NOA3315

Digital Proximity Sensor with Dual Ambient Light Sensors and Interrupt

Description

The NOA3315 combines an advanced digital proximity sensor and LED driver with dual ambient light sensors (ALS) and tri−mode I^{2}C 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 NOA3315 enables a proximity sensor system with a 16:1 programmable LED drive current range and a 30 dB 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

[redacted]

Table 4. ELECTRICAL CHARACTERISTICS (Unless otherwise specified, these specifications apply over 2.3 V < VDD < 3.6 V, 1.7 V < VDD_I2C < 1.9 V, −40°C < T_A < 80°C, 10 pF < Cb < 100 pF) (See Note 4)

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		

Table 4. ELECTRICAL CHARACTERISTICS (Unless otherwise specified, these specifications apply over 2.3 V < VDD < 3.6 V, 1.7 V < VDD_I2C < 1.9 V, −40°C < T_A < 80°C, 10 pF < Cb < 100 pF) (See Note 4)

Parameter	Symbol	Min	Typ	Max	Unit
Capacitive load for each bus line (including all parasitic capacitance) (Note 6)	C_b	10		100	pF
Noise margin at the low level (for each connected device − including hysteresis)	V_{nL}	0.1 VDD		−	V
Noise margin at the high level (for each connected device − including hysteresis)	V_{nH}	0.2 VDD		−	V

Table 5. OPTICAL CHARACTERISTICS (Unless otherwise specified, these specifications are for VDD = 3.0 V, T_A = 25°C)

Parameter	Symbol	Min	Typ	Max	Unit
PROXIMITY SENSOR (Note 8)					
Detection range, Tint = 300 μs, I_{LED} = 150 mA, 860 nm IR LED (OSRAM SFH4650), White Reflector (RGB = 220, 224, 223), SNR = 8:1	$D_{PS\_300\_WHITE\_150}$		74		mm
Detection range, Tint = 300 μs, I_{LED} = 100 mA, 860 nm IR LED (OSRAM SFH4650), White Reflector (RGB = 220, 224, 223), SNR = 8:1	$D_{PS\_300\_WHITE\_100}$		62		mm
Detection range, Tint = 150 μs, I_{LED} = 100 mA, 860 nm IR LED (OSRAM SFH4650), White Reflector (RGB = 220, 224, 223), SNR = 8:1	$D_{PS\_150\_WHITE\_100}$		48		mm
Detection range, Tint = 1200 μs, I_{LED} = 100 mA, 860 nm IR LED (OSRAM SFH4650), Grey Reflector (RGB = 162, 162, 160), SNR = 6:1	$D_{PS\_1200\_GREY\_100}$		64		mm
Detection range, Tint = 2400 μs, I_{LED} = 150 mA, 860 nm IR LED (OSRAM SFH4650), Black Reflector (RGB = 16, 16, 15), SNR = 6:1	$D_{PS\_2400\_BLACK\_150}$		36		mm
Saturation power level	P_{DMAX}		0.8		mW/cm^2
Measurement resolution, Tint = 150 μs	MR_{150}		11		bits
Measurement resolution, Tint = 300 μs	MR_{300}		12		bits
Measurement resolution, Tint = 600 μs	MR_{600}		13		bits
Measurement resolution, Tint = 1200 μs	MR_{1200}		14		bits
Measurement resolution, Tint = 1800 μs	MR_{1800}		15		bits
Measurement resolution, Tint = 2400 μs	MR_{2400}		15		bits
Measurement resolution, Tint = 3600 μs	MR_{3600}		16		bits
Measurement resolution, Tint = 4800 μs	MR_{4800}		16		bits

7. Refer to Figure 4 for more information on spectral response.
8. Measurements performed with default modulation frequency and sample delay unless noted.

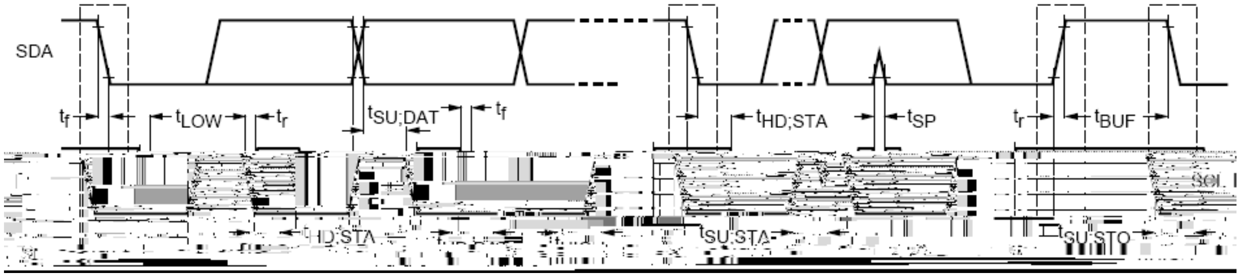


Figure 2. AC Characteristics, Standard and Fast Modes

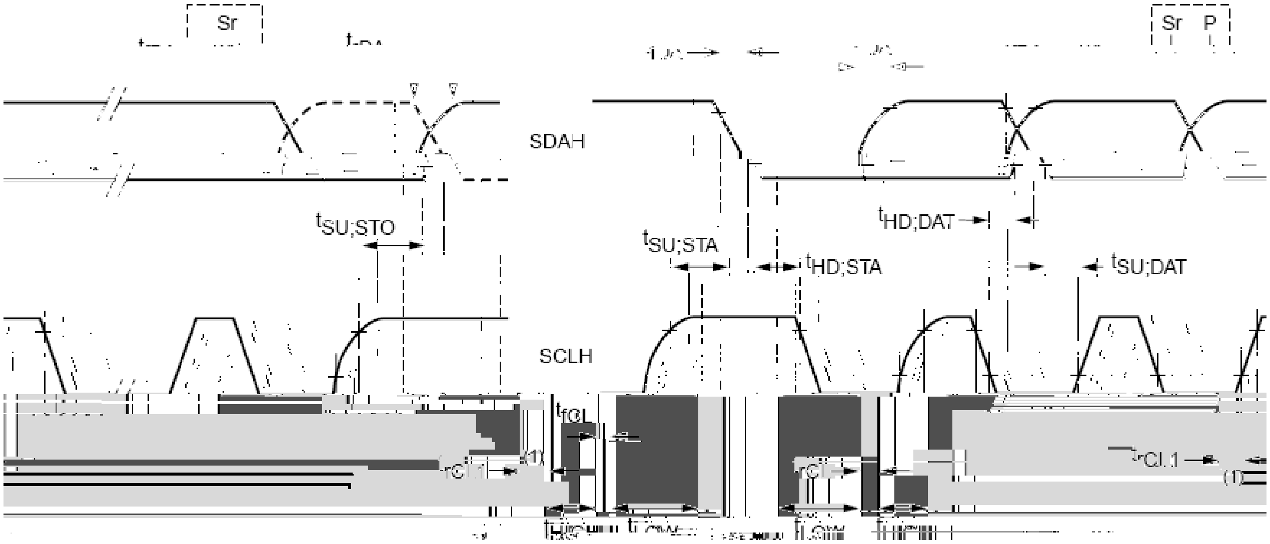
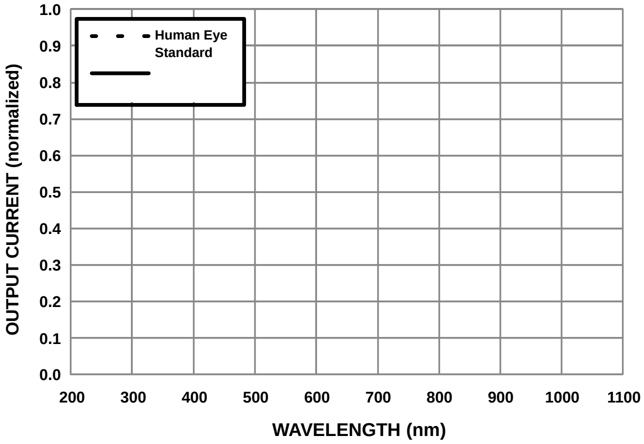


Figure 3. AC Characteristics, High Speed Mode



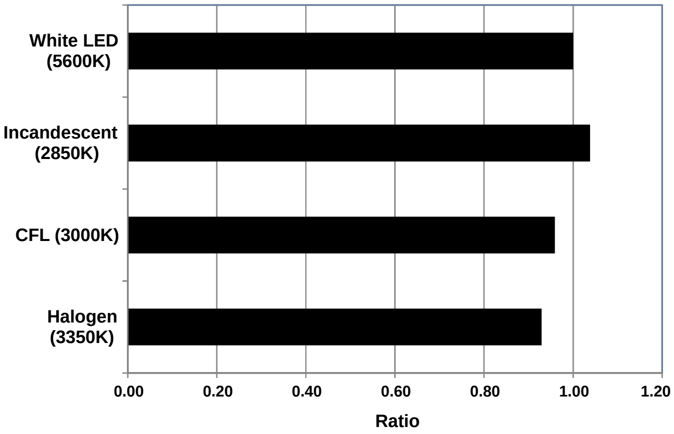


Figure 4. ALS Spectral Response (Normalized)

Figure 5. ALS1 Light Source Dependency (Normalized to White LED Light)

TYPICAL CHARACTERISTICS

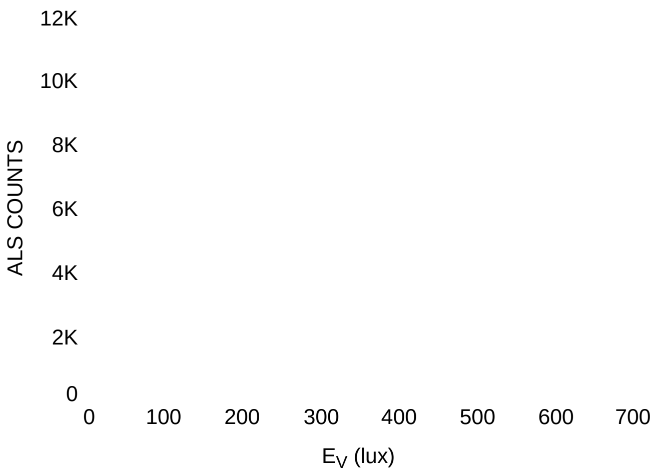


Figure 6. ALS1 Linearity 0−700 lux

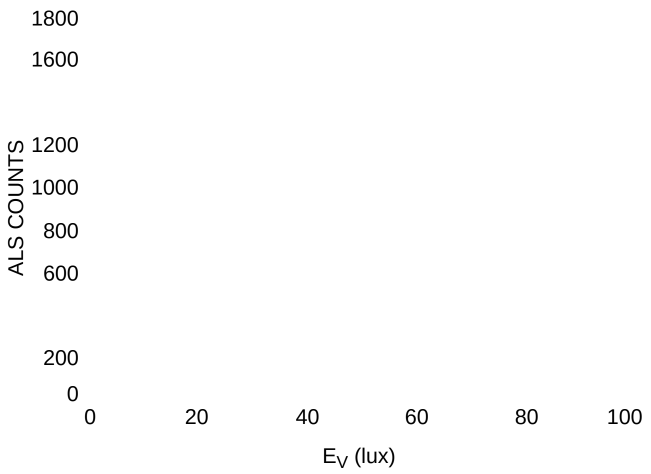


Figure 7. ALS1 Linearity 0−100 lux

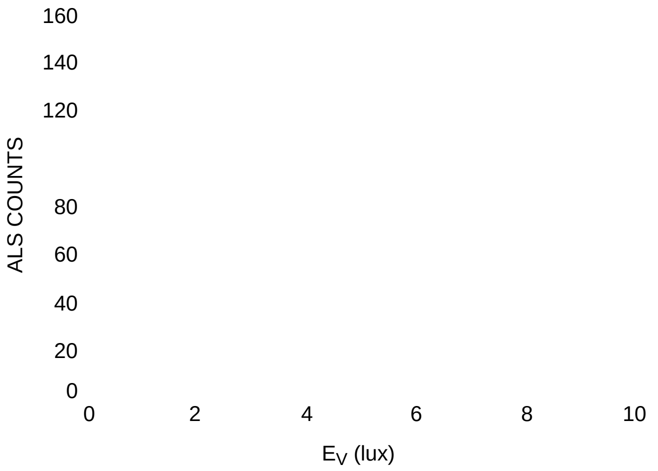


Figure 8. ALS1 Linearity 0−10 lux

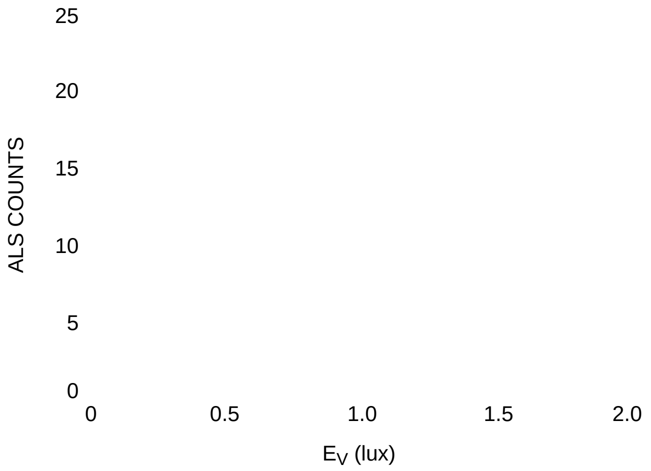


Figure 9. ALS1 Linearity 0−2 lux

Figure 10. ALS1 & ALS2 Horizontal Response to White LED Light vs Angle (Source swept from LED pin (+90°) to VDD pin (−90°))

Figure 11. ALS1 & ALS2 Vertical Response to White LED Light vs Angle (Source swept from LED pin (+90°) to INT pin (−90°))

TYPICAL CHARACTERISTICS

Figure 12. PS Horizontal Response to IR LED Light vs Angle (Source swept from LED pin (+90°) to VDD pin (−90°))

Figure 13. PS Vertical Response to IR LED Light vs Angle (Source swept from LED pin (+90°) to INT pin (−90°))

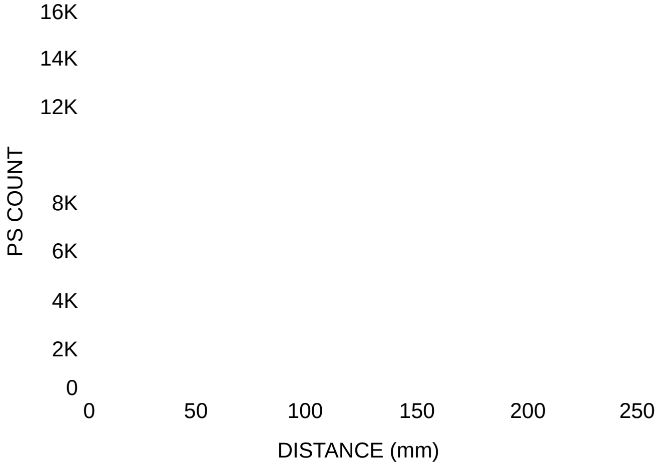


Figure 14. PS Response vs. Distance and LED Current (1200 μs Integration Time, White Reflector (RGB = 220, 224, 223))

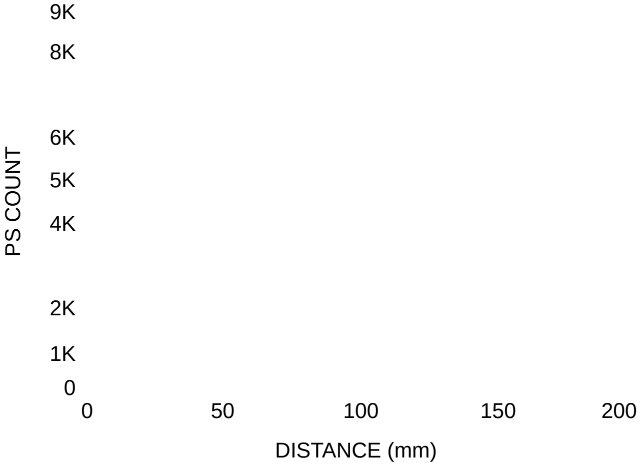


Figure 15. PS Response vs. Distance and LED Current (1200 μs Integration Time, Grey Reflector (RGB = 162, 162, 160))

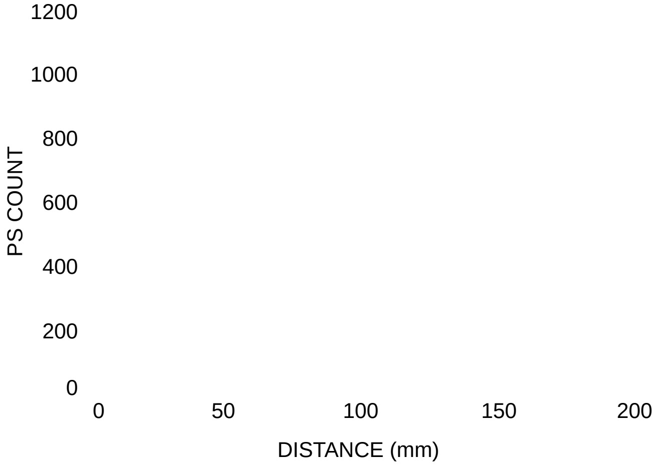


Figure 16. PS Response vs. Distance and LED Current (1200 μs Integration Time, Black Reflector (RGB = 16, 16, 15))

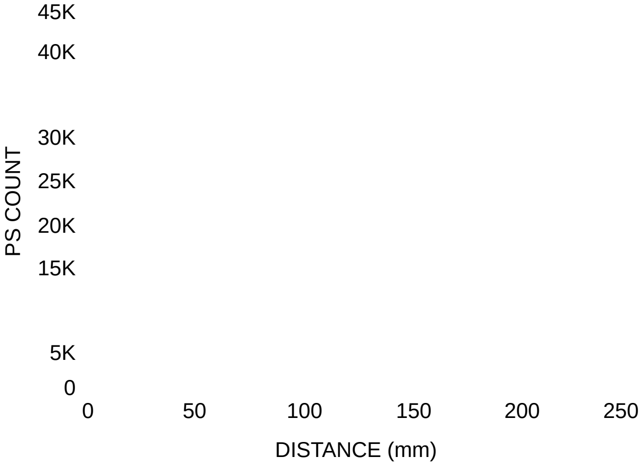


Figure 17. PS Response vs. Distance and Integration Time (80 mA LED Current, White Reflector (RGB = 220, 224, 223))

TYPICAL CHARACTERISTICS

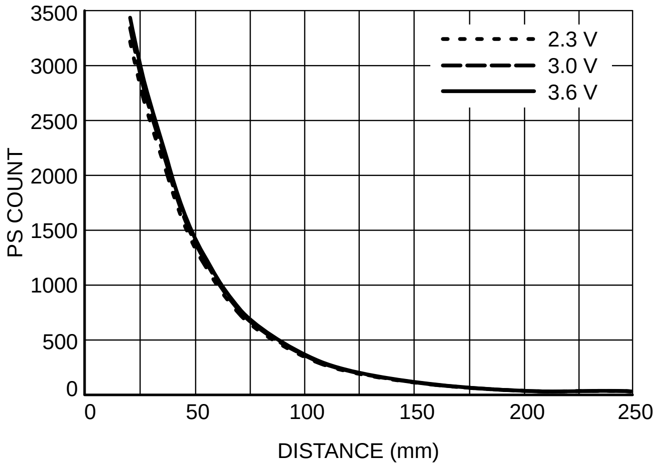


Figure 18. PS Response vs. Distance and Supply Voltage (1200 μs Integration Time, 40 mA LED Current, White Reflector (RGB = 220, 224, 223))

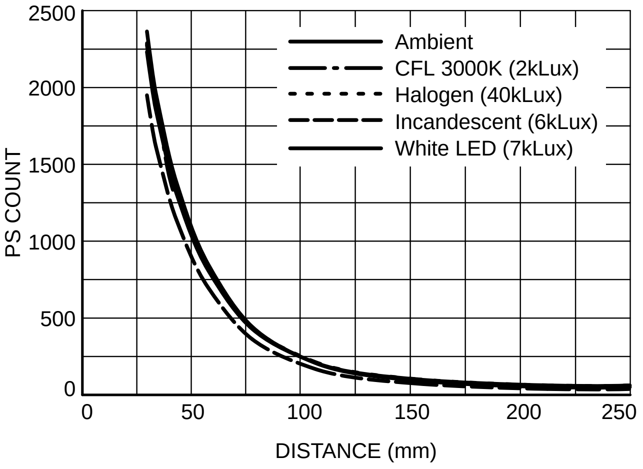


Figure 19. PS Ambient Rejection (1200 μs Integration Time, 100 mA LED Current, White Reflector (RGB = 220, 224, 223))

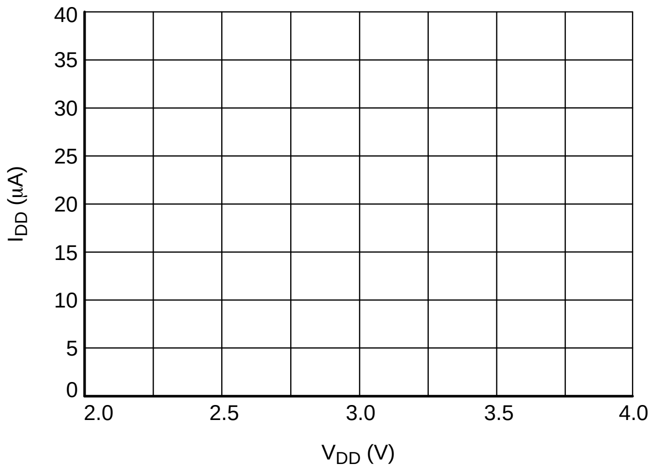


Figure 20. Supply Current vs. Supply Voltage ALS1 or ALS2 TINT = 100 ms, TR = 500 ms PS TINT = 300 μs, TR = 100 ms

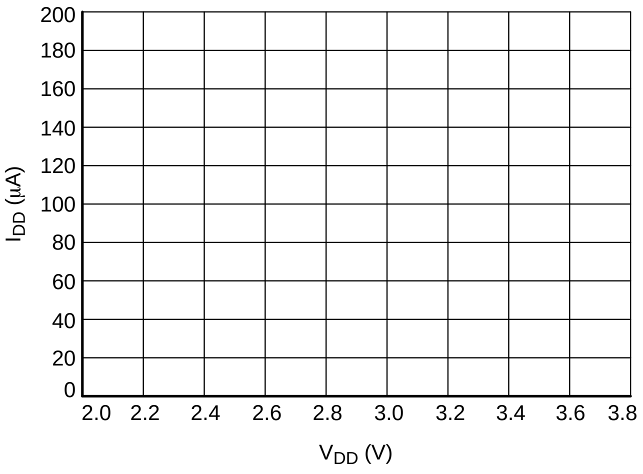


Figure 21. Supply Current vs. Supply Voltage ALS1 and ALS2 TINT = 100 ms, TR = 500 ms PS TINT = 1200 μs, TR = 50 ms

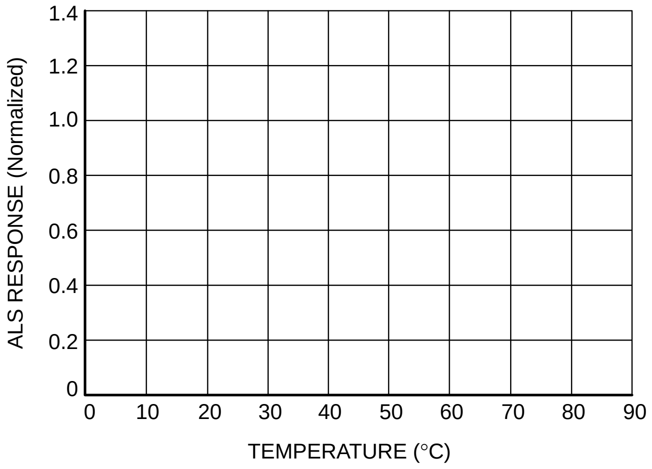


Figure 22. ALS1 Response vs. Temperature

NOA3315

and the intensity of the ambient incandescent light (in lux):

$$I_L = \frac{C_{nt}}{(2080 \cdot T_{int})} \qquad \text{(eq. 3)}$$

For example let:

C_{nt} = 2000 counts
T_{int} = 50 ms

Intensity of ambient fluorescent light, I_L(in lux):

$$I_L = \frac{2000}{(1920 \cdot 50\ \text{ms})} \qquad \text{(eq. 4)}$$

$$I_L = 20.83\ \text{lux}$$

ALS Spectral Response Correction

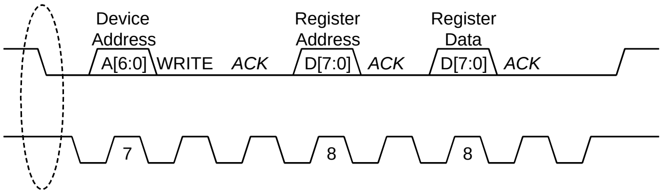
The ALS1 photopic filter has some IR leakage which results in higher ALS readings for light sources with higher IR content, such as incandescent lighting. For purely photopic light, ALS1 is very accurate and correction is not needed. For other light sources, or if the spectral response of the light is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

$$ALS = ALS1 \cdot \left(0.1 \cdot \left(\frac{ALS1}{ALS2}\right) + 0.5\right)$$

The equation shown does not work well for very low ALS1 and/or ALS2 values (a single count introduces a large correction factor), 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.

I^{2}C Interface

The NOA3315 acts as an I^{2}C 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.



PART_ID Register (0x00)

The PART_ID register provides part and revision identification. These values are hard−wired at the factory and cannot be modified.

Table 8. PART_ID Register (0x00)

Bit	7	6	5	4	3	2	1	0
Field	Part number ID				Revision ID			

Field	Bit	Default	Description
Part number ID	7:4	1011	Part number identification
Revision ID	3:0	NA	Silicon revision number

RESET Register (0x01)

Software reset is controlled by this register. Setting this register followed by an I2C_STOP sequence will immediately reset the NOA3315 to the default startup

Table 11. PS_LED_FREQUENCY Register (0x0D)

Bit

Table 14. 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 15. 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. N must be greater than or equal to M. A setting of 0 for either M or N is not allowed and disables the PS Interrupt.

Table 16. PS_FILTER_CONFIG Register (0x14)

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

Field	Bit	Default	Description
filter_N	7:4	0001	Filter N
filter_M	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 1.5 μs. Changing the integration time affects the sensitivity of the detector and directly affects the power consumed by the LED. The default is 1200 μs 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 17. 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	150 μs integration time
			001	300 μs integration time
			010	600 μs integration time
			011	1200 μs integration time
			100	1800 μs integration time
			101	2400 μs integration time
			110	3600 μs integration time
			111	4800 μs 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 10 in milliseconds plus 10ms. The range is therefore 10 ms to 1.28 s. The default startup value is 0x04 (50 ms).

Table 18. PS_INTERVAL Register (0x16)

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

Field	Bit	Default	Description	
NA	7	0		
Interval	6:0	0x04	0x00 to 0x7F	Interval time between measurement cycles. Binary weighted value times 10 ms plus a 10 ms 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

Table 19. 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 sets 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 20. 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 21. 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_FILTER_CONFIG Register (0x24)

ALS_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. N must be greater than or equal to M. A setting of 0 for either M or N is not allowed and disables the ALS Interrupt.

Table 22. ALS_FILTER_CONFIG Register (0x24)

Bit	7

ALS_CONFIG Register (0x25)

The ALS_CONFIG register controls the operation of the

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 IDD_{STBY} 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 (below approximately 3 lux) ALS readings must be taken at least once per second and the first measurement after a reset (software reset or power cycling) should be ignored.

Table 25. 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
[redacted]LS_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 26. INTERRUPT Register (0x40)

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

Field

[redacted]

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 (I2C_STOP received) to prevent possible data corruption from a concurrent measurement cycle.

Table 28. 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 (I2C_STOP received) to prevent possible data corruption from a concurrent measurement cycle.

Table 29. 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

Proximity Sensor Operation

NOA3315 operation is divided into three phases: power

Ambient Light Sensor Operation

The NOA3315 supports dual ambient light sensors. ALS1 has a photopic filter which closely mimics the spectral response of the human eye. ALS2 has no filters. In many respects ALS1 and ALS2 are similar, but each sensor can be separately enabled or disabled and each ALS has its own data registers. ALS1 and ALS2 share control, configuration and operational details except that ALS2 is not compared to the threshold registers and cannot create an interrupt. ALS1 and ALS2 support simultaneous concurrent measurements allowing the two sensor values to be read out and used in computations as desired.

ALS configuration is accomplished by writing the desired configuration values to registers 0x02 and 0x20 through 0x27. Writing to configuration registers can be done with either individual I^{2}C byte−write commands or with one or more I^{2}C block write commands. Block write commands specify the first register address and then write multiple bytes of data in sequence. The NOA3315 automatically increments the register address as it acknowledges each byte transfer.

ALS measurement is initiated by writing appropriate values to the CONTROL register (0x27). Sending an I2C_STOP sequence at the end of the write signals the internal state machines to wake up and begin the next measurement cycle. Figure 27 and Figure 28 illustrate the activity of key signals during an ambient light sensor measurement cycle. The cycle begins by starting the calibrated low frequency (LF) oscillator and powering up the ambient light sensor. Next, the ambient light measurement is made for the specified integration time and the result is stored in the appropriate 16 bit ALS Data registers. If in One−shot mode, the ALS is powered down and awaits the next command. If in Repeat mode the ALS is powered down, the interval is timed out and the operation repeated. There are some special cases if the interval timer is set to less than the integration time. For continuous mode, the interval is set to either 0 or a value less than or equal to the integration time and the ALS makes continuous measurements with only a 5 μs delay between integration times and the ALS remains powered up.

I2C Stop

ALS Power

LF Osc4ious

Example Programming Sequence

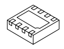
The following pseudo code configures the NOA3315 proximity sensor in repeat mode with 50 ms wait time between each measurement and then runs it in an interrupt driven mode. When the controller receives an interrupt, the interrupt determines if the interrupts was caused by the proximity sensor and if 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.

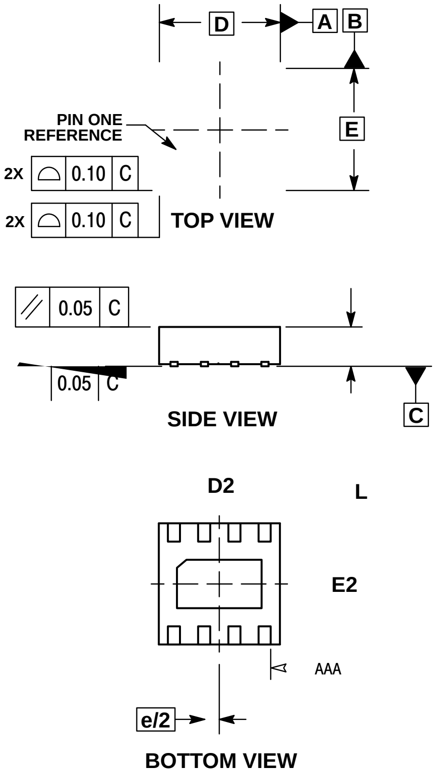
```
                    2C       B   ( 2C A       , D    A       );
                    2C       B     ( 2C A       , D     A       , C    ,          );
                    2C     B   ( 2C A       , D    A       , D  );
                    2C     B     ( 2C A       , D     A       , C    ,          );
                                 ()
    B   0 02  = 0 02;   //   C F
    B   0 0F  = 0 09;   //     ED C   E   50 A
    B   0 10  = 0 8F;   //            B
    B   0 11  = 0 FF;   //            B
    B   0 12  = 0 70;   //            B
    B   0 13  = 0 00;   //            B
    B   0 14  = 0 11;   //    F   E  C  F
    B   0 15  = 0 09;   //    C  F   A                 , 300
    B   0 16  = 0 0A;   //      E  A  50
    B   0 17  = 0 02;   //    C
    B   0 20  = 0 FF;   // A           B
    B   0 21  = 0 FF;   // A           B
    B   0 22  = 0 00;   // A           B
    B   0 23  = 0 00;   // A           B
    B   0 25  = 0 40;   // A   C  F   A  2         , A  1        ,                   , 50
    B   0 26  = 0 00;   // A     E  A
    B   0 27  = 0 02;   // A   C                          A
  2C       B      ( 2CA   , 0 02, 37,    B  );

           2C                  ()
 //
      =  2C       B    ( 2CA   , 0 40);
    (     == 0 11        == 0 12)
  //
     D       B =  2C       B    ( 2CA   , 0 41);
     D       B =  2C       B    ( 2CA   , 0 42);
            = 0 01;


                              ()
  2CA     = 0 37;
         = 0 00;
                 ();

  // D
    (       == 0 01)
           = 0 00;
   // D                          D
```

Physical Location of Photodiode Sensors

The physical locations of the NOA3315 proximity sensor and ambient light sensor photodiodes are shown in Figure 29.

Figure 29. Photodiode Locations





NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: MILLIMETERS.
3. DIMENSION b APPLIES TO PLATED TERMINAL AND IS MEASURED BETWEEN 0.15 AND 0.30 MM FROM THE TERMINAL TIP.
4. COPLANARITY APPLIES TO THE EXPOSED PAD AS WELL AS THE TERMINALS.

(*Note: Clear package, no marking is present)