be applied. To provide the best possible correction, the equation will change based on the spectral characteristics of the glass used between the sensor and the light source. The equation shown was chosen to provide the best fit of a number of different light sources with no filter glass used. See Figure 5 for ALS response before and after the correction equation is applied.

I^2C Interface

The HS3000A acts as an I^2C slave device and supports single register and block register read and write operations. All data transactions on the bus are 8 bits long. Each data byte transmitted is followed by an acknowledge bit. Data is transmitted with the MSB first.

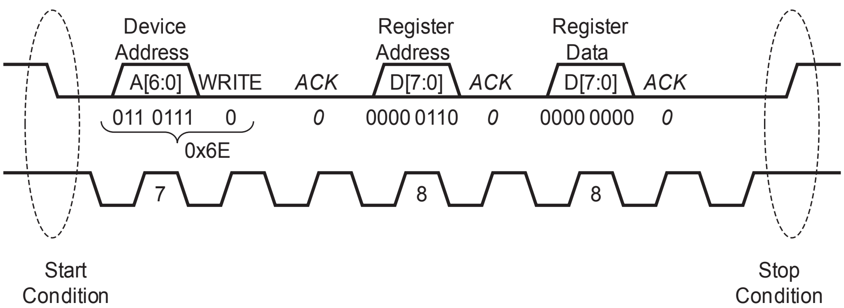
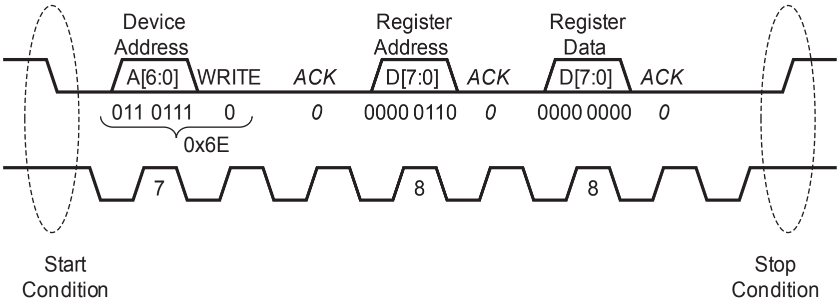


Figure 15: I^2C Write Command

SHIN OH

Figure 15 shows an I^2C write operation. Write transactions begin with the master sending an I^2C start sequence followed by the seven bit slave address (HS3000A = 0x37) and the write(0) command bit. The HS3000A will acknowledge this byte transfer with an appropriate ACK. Next the master will send the 8 bit register address to be written to. Again the HS3000A will acknowledge reception with an ACK. Finally, the master will begin sending 8 bit data segment(s) to be written to the HS3000A register bank. The HS3000A will send an ACK after each byte and increment the address pointer by one in preparation for the next transfer. Write transactions are terminated with either an I^2C STOP or with another I^2C START (repeated START).
Figure 16 shows an I^2C read command sent by the master to the slave device. Read transactions begin in much the same manner as the write transactions in that the slave address must be sent with a write(0) command bit.



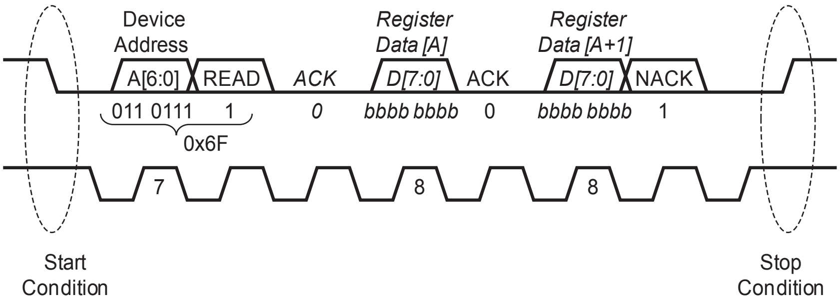


Figure 16: I^2C Read Command

After the HS3000A sends an ACK, the master sends the register address as if it were going to be written to. The HS3000A will acknowledge this as well. Next, instead of sending data as in a write, the master will re-issue an I^2C START (repeated start) and again send the slave address and this time the read(1) command bit. The HS3000A will then begin shifting out data from the register just addressed. If the master wishes to receive more data (next register address), it will ACK the slave at the end of the 8 bit data transmission, and the slave will respond by sending the next byte, and so on. To signal the end of the read transaction, the master will send a NACK bit at the end of a transmission followed by an I^2C STOP.
The HS3000A also supports I^2C high-speed mode. The transition from standard or fast mode to high-speed mode is initiated by the I^2C master. A special reserve device address is called for and any device that recognizes this and supports high speed mode immediately changes the performance characteristics of its I/O cells in preparation for I^2C transactions at the I^2C high speed data protocol rates.. From then on, standard I^2C commands may be issued by the master, including repeated START commands. When the I^2C master terminates any I^2C transaction with a STOP sequence, the master and all slave devices immediately revert back to standard/fast mode I/O performance.
By using a combination of high-speed mode and a block write operation, it is possible to quickly initialize the HS3000A I^2C register bank.

HS3000A Data Registers

HS3000A operation is observed and controlled by internal data registers read from and written to via the external I^2C interface. Registers are listed in Table 7. Default values are set on initial power up or via a software reset command (register 0x01).

Table 7. HS3000A Data Registers

Address	Type	Name	Description
0x01	RW	RESET	Software reset control
0x02	RW	INT_CONFIG	Interrupt pin functional control settings
0x0D	RW	PS_LED_FREQUENCY	PS LED Pulse Frequency
0x0E	RW	PS_SAMPLE_DELAY	PS Sample Delay
0x0F	RW	PS_LED_CURRENT	PS LED pulse current (5, 10, …, 160 mA)
0x10	RW	PS_TH_UP_MSB	PS Interrupt upper threshold, most significant bits
0x11	RW	PS_TH_UP_LSB	PS Interrupt upper threshold, least significant bits
0x12	RW	PS_TH_LO_MSB	PS Interrupt lower threshold, most significant bits
0x13	RW	PS_TH_LO_LSB	PS Interrupt lower threshold, least significant bits
0x14	RW	PS_FILTER_CONFIG	PS Filter configuration
0x15	RW	PS_CONFIG	PS Integration time configuration
0x16	RW	PS_INTERVAL	PS Interval time configuration
0x17	RW	PS_CONTROL	PS Operation mode control
0x20	RW	ALS_TH_UP_MSB	ALS Interrupt upper threshold, most significant bits
0x21	RW	ALS_TH_UP_LSB	ALS Interrupt upper threshold, least significant bits
0x22	RW	ALS_TH_LO_MSB	ALS Interrupt lower threshold, most significant bits
0x23	RW	ALS_TH_LO_LSB	ALS Interrupt lower threshold, least significant bits
0x24	RW	RESERVED	Reserved
0x25	RW	ALS_CONFIG	ALS Integration time configuration
0x26	RW	ALS_INTERVAL	ALS Interval time configuration
0x27	RW	ALS_CONTROL	ALS Operation mode control
0x40	R	INTERRUPT	Interrupt status
0x41	R	PS_DATA_MSB	PS measurement data, most significant bits
0x42	R	PS_DATA_LSB	PS measurement data, least significant bits
0x43	R	ALS1_DATA_MSB	ALS1 measurement data, most significant bits
0x44	R	ALS1_DATA_LSB	ALS1 measurement data, least significant bits
0x45	R	ALS2_DATA_MSB	ALS2 measurement data, most significant bits
0x46	R	ALS2_DATA_LSB	ALS2 measurement data, least significant bits

RESET Register (0x01)

Software reset is controlled by this register. Setting this register followed by an I^{2}C_STOP sequence will immediately reset the HS3000A to the default startup standby state. Triggering the software reset has virtually the same effect as cycling the power supply tripping the internal POR circuitry.

Table 8. RESET Register (0x01)

Bit	7	6	5	4	3	2	1	0
Field	NA							SW_reset

Field	Bit	Default	Description
NA	7:1	XXXXXXX	Don't care
SW_reset	0	0	Software reset to startup state

INT_CONFIG Register (0x02)

INT_CONFIG register controls the external interrupt pin function.

Table 9. INT_CONFIG Register (0x02)

Bit	7	6	5	4	3	2	1	0
Field	NA						auto_clear	polarity

Field	Bit	Default	Description	
NA	7:3	XXXXX	Don't care	
Edge_triggered	2	0	0	Interrupt pin stays asserted while the INTERRUPT register bit is set (level)
			1	Interrupt pin pulses at the end of each measurement while the INTERRUPT register bit is set
auto_clear	1	1	0	When an interrupt is triggered, the interrupt pin remains asserted until cleared by an I^{2}C read of INTERRUPT register
			1	Interrupt pin state is updated after each measurement
polarity	0	0	0	Interrupt pin active low when asserted
			1	Interrupt pin active high when asserted

PS_LED_FREQUENCY Register (0x0D)

The LED FREQUENCY register controls the frequency of the LED pulses. The LED modulation frequency is determined by dividing 4MHz by the register value. Valid divisors are 2-31.
The default value is 16 which results in an LED pulse frequency of 250KHz (one pulse every 4us)

Table 10. PS_LED_FREQUENCY Register (0x0D)

Bit	7	6	5	4	3	2	1	0
Field	NA			LED_Modulation Frequency				

Field	Bit	Default	Description
NA	7:5	XXX	Don't care
LED_Frequency	4:0	10000	Defines the divider of the 4MHz clock to generate the LED pulses. Valid values are 2-31.

PS_SAMPLE_DELAY Register (0x0E)

The PS_SAMPLE_DELAY register controls the time delay after an LED pulse edge before the resulting signal is sampled by the proximity sensor. This can be used to reduce the effect of noise caused by the LED current switching. Values are related to the LED pulse frequency setting (register 0x0D) and are determined algorithmically. Default value is 500ns. See the Description of Operation section for more information on programming this register.

Table 11. PS_SAMPLE_DELAY Register (0x0E)

Bit	7	6	5	4	3	2	1	0
Field	NA			PS_Sample_Delay				

Field	Bit	Default	Description
NA	7:5	XXX	Don’t care
Sample Delay	4:0	01101	Defines the delay from the LED pulse edge before the pulse is sampled.

PS_LED_CURRENT Register (0x0F)

The LED_CURRENT register controls how much current the internal LED driver sinks through the IR LED during modulated illumination. The current sink range is 5mA plus a binary weighted value of the LED_Current register times 5mA, for an effective range of 10mA to 160mA in steps of 5mA. The default setting is 50mA. A register setting of 00 turns off the LED Driver.

Table 12. PS_LED_CURRENT Register (0x0F)

Bit	7	6	5	4	3	2	1	0
Field	NA			LED_Current				

Field	Bit	Default	Description
NA	7:5	XXX	Don’t care
LED_Current	4:0	01001	Defines current sink during LED modulation. Binary weighted value times 5mA plus 5mA.

PS_TH Registers (0x10 – 0x13)

With hysteresis not enabled (see PS_CONFIG register), the PS_TH registers set the upper and lower interrupt thresholds of the proximity detection window. Interrupt functions compare these threshold values to data from the PS_DATA registers. Measured PS_DATA values outside this window will set an interrupt according to the INT_CONFIG register settings.
With hysteresis enabled, threshold settings take on a different meaning. If PS_hyst_trig is set, the PS_TH_UP register sets the upper threshold at which an interrupt will be set, while the PS_TH_LO register then sets the lower threshold hysteresis value where the interrupt would be cleared. Setting the PS_hyst_trig low reverses the function such that the PS_TH_LO register sets the lower threshold at which an interrupt will be set and the PS_TH_UP represents the hysteresis value at which the interrupt would be subsequently cleared. Hysteresis functions only apply in “auto_clear INT_CONFIG mode.
The controller software must ensure the settings for LED current, sensitivity range, and integration time (LED pulses) are appropriate for selected thresholds. Setting thresholds to extremes (default) effectively disables interrupts.

Table 13. PS_TH_UP Registers (0x10 – 0x11)

Bit	7	6	5	4	3	2	1	0
Field	PS_TH_UP_MSB(0x10), PS_TH_UP_LSB(0x11)							

Field	Bit	Default	Description
PS_TH_UP_MSB	7:0	0xFF	Upper threshold for proximity detection, MSB
PS_TH_UP_LSB	7:0	0xFF	Upper threshold for proximity detection, LSB

Table 14. PS_TH_LO Registers (0x12 – 0x13)

Bit	7	6	5	4	3	2	1	0
Field	PS_TH_LO_MSB(0x12), PS_TH_LO_LSB(0x13)							

Field	Bit	Default	Description
PS_TH_LO_MSB	7:0	0x00	Lower threshold for proximity detection, MSB
PS_TH_LO_LSB	7:0	0x00	Lower threshold for proximity detection, LSB

PS_FILTER_CONFIG Register (0x14)

PS_FILTER_CONFIG register provides a hardware mechanism to filter out single event occurrences or similar anomalies from causing unwanted interrupts. Two 4 bit registers (M and N) can be set with values such that M out of N measurements must exceed threshold settings in order to set an interrupt. The default setting of 1 out of 1 effectively turns the filter off and any single measurement exceeding thresholds can trigger an interrupt. (Note a setting of 0 is interpreted the same as a 1).

Table 15. PS_FILTER_CONFIG Register (0x14)

Bit	7	6	5	4	3	2	1	0
Field	filter_N				filter_M			

Field	Bit	Default	Description
PS_TH_LO_MSB	7:4	0001	Filter N
PS_TH_LO_LSB	3:0	0001	Filter M

PS_CONFIG Register (0x15)

Proximity measurement sensitivity is controlled by specifying the integration time. The integration time sets the number of LED pulses during the modulated illumination. The LED modulation frequency remains constant with a period of 1.5us. Changing the integration time affects the sensitivity of the detector and directly affects the power consumed by the LED. The default is 1200us integration period.
Hyst_enable and hyst_trigger work with the PS_TH (threshold) settings to provide jitter control of the INT function. ALS_blanking disables the ALS during the time the IR LED is on during a PS measurement. This will eliminate the effect of the PS IR signal bouncing off cover glass and affecting the ALS value.

Table 16. PS_CONFIG Register (0x15)

Bit	7	6	5	4	3	2	1	0
Field	NA		hyst_enable	hyst_trigger	als_blanking	integration_time		

Field	Bit	Default	Description	
NA	7:6	XX	Don't Care	
hyst_enable	5	0	0	Disables hysteresis
			1	Enables hysteresis
hyst_trigger	4	0	0	Lower threshold with hysteresis
			1	Upper threshold with hysteresis
als_blanking	3	1	0	Disables ALS blanking
			1	Enables ALS blanking
integration_time	2:0	011	000	150µs integration time
			001	300µs integration time
			010	600µs integration time
			011	1200µs integration time
			100	1800µs integration time
			101	2400µs integration time
			110	3600µs integration time
			111	4800µs integration time

PS_INTERVAL Register (0x16)

The PS_INTERVAL register sets the wait time between consecutive proximity measurements in PS_Repeat mode. The register is binary weighted times 5 in milliseconds plus 5ms. The range is therefore 5ms to 1.28s. The default startup value is 0x09 (50ms).

Table 17. PS_INTERVAL Register (0x16)

Bit	7	6	5	4	3	2	1	0
Field	interval							

Field	Bit	Default	Description	
Interval	7:0	0x09	0x00 to 0xFF	Interval time between measurement cycles. Binary weighted value times 5ms plus a 5ms offset.

PS_CONTROL Register (0x17)

The PS_CONTROL register is used to control the functional mode and commencement of proximity sensor measurements. The proximity sensor can be operated in either a single shot mode or consecutive measurements taken at programmable intervals.
Both single shot and repeat modes consume a minimum of power by immediately turning off LED driver and sensor circuitry after each measurement. In both cases the quiescent current is less than the IDDSTBY parameter. These automatic power management features eliminate the need for power down pins or special power down instructions.

Table 18. PS_CONTROL Register (0x17)

Bit	7	6	5	4	3	2	1	0
Field	NA						PS_Repeat	PS_OneShot

Field	Bit	Default	Description
NA	7:2	XXXXXX	Don't care
PS_Repeat	1	0	Initiates new measurements at PS_Interval rates
PS_OneShot	0	0	Triggers proximity sensing measurement. In single shot mode this bit clears itself after cycle completion.

ALS_TH Registers (0x20 – 0x23)

With hysteresis not enabled (see ALS_CONFIG register), the ALS_TH registers set the upper and lower interrupt thresholds of the ambient light detection window. Interrupt functions compare these threshold values to data from the ALS_DATA1 registers. Measured ALS_DATA1 values outside this window will set an interrupt according to the INT_CONFIG register settings.
With hysteresis enabled, threshold settings take on a different meaning. If the ALS_hyst_trig is set, the ALS_TH_UP register set the upper threshold at which an interrupt will be set, while the ALS_TH_LO register then sets the lower threshold hysteresis value where the interrupt would be cleared. Setting the ALS_hyst_trig low reverses the function such that the ALS_TH_LO register sets the lower threshold at which an interrupt will be set and the ALS_TH_UP represents the hysteresis value at which the interrupt would be subsequently cleared. Hysteresis functions only apply in "auto_clear INT_CONFIG mode.

Table 19. ALS_TH_UP Registers (0x20 – 0x21)

Bit	7	6	5	4	3	2	1	0
Field	ALS_TH_UP_MSB(0x20), ALS_TH_UP_LSB(0x21)							

Field	Bit	Default	Description
ALS_TH_UP_MSB	7:0	0xFF	Upper threshold for ALS detection, MSB
ALS_TH_UP_LSB	7:0	0xFF	Upper threshold for ALS detection, LSB

Table 20. ALS_TH_LO Registers (0x22 – 0x23)

Bit	7	6	5	4	3	2	1	0
Field	ALS_TH_LO_MSB(0x22), ALS_TH_LO_LSB(0x23)							

Field	Bit	Default	Description
ALS_TH_LO_MSB	7:0	0x00	Lower threshold for ALS detection, MSB
ALS_TH_LO_LSB	7:0	0x00	Lower threshold for ALS detection, LSB

ALS_CONFIG Register (0x25)

The ALS_CONFIG register controls the operation of the ambient light sensors. Als2_enable and als1_enable allow the desired sensors to be used while powering off unused sensors. Hyst_enable and hyst_trigger work with the ALS_TH (threshold) settings to provide jitter control of the INT function. The ambient light measurement sensitivity is controlled by specifying the integration time.

Table 21. ALS_CONFIG Register (0x25)

Bit	7	6	5	4	3	2	1	0
Field	als2_enable	als1_enable	hyst_enable	hyst_trigger	reserved	integration_time		

Field	Bit	Default	Description	
als2_enable	7	0	0	Disables ALS2 (unfiltered ALS)
			1	Enables ALS2
als1_enable	6	1	0	Disables ALS1 (ALS with photopic filter)
			1	Enables ALS1
hyst_enable	5	0	0	Disables hysteresis
			1	Enables hysteresis
hyst_trigger	4	0	0	Lower threshold with hysteresis
			1	Upper threshold with hysteresis
reserved	3	0	Must be set to 0	
integration_time	2:0	100	000	6.25ms integration time
			001	12.5ms integration time
			010	25ms integration time
			011	50ms integration time
			100	100ms integration time
			101	200 ms integration time
			110	400 ms integration time
			111	800 ms integration time

ALS_INTERVAL Register (0x26)

The ALS_INTERVAL register sets the interval between consecutive ALS measurements in ALS_Repeat mode. The register is binary weighted times 50 in milliseconds. The range is 0ms to 3.15s. The register value 0x00 and 0ms translates into a continuous loop measurement mode. The default startup value is 0x0A (500ms).

Table 22. ALS_INTERVAL Register (0x26)

Bit	7	6	5	4	3	2	1	0
Field	NA		interval					

Field	Bit	Default	Description
interval	5:0	0x0A	Interval time between ALS measurement cycles

ALS_CONTROL Register (0x27)

The ALS_CONTROL register is used to control the functional mode and commencement of ambient light sensor measurements. The ambient light sensor can be operated in either a single shot mode or consecutive measurements taken at programmable intervals.
Both single shot and repeat modes consume a minimum of power by immediately turning off sensor circuitry after each measurement.

In both cases the quiescent current is less than the IDDSTBY parameter. These automatic power management features eliminate the need for power down pins or special power down instructions. For accurate measurements at low light levels (belowapproximately 3 lux) ALS readings must be taken at least once per second.

Table 23. ALS_CONTROL Register (0x27)

Bit	7	6	5	4	3	2	1	0
Field	NA						ALS_Repeat	ALS_OneShot

Field	Bit	Default	Description
NA	7:2	XXXXXX	Don't care
ALS_Repeat	1	0	Initiates new measurements at ALS_Interval rates
ALS_OneShot	0	0	Triggers ALS sensing measurement. In single shot mode this bit clears itself after cycle completion.

INTERRUPT Register (0x40)

The INTERRUPT register displays the status of the interrupt pin and if an interrupt was caused by the proximity or ambient light sensor. If "auto_clear" is disabled (see INT_CONFIG register), reading this register also will clear the interrupt.

Table 24. INTERRUPT Register (0x40)

Bit	7	6	5	4	3	2	1	0
Field	NA			INT	ALS_intH	ALS_intL	PS_intH	PS_intL

Field	Bit	Default	Description
NA	7:5	XXX	Don't care
INT	4	0	Status of external interrupt pin (1 is asserted)
ALS_intH	3	0	Interrupt caused by ALS exceeding maximum
ALS_intL	2	0	Interrupt caused by ALS falling below the minimum
PS_intH	1	0	Interrupt caused by PS exceeding maximum
PS_intL	0	0	Interrupt caused by PS falling below the minimum

PS_DATA Registers (0x41 – 0x42)

The PS_DATA registers store results from completed proximity measurements. When an I^2C read operation begins, the current PS_DATA registers are locked until the operation is complete (I^2C_STOP received) to prevent possible data corruption from a concurrent measurement cycle.

Table 25. PS_DATA Registers (0x41 – 0x42)

Bit	7	6	5	4	3	2	1	0
Field	PS_DATA_MSB(0x41), PS_DATA_LSB(0x42)							

Field	Bit	Default	Description
PS_DATA_MSB	7:0	0x00	Proximity measurement data, MSB
PS_DATA_LSB	7:0	0x00	

ALS1_DATA Registers (0x43 – 0x44)

The ALS1_DATA registers store results from completed ALS1 measurements. When an I^2C read operation begins, the current ALS1_DATA registers are locked until the operation is complete (I^2C_STOP received) to prevent possible data corruption from a concurrent measurement cycle.

Table 26. ALS1_DATA Registers (0x43 – 0x44)

Bit	7	6	5	4	3	2	1	0
Field	ALS1_DATA_MSB(0x43), ALS1_DATA_LSB(0x44)							

Field	Bit	Default	Description
ALS1_DATA_MSB	7:0	0x00	ALS1 measurement data, MSB
ALS1_DATA_LSB	7:0	0x00	ALS1 measurement data, LSB

ALS2_DATA Registers (0x45 – 0x46)

The ALS2_DATA registers store results from completed ALS2 measurements. When an I^2C read operation begins, the current ALS2_DATA registers are locked until the operation is complete (I^2C_STOP received) to prevent possible data corruption from a concurrent measurement cycle.

Table 27. ALS2_DATA Registers (0x45 – 0x46)

Bit	7	6	5	4	3	2	1	0
Field	ALS2_DATA_MSB(0x45), ALS2_DATA_LSB(0x46)							

Field	Bit	Default	Description
ALS2_DATA_MSB	7:0	0x00	ALS2 measurement data, MSB
ALS2_DATA_LSB	7:0	0x00	ALS2 measurement data, LSB

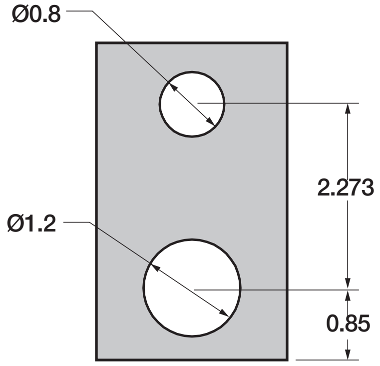
Example Programming Sequence

The following pseudo code configures the HS3000A proximity sensor in repeat mode with 50ms wait time between each measurement and then runs it in an interrupt driven mode. When the controller receives an interrupt, the interrupt determines if the interrupts was caused by the proximity sensor and if so, reads the PS_ Data from the device, sets a flag and then waits for the main polling loop to respond to the proximity change.

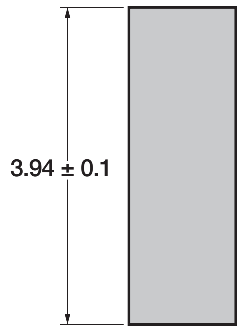
```
external subroutine I2C_Read_Byte (I2C_Address, Data_Address);
external subroutine I2C_Read_Block (I2C_Address, Data_Start_Address, Count, Memory_Map);
external subroutine I2C_Write_Byte (I2C_Address, Data_Address, Data);
external subroutine I2C_Write_Block (I2 C_Address, Data_Start_Address, Count, Memory_Map);
subroutine Initialize_PS () {
MemBuf[0x02] = 0x02; // INT_CONFIG assert interrupt until cleared
MemBuf[0x0F] = 0x09; // PS_LED_CURRENT 50mA
MemBuf[0x10] = 0x8F; // PS_TH_UP_MSB
MemBuf[0x11] = 0xFF; // PS_TH_UP_LSB
MemBuf[0x12] = 0x70; // PS_TH_LO_MSB
MemBuf[0x13] = 0x00; // PS_TH_LO_LSB
MemBuf[0x14] = 0x11; // PS_FILTER_CONFIG turn off filtering
MemBuf[0x15] = 0x09; // PS_CONFIG ALS blanking enabled, 300us integration time
MemBuf[0x16] = 0x0A; // PS_INTERVAL 50ms wait
MemBuf[0x17] = 0x02; // PS_CONTROL enable continuous PS measurements
MemBuf[0x20] = 0xFF; // ALS_TH_UP_MSB
MemBuf[0x21] = 0xFF; // ALS_TH_UP_LSB
MemBuf[0x22] = 0x00; // ALS_TH_LO_MSB
MemBuf[0x23] = 0x00; // ALS_TH_LO_LSB
MemBuf[0x25] = 0x44; // ALS_CONFIG ALS2 disabled, ALS1 enabled, 100ms integration time
MemBuf[0x26] = 0x00; // ALS_INTERVAL continuous measurement mode
MemBuf[0x27] = 0x02; // ALS_CONTROL enable continuous ALS measurements
I2C_Write_Block (I2CAddr, 0x02, 37, MemBuf);
}
subroutine I2C_Interupt_Handler () {
// Verify this is a PS interrupt
INT = I2C_Read_Byte (I2CAddr, 0x40);
if (INT == 0x11 || INT == 0x12) {
// Retrieve and store the PS data
PS_Data_MSB = I2C_Read_Byte (I2CAddr, 0x41);
PS_Data_LSB = I2C_Read_Byte (I2CAddr, 0x42);
NewPS = 0x01;
}
}
subroutine main_loop () {
I2CAddr = 0x37;
NewPS = 0x00;
Initialize_PS ();
loop {
// Do some other polling operations
if (NewPS == 0x01) {
NewPS = 0x00;
// Do some operations with PS_Data
}
}
```

PACKAGE INFORMATION

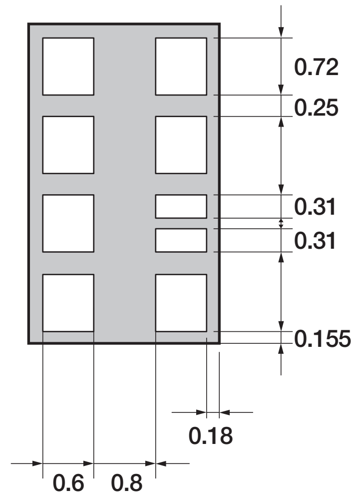
TOP VIEW



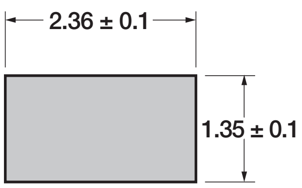
SIDE VIEW



BOTTOM VIEW



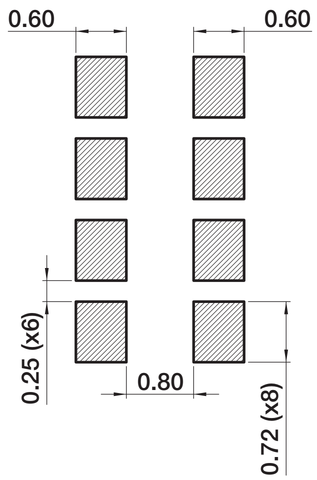
END VIEW



Notes:

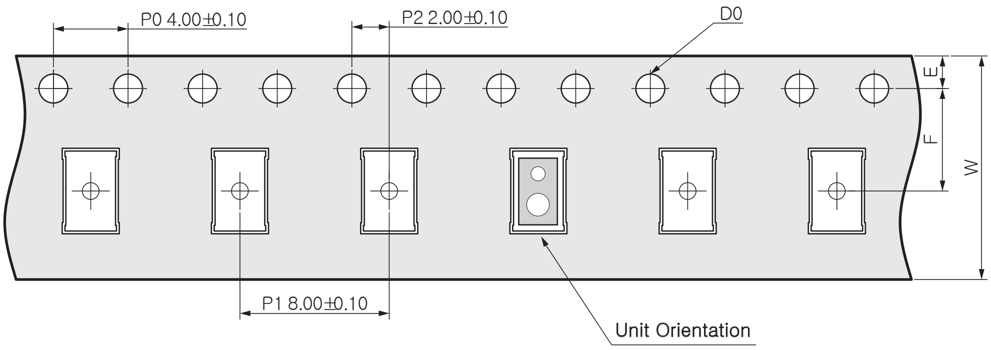
1. All dimensions are in millimeters.
2. Dimension tolerance is ± 0.05mm unless otherwise noted.
3. Drawing not to scale.

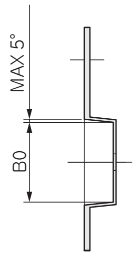
PCB Pad Layout

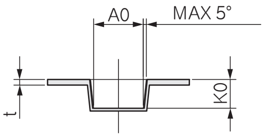


TAPE DIMENSIONS

(Unit : mm)



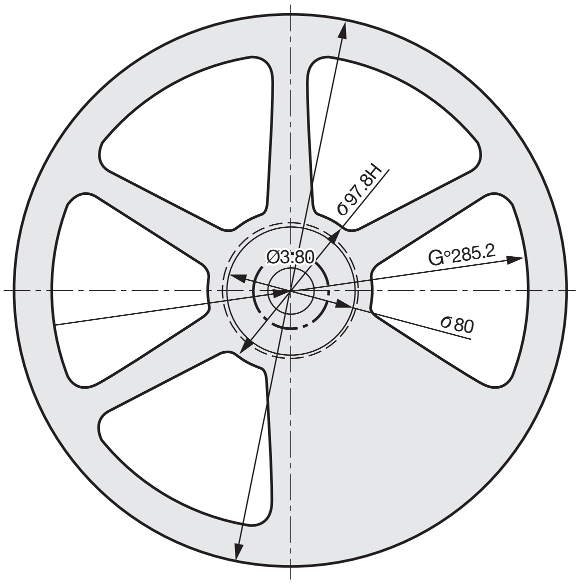


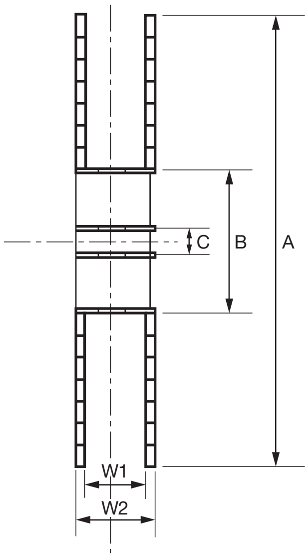


Description	HS3000A
E	1.75±0.10
F	5.50±0.10
A0	2.60±0.10
B0	4.25±0.10
K0	1.55±0.10
D0	1.55±0.05
W	12.00±0.30
t	0.30±0.05

REEL DIMENSIONS

(Unit : mm)





A	B	C	W1	W2
330±1	80±1	13.0±0.2	13.5	17.5

STORAGE INFORMATION

Recommended Storage Conditions

Moisture Barrier Bags
Temperature Range < 40°C
Relative Humidity < 90%
Total Time < 12 months from the date code
Rebaking of the reel will be required if the devices have been stored unopened for more than 12 months and the Humidity Indicator Card shows the parts to be out of the allowable moisture region.

Recommended Baking Conditions

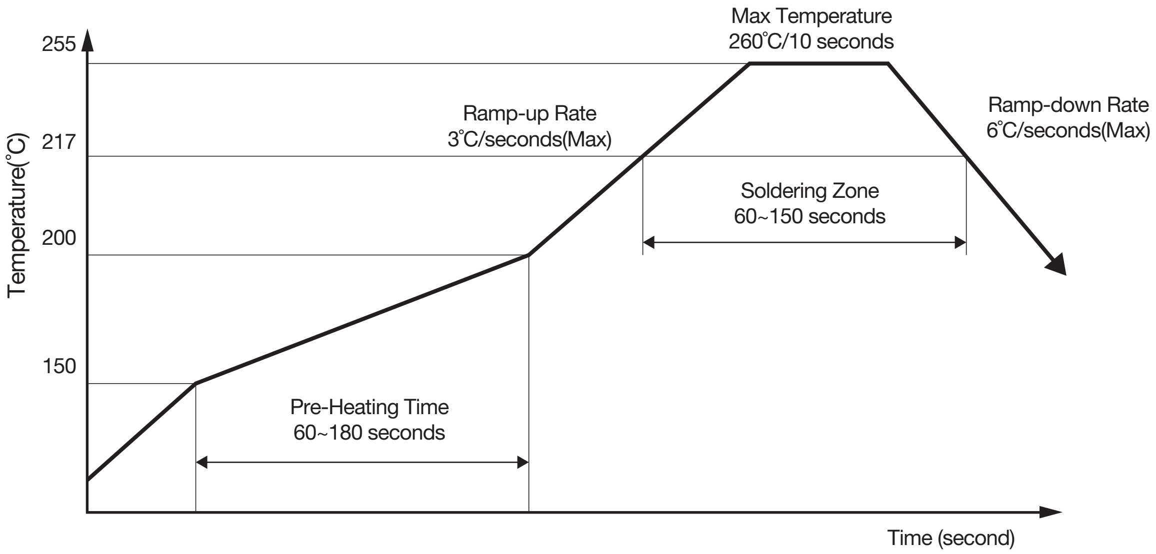
In Reel : 60 °C, 48 hours
In Bulk : 100 °C, 4 hours

The device has been assigned a moisture sensitivity level of MSL 3.

SOLDERING INFORMATION

Solder Reflow Profile

Parameter	Temperature	Time	Condition
Peak temperature	260 °C	10 seconds	
Preheat temperature range and timing	150 ~ 200 °C	60 ~ 180 seconds	
Timing within 5 °C to peak temperature		10 ~ 30 seconds	
Timing maintained above temperature / time	217 °C	60 ~ 150 seconds	
Timing from 25 °C to peak temperature		8 minutes (Max)	
Ramp-up rate	3 °C / seconds (Max)		
Ramp-down rate	6 °C / seconds (Max)		



Solder Reflow Profile Chart