

# LIDAR-Lite Documentation

## LIDAR-Lite v2 "Blue Label"

Welcome to the documentation for LIDAR-Lite v2. Like our github repos, this is currently a work in progress but will be updated until we reach a sufficient plateau. Please contact the support team where you purchased your LIDAR-Lite if you need help not yet addressed here.

# LIDAR-Lite v2 Overview

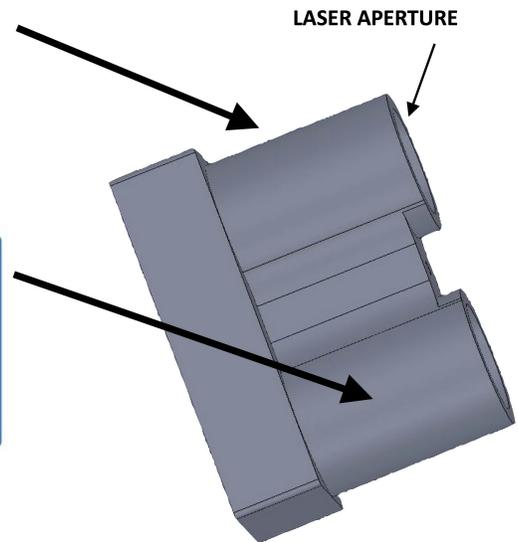
# LIDAR-Lite Specifications

General	Technical Specifications
Power	4.75-5.5V DC Nominal, Maximum 6V DC
Weight	PCB 4.5 grams, Module 22 grams with optics and housing
Size	PCB 44.5 X 16.5mm (1.75" by .65")
Housing	20 X 48 X 40mm (.8" X 1.9" X 1.6")
Current Consumption	<2mA @ 1Hz (shutdown between measurements), <100mA (continuous operation)
Max Operating Temp.	70° C
External Trigger	3.3V logic, high-low edge triggered
PWM Range Output	PWM (Pulse Width Modulation) signal proportional to range, 1msec/meter, 10µsec step size
I2C Machine Interface	100Kb – Fixed, 0xC4 slave address. Internal register access & control.
Supported I2C Commands	Single distance measurement, velocity, signal strength
Mode Control	Busy status using I2C, External Trigger input / PWM outputs
Max Range under typical conditions	~40m
Accuracy	+/- 2.5cm, or +/- ~1"
Default Rep Rate	~50 Hz.

# Laser Safety

**CLASS 1 LASER PRODUCT**  
CLASSIFIED EN/IEC 60825-1 2007  
Complies with US FDA performance standards for laser products except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007

**PULSEDLIGHT, LLC**  
**LIDAR-Lite Manufacture Date: July 2014**  
PulsedLight, LLC, PO Box 691, Bend, OR 97709  
sensors@pulsedlight3d.com



LIDAR-Lite is a laser rangefinder that emits laser radiation. This Laser Product is designated Class 1 during all procedures of operation. This means that the laser is safe to look at with the unaided eye. However, it is very advisable to avoid looking into the beam and power the module off when not in use.

No regular maintenance is required for LIDAR-Lite. In the event that the unit becomes damaged or is inoperable, repair or service of LIDAR-Lite is only to be handled by authorized, factory-trained technicians. No service of LIDAR-Lite by the user is allowed. Attempting to repair or service the unit on your own can result in direct exposure to laser radiation and the risk of permanent eye damage. For repair or service please contact PulsedLight directly for a return authorization.

No user should modify LIDAR-Lite or operate it without its housing or optics. The operation of LIDAR-Lite without a housing and optics or modification of the housing or optics that exposes the laser source may result in direct exposure to laser radiation and the risk of permanent eye damage. Removal or modification of the diffuser in front of the laser optic may result in the risk of permanent eye damage.

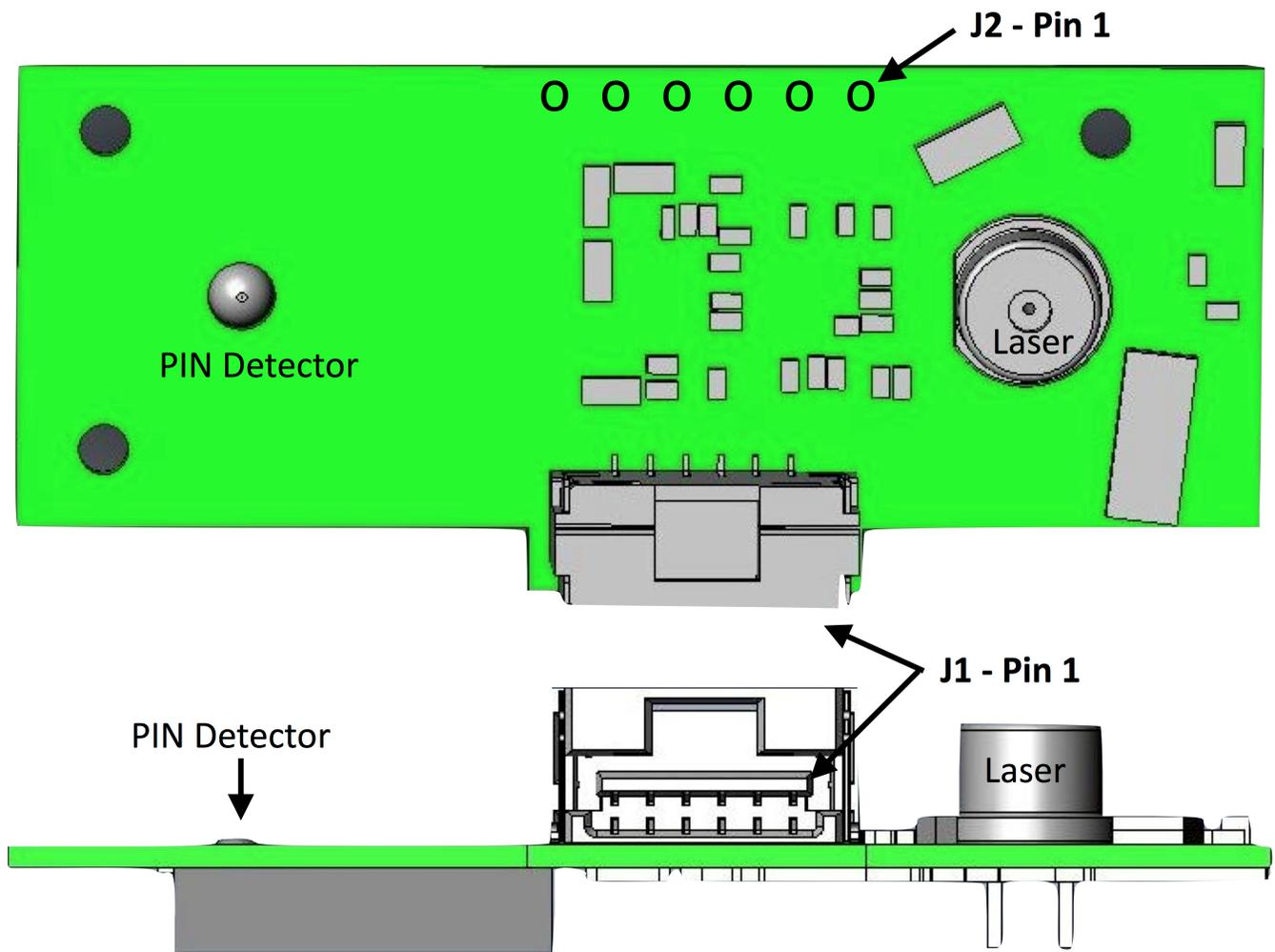
Caution – Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure. PulsedLight is not responsible for injuries caused through the improper use or operation of this product.

## Class 1 Laser Product

This Laser Product is designated Class 1 during all procedures of operation.

<b>Parameters</b>	<b>Laser Value</b>
Wavelength	905nm (nominal)
Total Laser Power - Peak	1.3Watts
Mode of operation	Pulsed (max pulse train 256 pulses)
Pulse Width	0.5 $\mu$ Sec (50% duty Cycle)
Pulse Repetition Frequency	10-20KHz nominal
Energy per Pulse	<280nj
Beam Diameter at laser aperture	12mm x 2mm
Divergence	4mRadian x 2mRadian (Approx)

# LIDAR-Lite Signal & Power Interface Definitions



## J1 - Primary interface

**Board Connector:** Molex part #5023860670 (DigiKey Part #: WM3917CT-ND)

**Mating Connector:** Molex # 5023800600 PLUG HSG 6POS (DigiKey Part #: WM2271-ND)

Pin	Description
PIN1	POWER_IN - 4.75-5.5V DC Nominal, Maximum 6V DC. Peak current draw from this input (which occurs during acquisition period) is typically < 100 mA over a duration from 4 to 20ms depending on received signal strength. Unless you use power management, the unit will draw 80 mA between acquisition times.
PIN2	POWER_EN - Active high, enables operation of the 3.3V micro-controller regulator. Low puts board to sleep, draws <40 $\mu$ A. (Internal 100K pull-up)

Pin	Description
PIN3	Mode Select – Provides trigger (high-low edge) PWM out (high)
PIN4	I2C Clock (SCL)
PIN5	I2C Data (SDA)
PIN6	Signal/power ground.

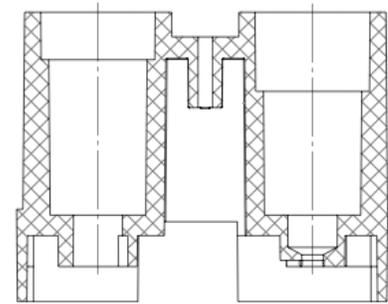
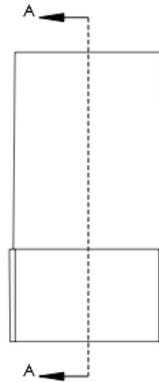
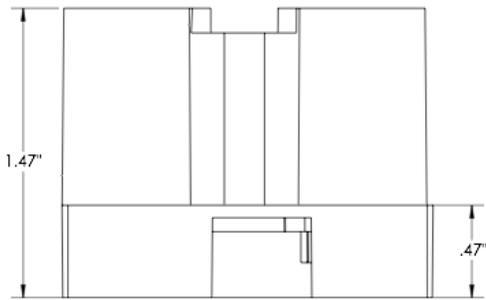
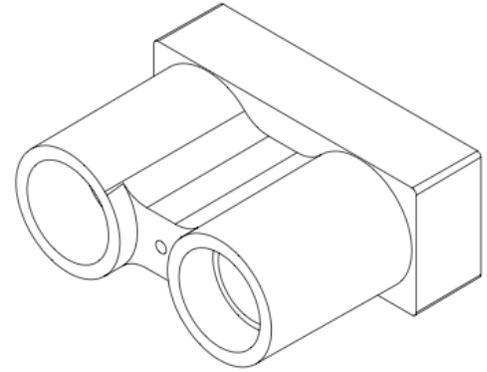
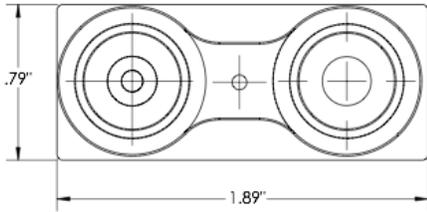
## J2 - Secondary signal/power - .1" spacing Molex style through hole (Factory Option Only)

Pin	Description
PIN1	Laser Bypass 5-20V max (nominally connected to pin 2 through inductor L8 – removed for external power)
PIN2	POWER_IN – 4.75-5.5V DC Nominal, Maximum 6V DC
PIN3	POWER_EN - Active high
PIN4	External reference clock input (Factory Option – Consult Factory)
PIN5	Signal/power ground.
PIN6	Detector bias – up to 25V external bias for PIN, external bias input 200V for APD (consult factory)

# Module Mechanical Drawings & Dimensions

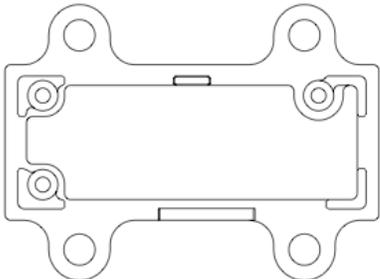
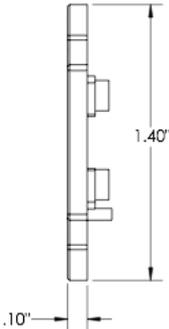
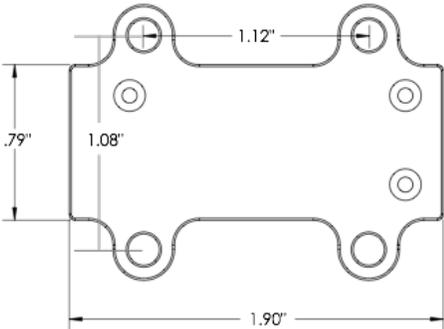
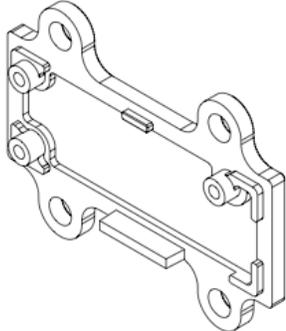
[Download Housing and Cover in PNG, STL, STEP and SLDPRT formats on GitHub](#)

PulsedLight, Inc. - LIDAR-Lite Housing



SECTION A-A

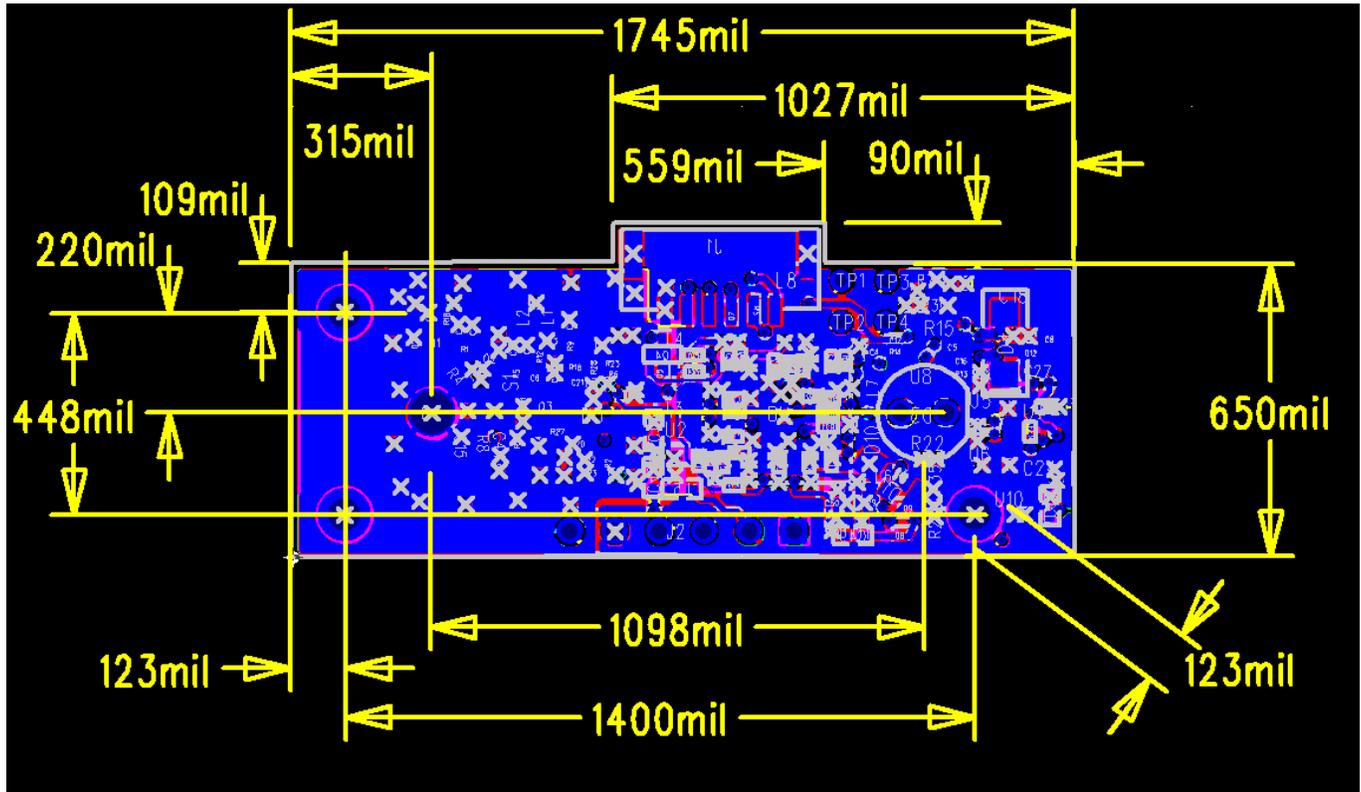
PulsedLight Inc. - LIDAR-Lite Housing Cover



Notes: - The hole diameters at their smallest are 0.15" or 0.385 cm with a little rounding erring small

# PCB Dimensions

Backside viewed through board



# Technology

# Technology and System Hardware Overview

## Technology

PulsedLight's "Time-of-flight" distance measurement technology is based on the precise measurement of the time delay between the transmission of an optical signal and its reception. Our patented, high accuracy measurement technique enables distance measurement resolution down to 1cm by the digitization and averaging of two signals; a reference signal fed from the transmitter prior to the distance measurement and a received signal reflected from the target. The time delay between these two stored signals is estimated through a signal processing approach known as correlation, which effectively provides a signature match between these two closely related signals. Our correlation algorithm accurately calculates the time delay, which is translated into distance based on the known speed-of-light. A benefit of PulsedLight's approach is the efficient averaging of low-level signals enabling the use of relatively low power optical sources, such as LEDs or VCSEL (Vertical-Cavity Surface-Emitting) lasers, for shorter-range applications and increased range capability when using high power optical sources such as pulsed laser diodes.

## System Hardware

The Single Board Sensor provides distance and velocity measurements in an ultra-small form factor. This small size is the result of PulsedLight's System-On-Chip (SoC) signal processing technology which, beyond being small, reduces the complexity and power consumption of supporting circuitry. The system consists of three key functionalities:

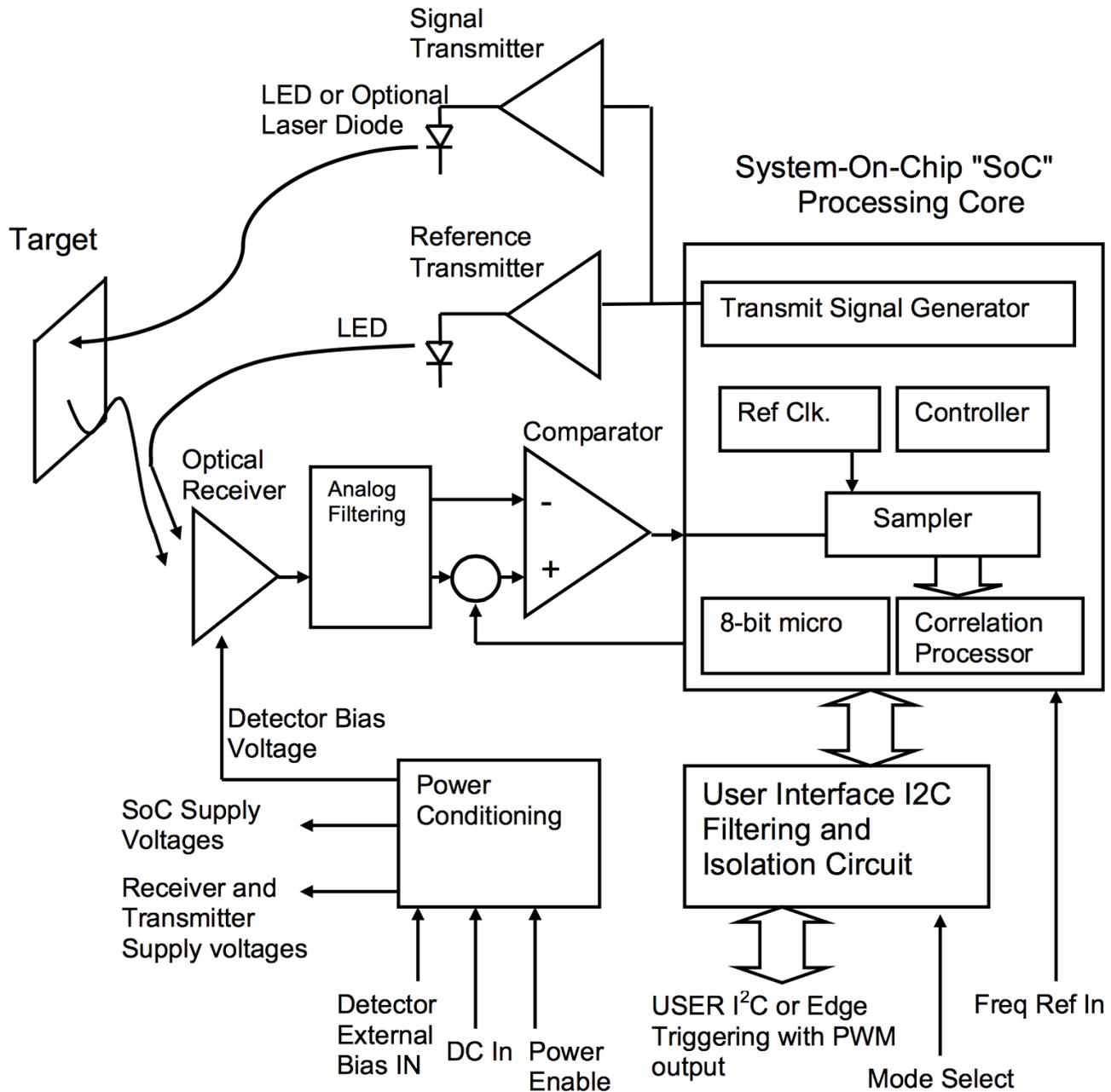
A Signal Processing Core (SPC) System-on-Chip solution encapsulating all the required functions in support of our proprietary range finding system architecture.

An optical transmitter and receiver tied to the SPC emit and receive a proprietary optical signal pattern generated by the SPC.

Power Conditioning and I2C signal filtering and buffering.

***Please refer to "LIDAR-Lite Block Diagram" section for a full overview of the system architecture.***

# LIDAR-Lite Block Diagram



## Signal Processing Core (SPC)

The key component within the system is our SPC chip which implements PulsedLight's signal processing algorithms and primary system architecture. The SPC contains four major subsystems; 1. An 8-bit microcontroller provides system control and communications. It contains an I2C slave peripheral. 2. A 500 MHz sampling clock and an associated sampler capture the logic state of the external comparator and convert the data into a slower speed 125 MHz four bit word which is sent to a correlation processor. 3. A correlation processor stores the incoming signal and performs a correlation operation against a stored signal reference

with optical burst reception and stores the result in the correlation memory with data points every 2 ns. 4. A transmit signal generator produces an encoded signal waveform with an overall duration of 500 ns that consists of a varying interval pattern of ones and zeroes. These outgoing signal pulses occur at a 20 KHz repetition rate and become either the reference signal or outgoing signal pulse depending on the state of the transmitter.

## Optical Transmitter and Receiver

The optical transmitter and receiver have been designed around the requirements of our signal-processing algorithm. The transmitter produces optical pulse bursts using signal patterns generated by the SPC. When an optical reference signal is desired, a separate reference transmitter is enabled and driven with the signal pattern using a reference fed to the optical receiver. The reference transmitter has been designed to match the delay and signal shape produced by the higher power signal transmitter. The signal transmitter can drive a variety of optical sources ranging from high speed LEDs, higher power VCSEL laser or much higher power pulsed laser diodes. For the LIDAR-Lite module, the signal transmit driver drives a T1-3/4 plastic packaged laser diode with a three-amp peak, 50% average duty cycle modulation over a burst duration of 500 ns. The driver has a capability to drive sources at up to 6 A using an external DC power supply.

<b>Parameter</b>	<b>Transmitter specification</b>
Bandwidth	50 MHz, on-off modulation, arbitrary pattern
Burst Time/rate	500 ns/20KHz
Typology	High side current source (programmable), low-side differential current steering
Reference Channel	1 A peak (nominal setting)
Signal Channel	3 A peak (nominal setting)
Transmit Power	Control 16 steps each Channel
Rise/fall	4 ns

The receiver incorporates a state-of-the-art low-noise preamplifier that is coupled to either a PIN photodiode or, optionally, an avalanche photodiode (APD). When using the higher performance APD, an external regulated high voltage bias voltage is needed. The APD is used to increased system sensitivity allowing either increased operating range or reduced measurement times. Before reaching the high-speed digital comparator, specialized analog filtering shapes the return signal originating from the output of the preamplifier.

Parameter	Receiver specification
Bandwidth	50 MHz
Detector	PIN diode, 500µm by 500µm , 1.5 pF, 1.8 mm diameter lens
Virtual Detector size	1 mm – roughly 2X magnification of the package lens
Detector Bias Voltage	8 V DC nominal. External
Preamp Noise Floor	1 pA/Hz-2
Transimpedance Gain	40 K ohm
Noise Equivalent Power	12 nW rms

## Background Light

LIDAR-Lite has been designed to operate effectively under a variety of indoor and bright outdoor solar background lighting conditions. The internal optical absorption filter in combination with the detector spectral response provides a transmission band from 800 nm to 1000 nm. Outdoors, this Spectral window allows roughly 14% of the total solar Irradiance to pass to the detector. Assuming a solar constant of roughly 1 KW per meter<sup>2</sup>, and a full receiver field of view of two degrees, we get the following calculated DC solar current and detector shot noise:

$$((1000\text{W/m}^2) (1/\pi))(.14)(1.1\text{e-}4\text{m}^2)(2\pi (1-\cos (\alpha/2)) (.9) \dots \text{where } \alpha \text{ is the Receiver FOV in degrees (2 degrees)}$$

RCVR Transmission

Solar radiance off diffuse reflections in W/m<sup>2</sup>/Srad    14% of solar    Area of RCVR lens in m<sup>2</sup>    Solid angle of RCVR FOV

- **Bright solar optical background** = 6 µW - **Solar DC current** = (6e-6 W)(.6 A/W) = 3.6e-6 A - **Shot noise** = ((3.6e-6 A)(2)(1.6e-19)(1/Hz))<sup>1/2</sup> = 1 pA/Hz<sup>1/2</sup>

Under the bright solar conditions and highly reflective diffuse background calculated above, the equivalent receiver input noise floor of 1 pA/Hz would increase by a factor of 1.4 resulting in a slight reduction in maximum range. A 20 nm spectral width narrow band optical filter is available as a factory option and results in a 10 fold reduction in solar DC current or a (10)<sup>1/2</sup> = 3 fold decrease in the resulting noise. The narrowband filter is of most benefit in applications where specular, "mirror like" reflective surfaces, are present.

## Power Conditioning

Multiple voltage references are required by various functions on the LIDAR-Lite board. The standard PIN

detector requires a DC bias voltage of roughly 8 V generated by an internal voltage multiplier. The use of optional APD detector requires a temperature dependent bias from 100 V up to 240 V depending on the selected detector. This voltage bias is varied based on the temperature compensation coefficient and is applied through the external detector bias input pin. A factory modification is required to allow external application of detector voltages above 30 V DC. A 3.7 V power supply is used by the receiver circuitry and is enabled by the SPC. Transmitter circuitry typically uses the 5 V nominal supply voltage. By default the power supply pin is coupled to the 5 V input through an isolation inductor. An enable pin allows the internal 3.3 V regulator to be disabled allowing very low power consumption under shutdown conditions.

# Operational Overview

Operation of LIDAR-Lite can be separated into two phases; initialization and triggered acquisitions as initiated by the user.

During initialization the microcontroller goes through a self-test sequence followed by initialization of the internal control registers with default values. Internal control registers can be customized by the user through the I2C interface after initialization. After the internal control registers are initialized the processor goes into sleep state reducing overall power consumption to under 10 mA. Initiation of a user command, through external trigger or I2C command, awakes a processor allowing subsequent operation.

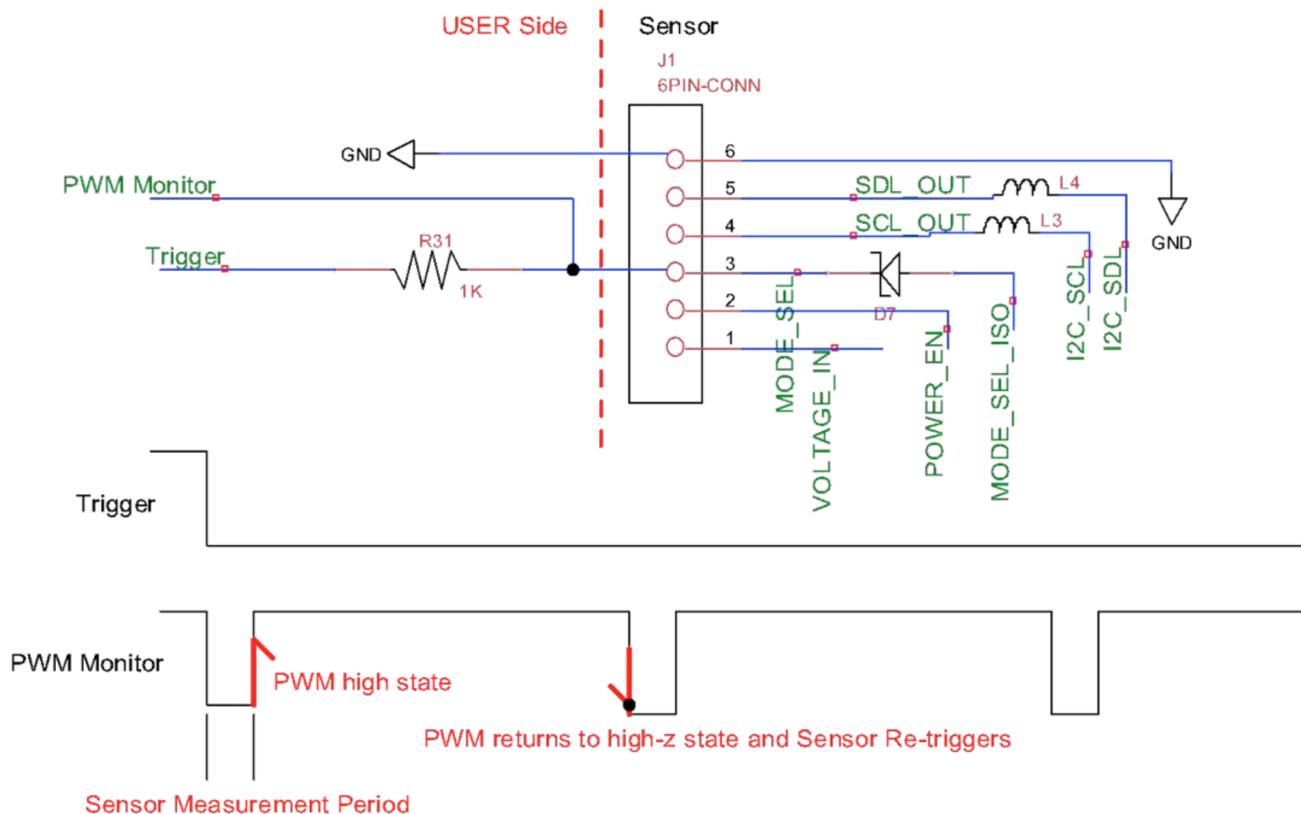
The input of a command through the I2C interfaces may initiate an acquisition or an operation to monitor or modify system parameters. In the event of an acquisition request, the system must first power up and initialize the external functions such as the SPC and transmit/receive circuitry. Acquisition begins with the transmission of a reference burst followed by a signal burst. These signal bursts occur over intervals of roughly 50- 100 $\mu$ s depending on the length of the selected correlation record. These signal bursts are repeated until the maximum number of acquisitions have been reached, as defined in the default or user settings or a sufficient number of acquisitions have been performed to achieve a maximum signal strength level. At the completion of the required number of acquisition cycles, the correlation results are processed to calculate the effective time delay of the reference and return within the correlation records. The total acquisition time for the reference and signal acquisitions is typically between 5 and 20ms depending on the desired number of integrated pulses and the length of the correlation record. The acquisition time plus the required 1 msec to download measurement parameters establish a roughly 100Hz maximum measurement rate.

## Mode Control Pin

A bi-directional control and status pin provides a means to trigger acquisitions and return the measured distance via Pulse Width Modulation [PWM] without having to use the I2C interface.

The pin driver in the processor has an internal current source pull-up of roughly 50 $\mu$ A with the driver output coupled to the user pin through a protection diode allowing only sourcing current into the pin. A low-going transition on the mode control pin will trigger a single measurement, and the pin will be actively pulled high with a pulse width proportional to distance. A 1K to 10K ohm termination resistance will solidly pull the pin low to trigger an acquisition state while allowing the pin to still be pulled high during the PWM output pulse. The pulse width follows a 10 $\mu$ sec/cm relationship to the measured distance or 1msec per meter.

A simple triggering method using a standard microcontroller interface uses a 1K ohm resistor in series with an output pin to pull the mode pin low initiating a measurement with a second port pin used to monitor the low-to-high output pulse width. If the pin is held low, the acquisition process will repeat indefinitely producing a variable frequency output proportional to distance.



## Acquisition Settings

Signal acquisition parameters can be easily changed to trade-off system performance parameters. If a high measurement rate is required, then the maximum signal integration time can be reduced to decrease measurement times at the expense of somewhat reduced sensitivity and maximum range. Optical transmit power can be increased by the setting loaded into the Laser Power Register. High pulse power may need to be compensated with an increased spacing between pulse bursts to maintain an acceptable laser duty cycle based on thermal derating requirements. If the length of the correlation record is increased to allow for longer range measurements, increased processing time will decrease the measurement rate.

Key control registers impacting acquisitions:

## Internal register space

Register	Description
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<b>Register</b>	<b>Description</b>
control_reg [2]	Maximum acquisition count sets the maximum number of acquisition cycles with a maximum value of 255. In most cases an acquisition of 128 is adequate.
control_reg [3]	Correlation record length establishes the portion of correlation memory allocated to the return signal. The value is broken in to upper and lower nibbles where the lower indicates the starting location and the upper nibble the end point. The nibble value multiplied by 64 is its location in memory. A value of 0xf indicates the end of the record with a value of 1024.
control_reg [4]	Acquisition mode control establish the enabled acquisition functions such as velocity measurement, lower power consumption states and inhibiting the reference.

## External register space

<b>Register</b>	<b>Description</b>
control_reg [0x43]	Laser power control.
control_reg [0x4b]	Range Processing Criteria for two echoes. Max signal, Max/Min Range.
control_reg [0x65]	Power management – Sleep states.

# Signal Acquisition Process

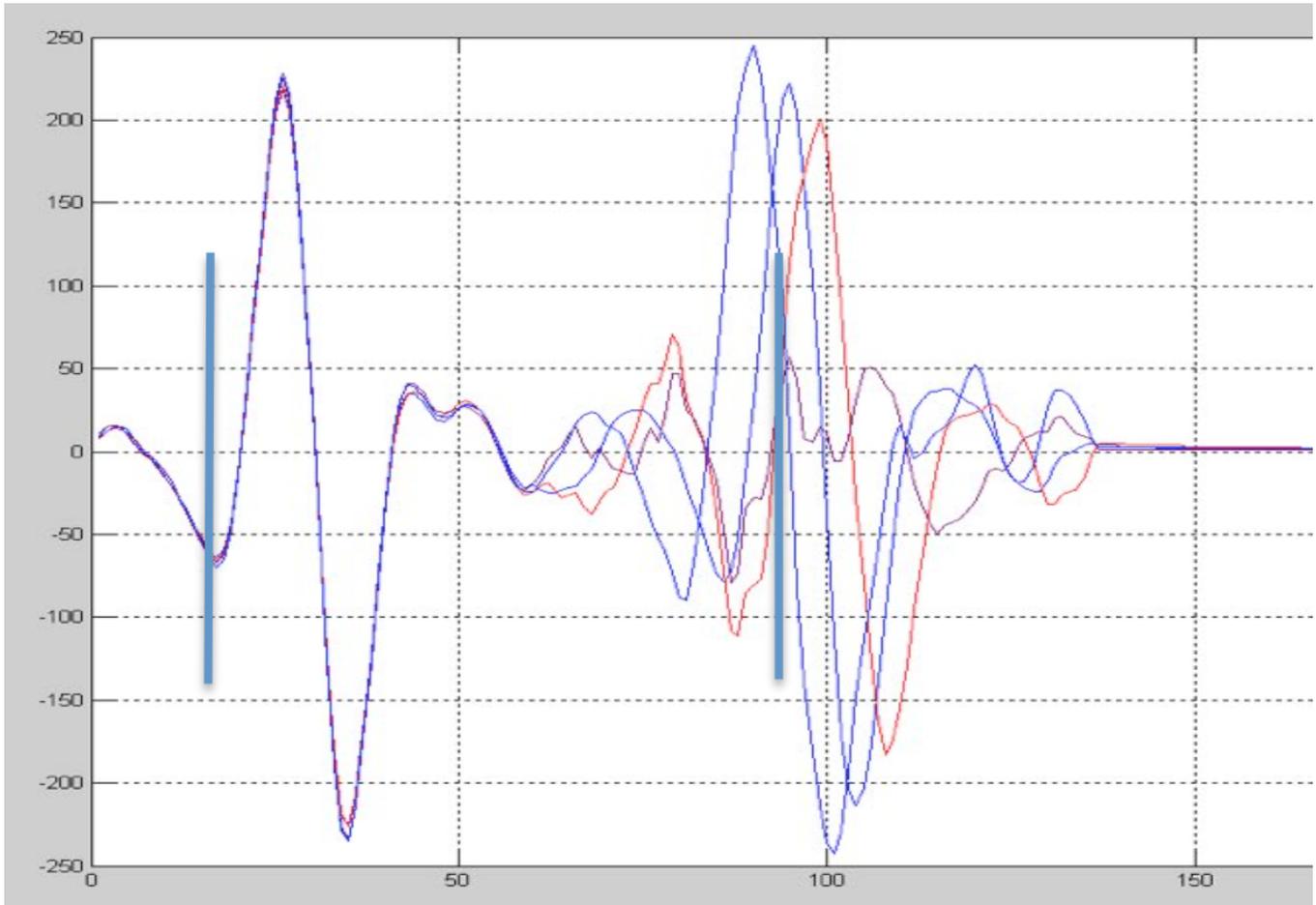
After loading new acquisition parameters or retaining default values, a command is sent to the SPC to initiate a signal acquisition. The steps of the acquisition are as follows:

1. Power is applied to the receiver preamp and, after a prescribed delay, the DC offset at the threshold detector is adjusted to set the effective slicing level or threshold in the middle of the noise distribution. The adjustment process is based on the measurement of the one/zero duty cycle at the comparator output. When the signal offset is nulled, the duty cycle of the noise pattern approaches an average of 50%. In more sophisticated applications the threshold can be offset as part of an algorithm to measure the approximate rms value of the noise supporting diagnostics or as part of a voltage control feedback signal supporting an avalanche photo detector biasing.
2. Prior to starting signal acquisition, the correlation memory is cleared and the transmitter is activated to generate a burst signal pattern that is stored in a signature memory that is used as key element in the correlation process.
3. Signal acquisition begins with the activation of the reference portion of the transmitter, followed by the feeding of the signal pattern necessary to generate the optical reference signal which then passes directly to the receiver photo detector. After amplification and zero-crossing detection, this record is stored in the signal memory.
4. The stored reference signal record is then correlation processed using the transmit pattern stored in the signature memory as a template which is then added to any correlation data previously processed and residing the reference portion of the correlation memory.
5. Next the signal transmit portion of the transmitter is enabled and the outgoing optical signal goes out to a target and the signal return is amplified, detected and stored in signal memory.
6. As in step 4, the stored signal record is correlation processed and then added to any correlation data previously processed and residing in the signal portion of the correlation memory.
7. As the signal and reference acquisitions are repeated, the peak correlation values in the correlation record increase and would ultimately overflow the 12-bit word size. To prevent this overflow condition, the correlation process is terminated for either the signal or reference records when a peak signal within the record exceeds a preset maximum value slightly under overflow. Once both the reference and signal records have reached their maximum values or that maximum acquisition count has been exceeded the acquisition process is terminated.
8. After the signal acquisition process is complete, a low-pass and DC restoring filtering process typically cleans-up the waveform to improve the final measurement accuracy at low signal conditions and short range. This function can be disabled by resetting the filter enable bit in control register 4 for improved accuracy and resolution at longer ranges.

# Correlation Record

Distance measurements are based on the storage and processing of reference and signal correlation records.

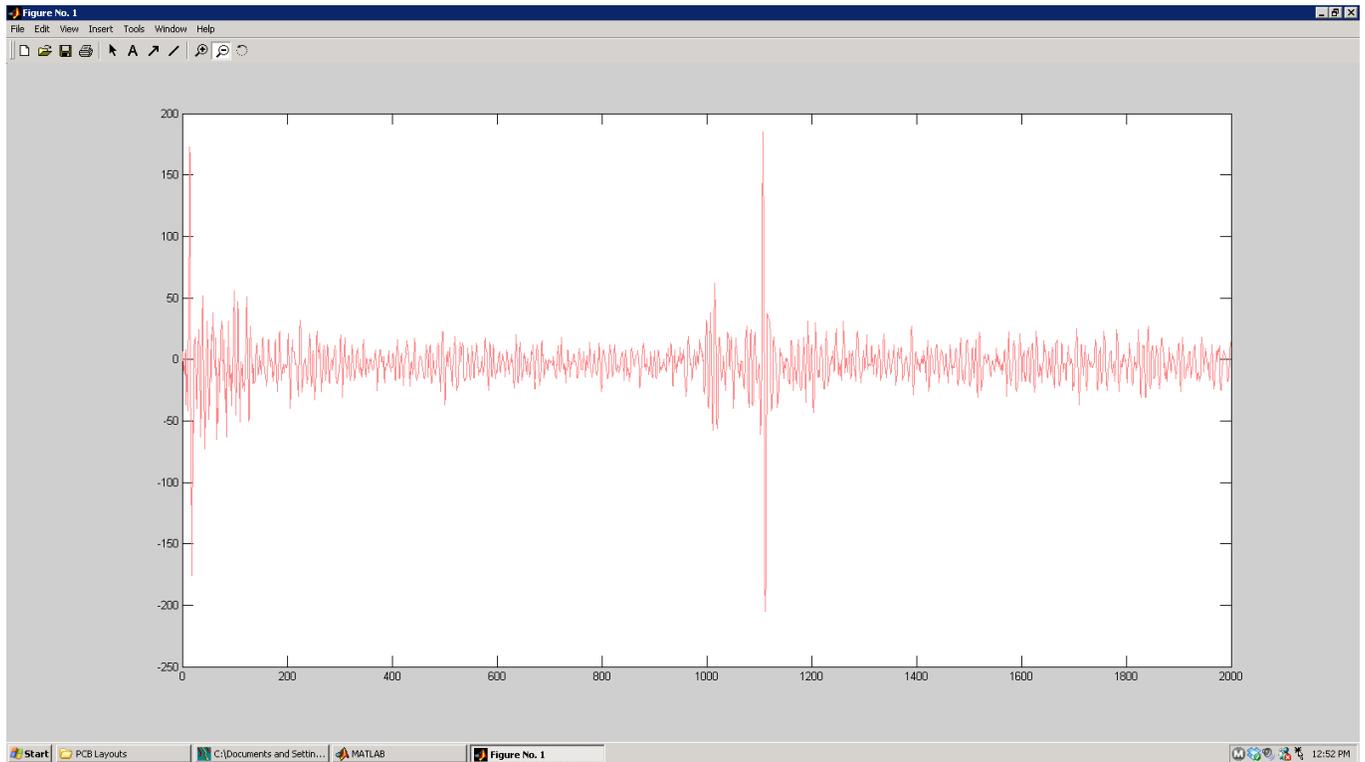
The figure below shows a correlation record for a sensor without optics at short distances of 0, 4 and 8 feet. The reference record runs from 0-63 and the signal record from 64 to 130. Each sample point represents 2nsec or roughly one foot.



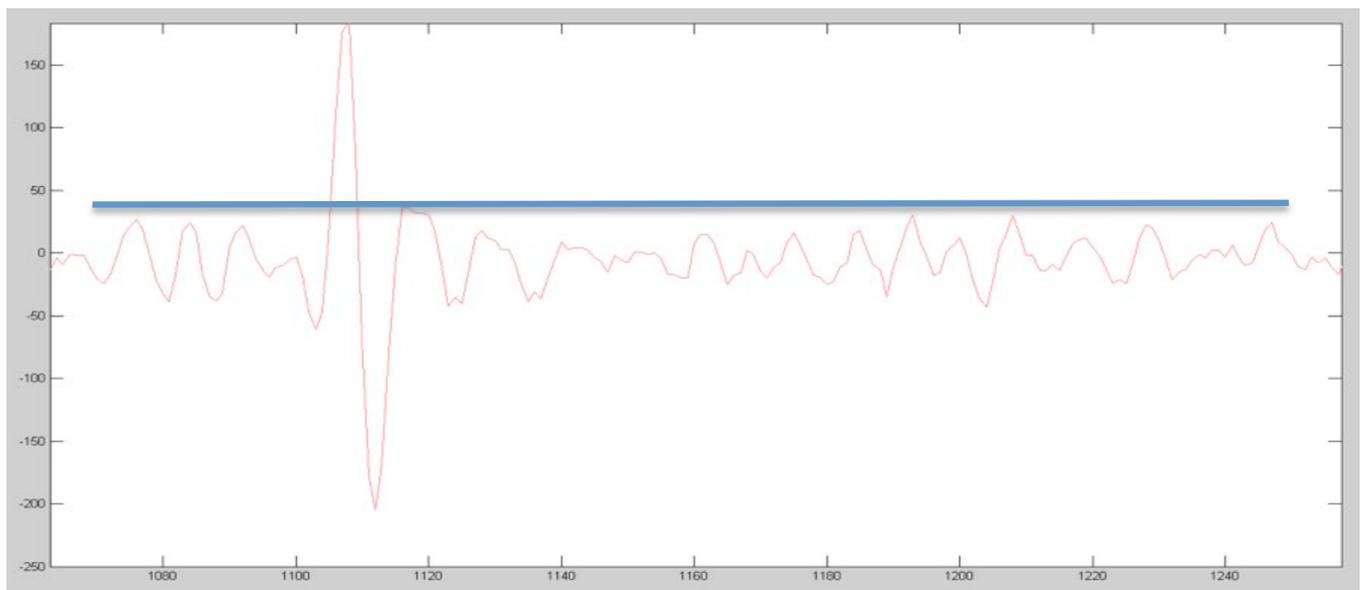
The correlation waveform has a bipolar wave shape, transitioning from a positive going portion to a roughly symmetrical negative going pulse. The point where the signal crosses zero represents the effective delay for the reference and return signals. Processing with the SPC determines the interpolated crossing point to a 1cm resolution along with the peak signal value.

The figure below illustrates a correlation record example for a long-range system using an avalanche photodiode or APD and laser with a processing chip with a half resolution 2-foot/correlation steps and two-thousand element signal record. The target is at 660 meters and forms the same bipolar correlation wave shape as in the short-range system, but in practice the correlation waveform must be distinguished from background noise present in the correlation record. A correlation record detection threshold is established based on the background noise and if no signals are detected above this threshold, a no signal status

indication is provided.



The correlation waveform is shown in more detail below. To distinguish the correlation pulse from the background noise, a specialized processing filter follows the envelope of the noise without being significantly affected by signal correlations present in the record. This noise reference is scaled by 1.25 to provide a detection threshold for the correlation.

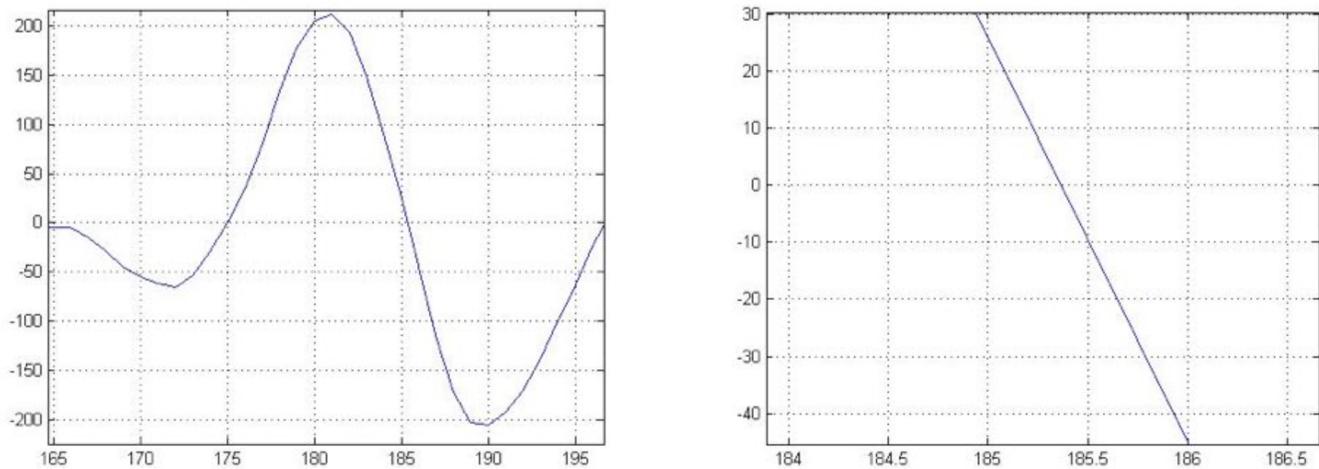


If more than one signal is detected within the correlation record, the return with the next highest signal strength is stored and is available for additional processing. A flag within the status register indicates the presence of a valid second reflection such as from a window or from a shorter-range object illuminated by the beam. The on-board processing of secondary returns is limited to weaker target reflections in the foreground.

The correlation record can be downloaded by the user to examine target details in post processing.

# Processing the Correlative Pulse

The calculation of the effective delay is based on the coarse location within the correlation record and the interpolated crossing between sample points. For the full resolution correlation record used in the LIDAR-Lite processor, each sample represents 2nsec in time or roughly one foot or .3 meters. To obtain a result in cm requires 30 resolution points obtained by interpolating between data points. The figure below illustrates a single correlation pulse obtained by processing either the reference or signal.



The correlation waveform on the left shows a zero crossing on the falling edge around the location 185. The detail of the crossing on the right shows a linear fit from the upper crossing point at 185 with a value of 26 and a value at 186 of -44. The calculation of the crossing is equal to  $(26 / (26 - -44)) * 30$  or 11.14cm.

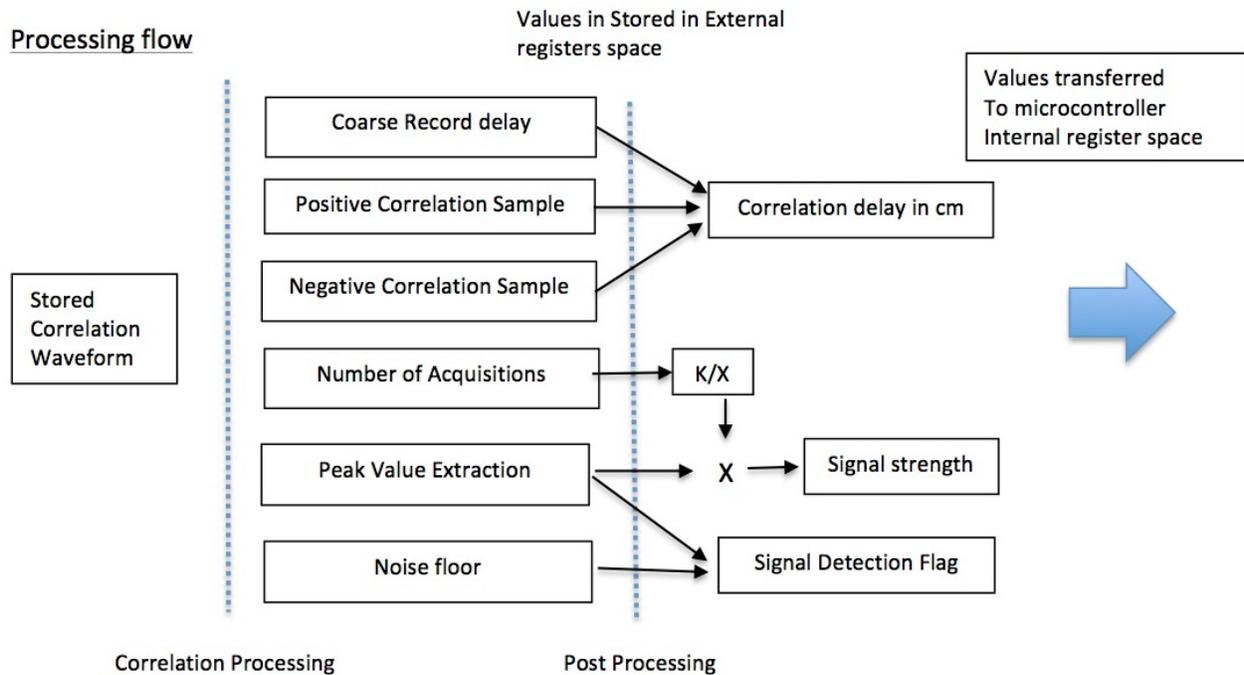
To get the total delay we multiply the index of the upper point 185 and multiply by 30 to get the coarse delay in cm. The total delay is then  $30 * 185 + 10 = 5560$ . If we have a delay for the reference waveform, with a crossing at  $30 * 30 + 15$  or 915cm we get a measured delay of  $5560 - 915 = 46.45$  meters.

## Processing

A module within the processor analyzes the correlation record looking for the largest peak waveform within the record. As it moves through the record, the crossing characteristics of each new larger peak is sampled. At each peak, the coarse delay to the positive sample prior to the zero crossing along with correlation values above and below the crossing and the peak value are stored. With each new peak sample, the previous peak and the crossing data (now the next largest peak sample) is stored to allow post processing of the data to extract the distance and peak value. The secondary peak in some cases may be the small reflection of the

beam passing through a window or possibly the reflection off objects in the foreground.

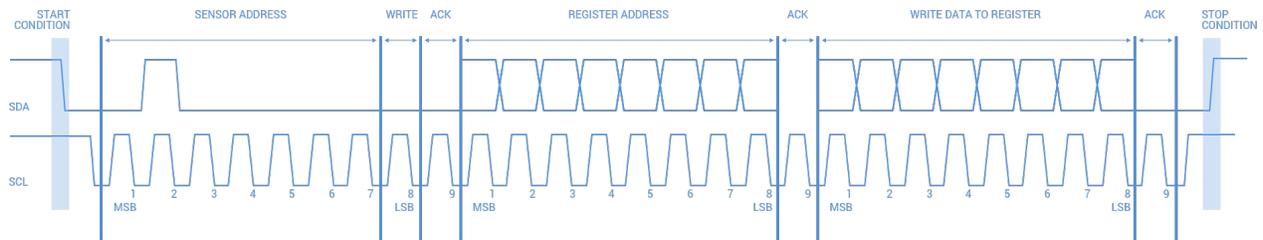
The figure below details the processing flow within the correlation processor after a final correlation waveform is complete.



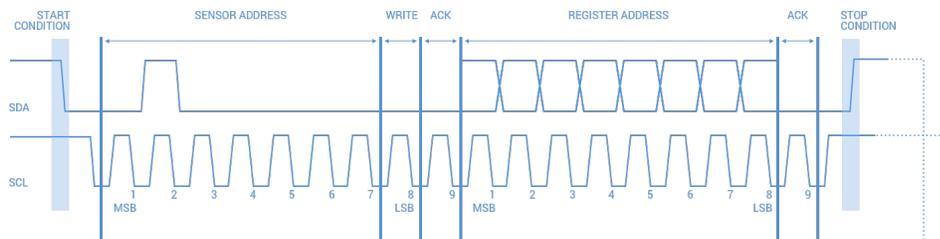
The processed correlation waveform is processed and the various extracted parameters are stored in the external register space. For both the reference and signal records, the coarse record delay and the positive and negative correlation samples are processed to determine the delay in the record to the correlative peak. The difference between the delay measured for the signal and reference determine the effective round trip delay to the target. The delay is scaled to produce a result in centimeters. Signal strength is determined by multiplying the peak value of the correlation by the scaled inverse of the number of acquisitions. It is an inverse relationship because more samples are required to increase the strength of a small signal than a larger one. A valid signal is determined by comparing the signal peak value with the value of the noise floor observed in the range record.

# I2C Protocol Summary

## Write



## Read



### NOTES:

- LIDAR-Lite does not work with repeated START, it must receive a STOP and then a START
- The ACK/NACK's are responses from the Master device to the slave device
- The last NACK in the read is technically optional but the formal protocol for I2C says that the master shall NOT acknowledge the last byte



LIDAR-Lite has a 2-wire I2C-compatible serial interface (refer to I2C-Bus Specification, Version 2.1, January 2000, available from Philips Semiconductor). It can be connected to an I2C bus as a slave device, under the control of an I2C master device. It supports standard 100 kHz data transfer mode. Support is not provided for 10-bit addressing.

The Sensor module has a 7-bit slave address with a default value of 0x62 in hexadecimal notation. The effective 8 bit I2C address is: 0xC4 write, 0xC5 read. The unit will not presently respond to a general call.

The I2C serial bus protocol operates as follows:

1. The master initiates data transfer by establishing a start condition, which is when a high-to-low transition on the SDA line occurs while SCL is high. The following byte is the address byte, which consists of the 7-bit slave address followed by a read/write bit with a zero state indicating a write request. A write operation is

used as the initial stage of both read and write transfers. If the slave address corresponds to the module's address the unit responds by pulling SDA low during the ninth clock pulse (this is termed the acknowledge bit). At this stage, all other devices on the bus remain idle while the selected device waits for data to be written to or read from its shift register.

2. Data is transmitted over the serial bus in sequences of nine clock pulses (eight data bits followed by an acknowledge bit). The transitions on the SDA line must occur during the low period of SCL and remain stable during the high period of SCL.
3. An 8 bit data byte following the address loads the I2C control register with the address of the first control register to be read along with flags indicating if auto increment of the addressed control register is desired with successive reads or writes; and if access to the internal micro or external correlation processor register space is requested. Bit locations 5:0 contain the control register address while bit 7 enables the automatic incrementing of control register with successive data blocks. Bit position 6 selects correlation memory external to the microcontroller if set. (Presently an advanced feature)
4. If a read operation is requested, a stop bit is issued by the master at the completion of the first data frame followed by the initiation of a new start condition, slave address with the read bit set (one state). The new address byte is followed by the reading of one or more data bytes succession. After the slave has acknowledged receipt of a valid address, data read operations proceed by the master releasing the I2C data line SDA with continuing clocking of SCL. At the completion of the receipt of a data byte, the master must strobe the acknowledge bit before continuing the read cycle.
5. For a write operation to proceed, Step 3 is followed by one or more 8 bit data blocks with acknowledges provided by the slave at the completion of each successful transfer. At the completion of the transfer cycle a stop condition is issued by the master terminating operation.

# Detailed Register Definitions

The rangefinder can be configured using an I2C machine interface. Settings control the acquisition and processing of ranging data. The I2C interface supports a transfer rate up to 100kb per second. Control Registers are divided between "internal" microprocessor registers and "external" registers residing in the Correlation processor. The internal registers are mapped to register addresses from 0 to 15 hex and external registers from 40 to 68 hex. Internal registers are both read and write, while external registers are read or write only. The most significant bit of the address byte in the I2C address byte triggers the auto incrementing of register address with successive reads or writes within an I2C block transfer.

# Control Registers

## μP internal Control Registers

Register	Description
control_reg [0x0]	Command Control
control_reg [0x1]	Status - system status.
control_reg [0x2]	Maximum acquisition count
control_reg [0x3]	Correlation record length setting
control_reg [0x4]	Acquisition mode control
control_reg [0x5]	Measured threshold offset during acquisition
control_reg [0x6-7]	Measured delay of reference in correlation record
control_reg [0x8]	Reference correlation measured peak value
control_reg [0x9]	Velocity Measurement Output
control_reg [0xa-b]	Measured delay of signal return in correlation record
control_reg [0xc]	Signal correlation measured peak value
control_reg [0xd]	Correlation record noise floor * 1.25 (for setting valid signal threshold)
control_reg [0xe]	Received signal strength (typical range 10 min - 128 maximum)
control_reg [0xf-10]	Calculated distance in cm (difference between signal and reference delay)
control_reg [0x11]	DC threshold command value
control_reg [0x12]	Added delay to reduce signal acquisition burst frequency
control_reg [0x13]	Distance calibration. Signed 8 bit value adds or subtracts from distance
control_reg [0x14-15]	Previous measured distance

## Correlation Core External Control Registers

**Register**                      **Description**

<b>Register</b>	<b>Description</b>
control_reg [0x40]	Command register
control_reg [0x41]	Hardware Version
control_reg [0x42]	Preamplifier DC control
control_reg [0x43]	Transmit power control
control_reg [0x44]	Processing range gate (low byte)
control_reg [0x45]	Processing range gate (high byte)
control_reg [0x46]	Range Measurement PWM output pin bit[0] used
control_reg [0x47]	Acquisition status
control_reg [0x49]	Measured preamp DC offset
control_reg [0x4a]	Output port
control_reg [0x4b]	Range Processing Criteria for two echoes. Max signal, Max/Min Range.
control_reg [0x4c]	2nd largest detected peak in signal correlation record.
control_reg [0x4f]	Software Version.
control_reg [0x51]	Correlation record size select - (reference and signal return)
control_reg [0x52]	Correlation Data access port (low byte)
control_reg [0x53]	Acquisition Settings - selects ext. memory access, signal record select
control_reg [0x57-8]	Measured delay of reference or signal in correlation window
control_reg [0x59]	Correlation peak value of reference or signal
control_reg [0x5a]	Correlation record noise floor * 1.25 (for setting valid signal threshold)
control_reg [0x5b]	Received signal strength (typical range 10 minimum to 255 maximum)
control_reg [0x5c]	Reset correlator / increment transmit signal pattern
control_reg [0x5d]	Correlation Data access port (sign bit)
control_reg [0x5e]	Clock synchronizer control
control_reg [0x5f]	Measured transmit power - Supports Laser safety monitoring
control_reg [0x60]	Measured fine delay (used as part of measured delay calculation)
control_reg [0x61-62]	Coarse delay (used as part of measured delay calculation)

<b>Register</b>	<b>Description</b>
control_reg [0x63]	Positive correlation sample before zero crossing (correlation pulse falling edge)
control_reg [0x64]	Negative correlation sample after zero crossing (correlation pulse falling edge)
control_reg [0x65]	Power control settings
control_reg [0x68]	Velocity measurement window setting register

# Internal Register Descriptions

*Unless otherwise noted, all registers contain one byte and are read and write.*

## 0x00 (control\_reg[0]:)

### Notes

- Command Register
- Write 0x00 to Register 0x00: Reset FPGA. Re-loads FPGA from internal Flash memory: all registers return to default values
- Write 0x03 to Register 0x00: Take acquisition & correlation processing without DC correction
- Write 0x04 to Register 0x00: Take acquisition & correlation processing with DC correction

---

## 0x01 - Mode/Status (control\_reg[1]:)

Bit	Function	Notes
Bit 7	Eye Safe	This bit will go high if eye-safety protection has been activated
Bit 6	Error Detection	Process error detected / measurement invalid
Bit 5	Health	"1" if good, "0" if bad
Bit 4	Secondary return	Secondary return detected above correlation noise floor threshold
Bit 3	Signal not valid	Indicates that the signal correlation peak is equal to or below correlation record noise threshold
Bit 2	Sig overflow flag	Overflow detected in correlation process associated with a signal acquisition
Bit 1	Ref overflow flag	Overflow detected in correlation process associated with a reference acquisition
Bit 0	Ready Status	"0" is ready for new command, "1" is busy with acquisition

*Health status indicates that the preamp is operating properly, transmit power is active and a reference pulse has been processed and has been stored.*

---

# 0x02 (control\_reg[2]:)

## Notes

- Controls Maximum Acquisition Count
  - Default Value: 0x80
  - Range: 0x00-0xFF (0-255).
  - Controls the FPGA maximum signal integration time.
  - Stronger signal results in reduced acquisition count to prevent internal register overflow.
  - Signal overflow flag and Reference overflow flag in Control Register [1] are set when automatic limiting occurs.
- 

# 0x03 (control\_reg [3]:)

Bit	Function
Bits 7-4	Stop address (default 5 corresponding to 512)
Bits 3-0	Start address (default 1 corresponding to 64)

## Notes

- control\_reg[0x51]: Correlation start and stop locations used for signal acquisition (write only)
  - Start address: Value in the range from 0x00-0x0f – starting point in correlation record (record broken into 64 element segments 1024 total)
  - Stop address: Value in the range from 0x00-0x0f – stopping point in correlation record
  - With longer correlation records, burst pulse period is roughly proportional to the length of the correlation record. Unnecessarily long record length increases the probability of false detections.
- 

# 0x04 – Mode Control (control\_reg[4]:)

Bit	Function
Bit 7	Velocity
Bit 6	Inhibit Reference

Bit	Function
Bit 5	Velocity Scale factor (also used to set delay between measurements in burst/continuous measurement mode)
Bit 4	Disable reference filter
Bit 3	Disable short signal acquisition (runs to the correlation limit of 250)
Bit 2	Disable short reference (allows reference maximum count from reference acquisition count register rather than default value of 0x05)
Bit 1	CLK SHUT
Bit 0	Preamp Off

## Notes

- Mode Pin Settings:
  - "0" is normal mode pin triggering with free-running PWM.
  - "1" is status output (busy active high)
  - "2" is Fixed frequency PWM out
  - "3" is 32kHz oscillator output for oscillator frequency calibration
- Default Value: 0x00
- Velocity Scale factor: "1" sets the velocity measurement separation to a frequency set by measurement rate register resulting in a velocity calibration in meters/sec. A "0" value results in a measurement separation of 100msec.
- Inhibit Reference : "1" inhibits the acquisition of reference pulses reducing measurement times and reducing measurement variations at the expense of decreasing accuracy over time. "0" allows normal operation
- Velocity: Enable velocity measurement
- Reference Filter averages 8 reference measurements for reduced measurement variability [increased measurement consistency?]

## 0x05 (control\_reg[5]:)

### Notes

- Nominal 128
- Measured DC value out of correlation sampler input. Value based on the ratio of 1's and 0's (read only)

preamp

- Parameter used as part of health flag criteria
- 

## 0x06 (control\_reg [6]:)

### Notes

- [Read Only]: High byte of calculated delay of reference– calculated after correlation record processing
- 

## 0x07 (control\_reg [7]:)

### Notes

- [Read Only]: Low byte of calculated delay of reference– calculated after correlation record processing
- 

## 0x08 (control\_reg [8]:)

### Notes

- Correlation Peak value reference [Read Only]: (scaled to 0 – 0xff max peak value) – Parameter used as part of health flag criteria
- 

## 0x09 (control\_reg [9]:)

### Notes

- Velocity [Read Only]: in .1 meters/sec (8 bit signed value) See Mode Control, Register 0x04 for information on changing the scale factor to 1m/sec
-

## 0x0a (control\_reg [10]:)

### Notes

- High byte of calculated delay of signal correlation [Read Only]: calculated after correlation record processing
- 

## 0x0b (control\_reg [11]:)

### Notes

- Low byte of calculated delay of signal correlation [Read Only]: calculated after correlation record processing
- 

## 0x0c (control\_reg [12]:)

### Notes

- Correlation Peak value of signal correlation [Read Only]: (scaled to 0 – 0xff max peak value)
- 

## 0x0d (control\_reg [13]:)

### Notes

- Maximum noise within correlation record [Read Only]: scaled by 1.25 (typically between 0x10–0x30)
- 

## 0x0e (control\_reg [14]:)

### Notes

- Calculated signal strength [Read Only]: Calculation based on the number of averaged samples and correlation peak value
- 

## 0x0f (control\_reg [15]:)

### Notes

- High byte of calculated delay of signal [Read Only]: reference – calculated after correlation record processing
  - If the MSB is 1 then the reading is not considered valid.
- 

## 0x10 (control\_reg [16]:)

### Notes

- Low byte of calculated delay of signal [Read Only]: reference – calculated after correlation record processing
- 

## 0x11 (control\_reg [17]:)

### Notes

- Outer Loop Count: Allows multiple measurements with a single measurement command. If set to - 'Off', continuous measurement will be performed. A value of less than 0xff will terminate continuous measurement after that amount of measurements (ex. 0xfe will take 254 measurements and stop).
- 

## 0x12 (control\_reg [18]:)

### Notes

- Reference Acquisition Count: Normal setting is 0x05 to force multiple reference acquisitions before

updating the reference delay used in the calculation of distance.

- Note: Short Reference Distance Flag [2] in Register 4 must be set to enable operation of a reference count other than the default value.
- 

## 0x13 (control\_reg [19]:)

### Notes

- Distance Calibration value: The value is added to measured distance. 8bit signed value allows increasing or decreasing the measured value.
- 

## 0x14 (control\_reg [20]:)

### Notes

- Previous high byte of calculated delay of signal [Read Only]: reference
- 

## 0x15 (control\_reg [21]:)

### Notes

- Previous low byte of calculated delay of signal [Read Only]: reference
- 

## 0x16 (control\_reg [22]:)

### Notes

- Upper byte of unit serial #
-

## 0x17 (control\_reg [23]:)

### Notes

- Lower byte of unit serial #
- 

## 0x18 (control\_reg [24]:)

### Notes

- Load upper register serial # (reg [22]) into register [24] to allow changing I2C address
- 

## 0x19 (control\_reg [25]:)

### Notes

- Load lower register serial # (reg [23]) into register [25] to allow I2C register loading
- 

## 0x1a (control\_reg [26]:)

### Notes

- I2C address of desired new I2C address
- 

## 0x1c (control\_reg [28]:)

### Notes

- Threshold by-pass. Overrides the automatic setting of the detection threshold. If value  $\neq 0$ , can base threshold on measured noise and the peak signal value to decrease false alarms or to improve sensitivity.

---

## 0x1d (control\_reg [29]:)

### Notes

- I2C address read off the bus (last access)

---

## 0x1e (control\_reg [30]:)

### Notes

- I2C configuration bits. Writing register initiates change in I2C address if Register 0x16 is set to the value in Register 0x18 AND Register 0x17 is set to the value in Register 0x19. [3] - Keeps primary address open after programming secondary address. Other bits presently not used.

# External Register Descriptions

Unless otherwise noted, all registers contain one byte and are read and write.

---

## 0x40 - Command Control (control\_reg[64]:)

Bit	Description
Bit 7	Peak Processing Flag
Bit 6	Perform Correlation Process Flag
Bit 5	Signal Acquisition Flag
Bit 4	Clear Correlation Memory Flag
Bit 3	Store Template Pattern Enable Flag
Bit 0 ... Bit 2	Starting action address

## Bits 0 through 2 Definitions

Value	Description
000	No Operation
001	Start processes at template store
010	Clear Correlation Record
011	Signal Acquisition
100	Start processes at Perform Correlation process
101	Start processes at Delay calculation Processing
110	NOP
111	Perform only correlation record filtering - Test Mode Enable

## Notes

- Command control register: Writing to this register through the I2C interface immediately initiates a command operation. Thus it is important to initiate this command only at the completion of defining

other registers.

---

## 0x41 (control\_reg[65]:)

### Notes

- Hardware Version: revisions begin with 0x01
- 

## 0x42 (control\_reg[66]:)

### Notes

- Preamp DC control: Range 0-255
  - Used in DC compensation servo loop
- 

## 0x43 (control\_reg[67]:)

Bit	Description
Bits 4-7	Reference Power Control (0x0 to 0xf)
Bits 0-3	Signal Power Control (0x0 to 0xf)

### Notes

- Transmit power control: Laser drive control bits (7 through 4) ref, bits (3 through 0) signal.
  - Maximum value set at factory 3amps. The maximum output power of the optical source is set through a factory selected resistor which limits available current to the transmit source.
  - When using laser devices, which have a much higher operating current, do not increase the reference control level beyond the factory settings.
  - Increasing the reference control level may cause premature failure of the internal reference diode.
-

# 0x45 (control\_reg[69]:)

## Notes

- Measurement Delay - Sets the time between measurements. 0xc8 corresponds to 10Hz while 0x13 corresponds to 100Hz. Minimum value is 0x02 for proper operation.
  - The velocity scale factor flag in Register 0x04 must be set to operate at the non-default value. The measurement time will ultimately limit the maximum achievable rate in burst or continuous operation.
- 

# 0x48 (control\_reg [72]:)

## Notes

- Health Status Flags:
    - [0] Health Flag
    - [1] Reference is working
    - [2] Transmit power is good
    - [3] DC is good (pre-amp status)
- 

# 0x49 (control\_reg [73]:)

## Notes

- Measured DC value out of correlation sampler input [Read Only]: Value based on the ratio of 1's and 0's
- 

# 0x4b (control\_reg [75]:)

Bit	Function	Notes
Bit 7	Disable DC Correction	Skips DC stabilization. Used to increase repetition rate
Bit 6	NOT USED	

Bit	Function	Notes
Bit 5	NOT USED	
Bit 4	Select Reference/Signal	Selects Reference or Signal Records when operating from control register 0x40
Bit 3	NOT USED	
Bit 2	Select Max Range	"1" selects the longer distance; "0" selects the shorter distance
Bit 1	Select Range Criteria	"1" selects return data based on distance; "0" selects strongest return, regardless of distance
Bit 0	Select Second Return	Controls echo processing selection : "1" switches to alternative return; "0" Selects data associated with detection criteria

## Notes

- Mode Configuration Register
- Range Processing Criteria for two echoes: Max signal, Max/Min Range.

---

## 0x4c (control\_reg [76]:)

### Notes

- Peak Value of 2nd largest pulse in the signal correlation record [Read Only]

---

## 0x4d (control\_reg [77]:)

### Notes

- Inner loop count (working)

---

## 0x4f (control\_reg[79]:)

# Notes

- Software Version: Revisions begin with 0x01
- 

## 0x51 (control\_reg [81]:)

Bit	Function	Notes
Bits 4-7	Stop Address	Value in the range from 0x00-0x0f – stopping point in correlation record
Bits 0-3	Start Address	Value in the range from 0x00-0x0f – starting point in correlation record ( record broken into 64 element segments 1024 total

# Notes

- Correlation start and stop locations [Write Only]
  - Not used in general use (working register)
- 

## 0x52 (control\_reg [82]:)

# Notes

- Data from memory records [Read Only]: Template memory, Signal memory or Correlation memory (low byte of 9 bit value)
- 

## 0x53 (control\_reg [83]:)

# Notes

- Correlation Data Sign [0]
  - Acquisition and control settings [Write Only]
-

## 0x5a (control\_reg [90]:)

### Notes

- Maximum noise within correlation record [Read Only]: Scaled by 1.25 (typically between 0x10 – 0x30)
- 

## 0x5c (control\_reg [92]:)

### Notes

- Reset Control Register (working register)

## 0x5d (control\_reg [93]:)

### Acquisition Settings

Bit	Notes
Bits 7-6	[1]: Access template memory, [2]: Access signal memory, [3]: Access correlation memory
Bits 5-0	NOT USED

---

## 0x5f (control\_reg [95]:)

### Notes

- Measured transmit power [Read Only]: Using internal power monitor
- 

## 0x60 (control\_reg [96]:)

### Notes

- Fine delay [Read Only]: Interpolated fine delay (0-29)
- 

## 0x61 (control\_reg [97]:)

### Notes

- Peak Index high byte [Read Only]: Coarse crossing point in the correlation record prior to zero crossing
- 

## 0x62 (control\_reg [98]:)

### Notes

- Peak Index low byte [Read Only]: Coarse crossing point in the correlation record prior to zero crossing
- 

## 0x63 (control\_reg [99]:)

### Notes

- Positive Crossing - Upper correlation pulse data value prior to zero crossing
- Used to interpolate fine delay

## 0x64 (control\_reg [100]:)

### Notes

- Negative Crossing: Lower correlation pulse data value after zero crossing
  - Used to interpolate fine delay
- 

## 0x65 (control\_reg [101]:)

Bit	Function
Bit 7	NOT USED
Bit 6	NOT USED
Bit 5	NOT USED
Bit 4	NOT USED
Bit 3	Det Bias Disable
Bit 2	SLEEP - Initiates partial FPGA shutdown
Bit 1	RCVR PWR Disable. OSC disable if "1"
Bit 0	Analog enable - turns off preamp if "1"

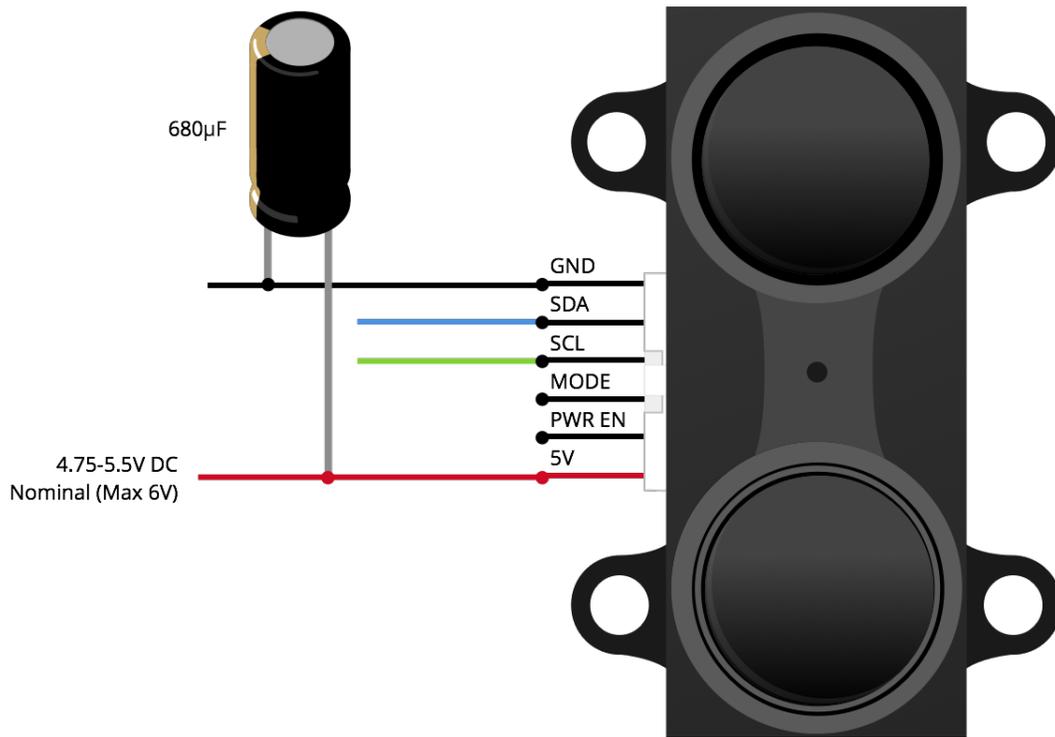
## Notes:

- Power control [Write Only]
- Default Value: 0x00
- OSC Disable: Disables oscillator reference – Not used in Lidar-Lite SPC
- RCVR PWR Disable: Turns on receiver regulator – decreases power consumption by 30mA when inhibited
- SLEEP: Processor sleep – Reduces power to 20mA with other hardware disabled (wakes on I2C transaction) Send dummy prior to any command or register access operation.
- Det Bias Disable: Turns off detector bias charge pump

# Connection Setup for I2C and PWM

There are two basic configurations for LIDAR-Lite

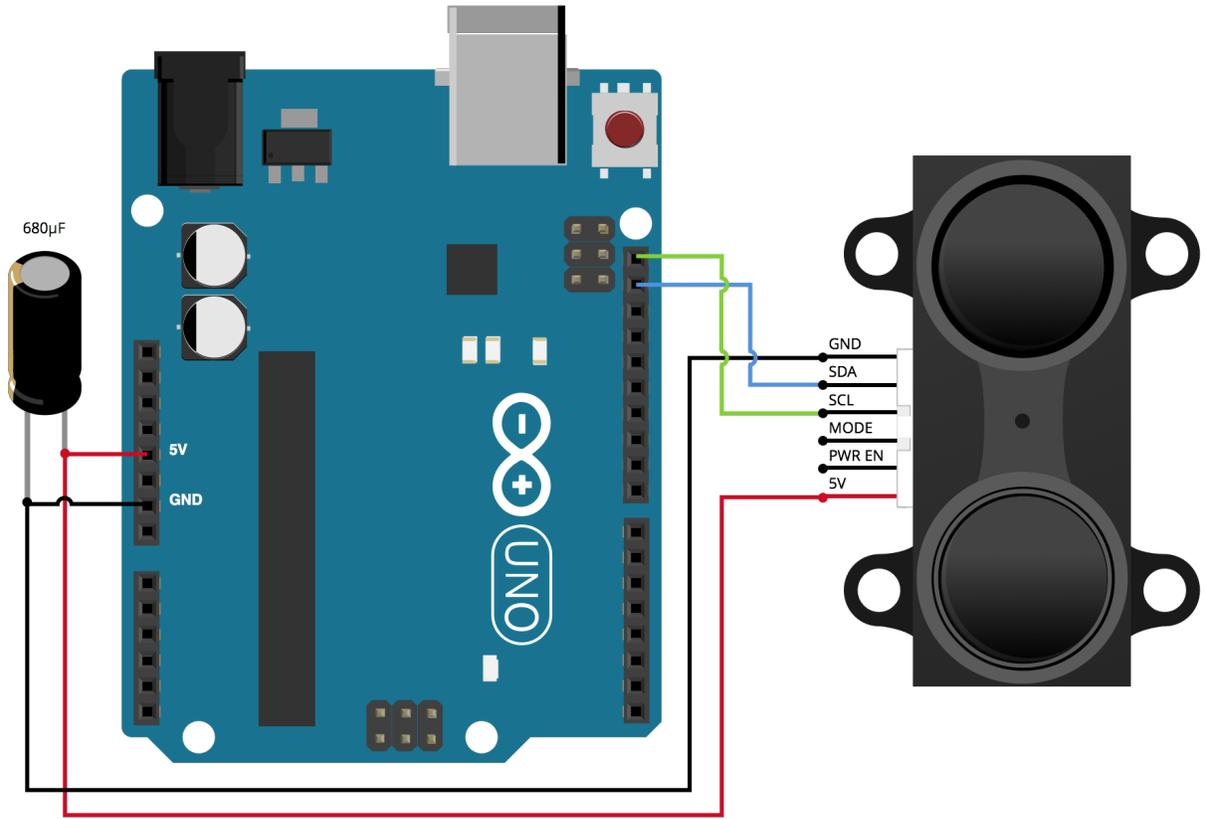
# I2C Wiring



1. Connect power and ground pins. The sensor operates at 4.75-5.5V DC Nominal, Maximum 6V DC.
2. Place a 680µF Electrolytic Capacitor between 5V and GND
3. Connect I2C SCL/SDA pins.

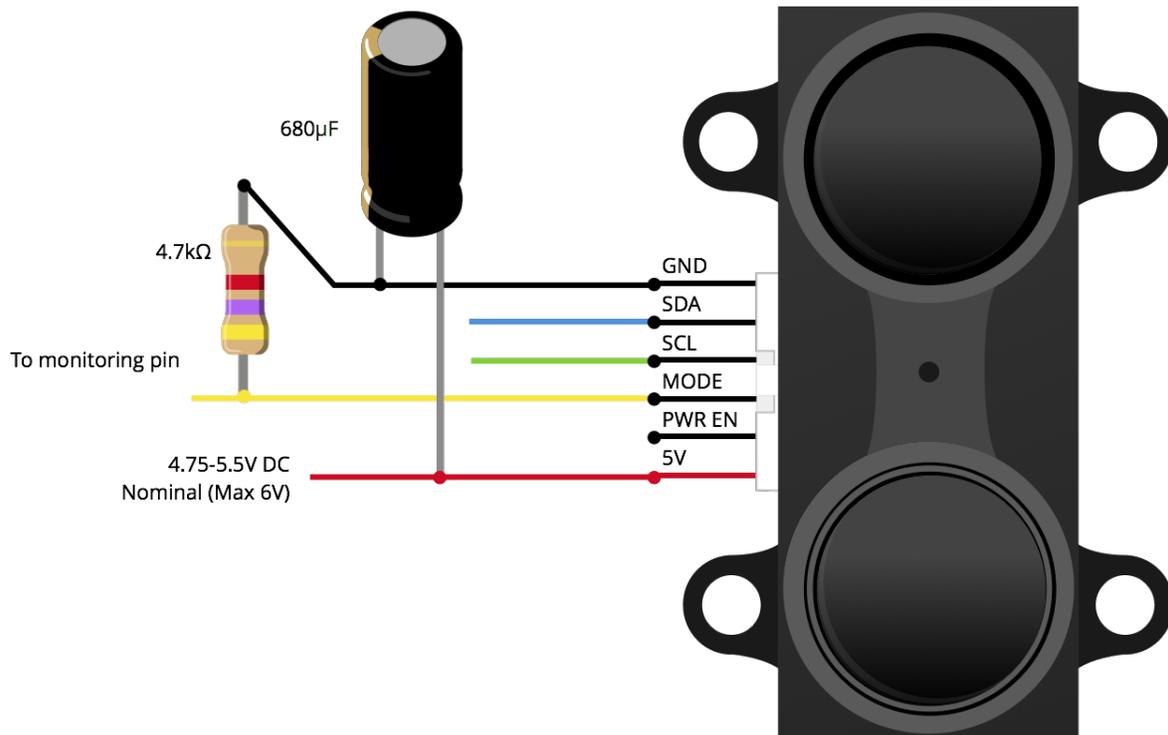
## Arduino I2C Connection

Connect the Arduino like the image below. *Be sure that the polarity of the electrolytic capacitor is correct.*



# Continuous Mode Wiring

## Continuous Mode Wiring

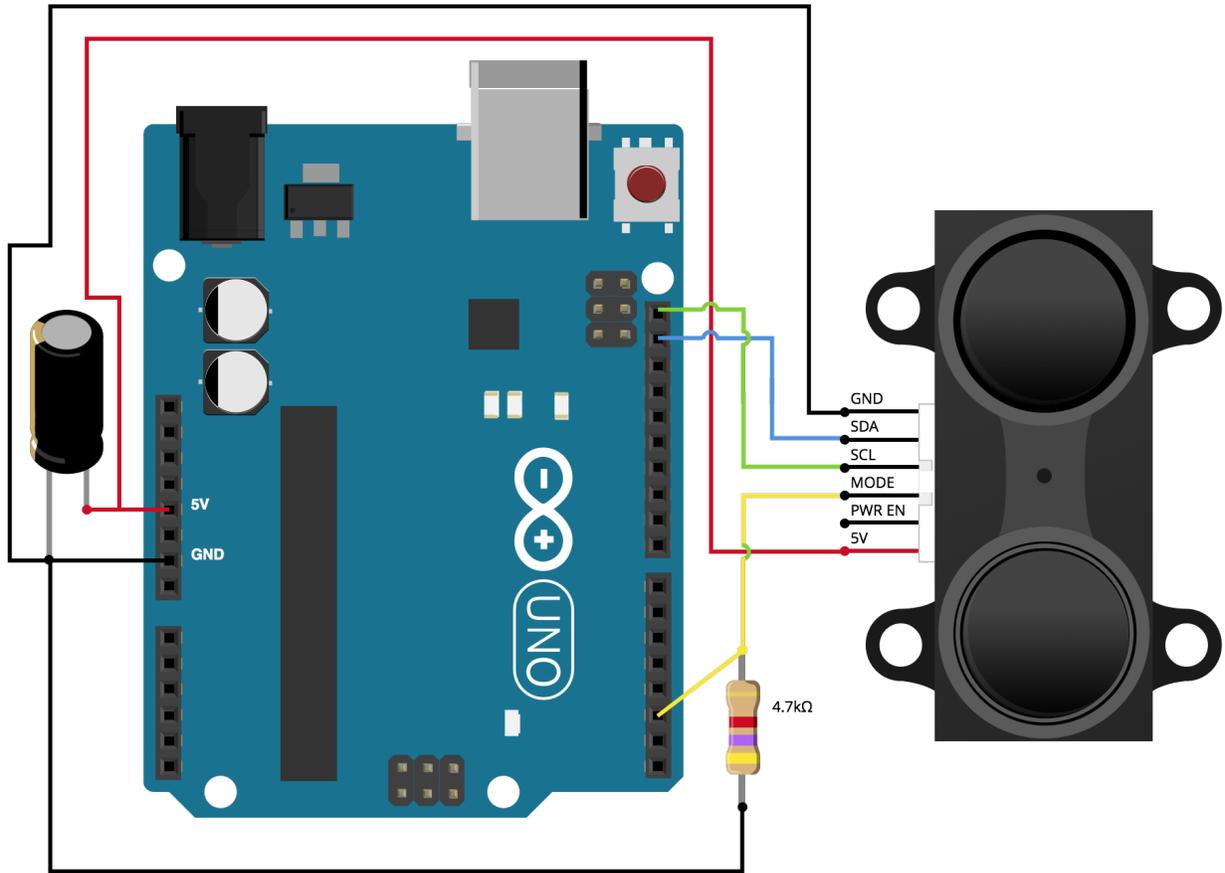


1. Connect power and ground pins. The sensor operates at 4.75-5.5V DC Nominal, Maximum 6V DC.
2. Place a 680µF Electrolytic Capacitor between 5V and GND
3. Connect I2C SCL/SDA pins.
4. Connect the MODE pin to a 4.7kΩ resistor and to a monitoring pin on your microcontroller
5. Connect the other side of the 4.7kΩ resistor to ground.

## Arduino I2C Connection

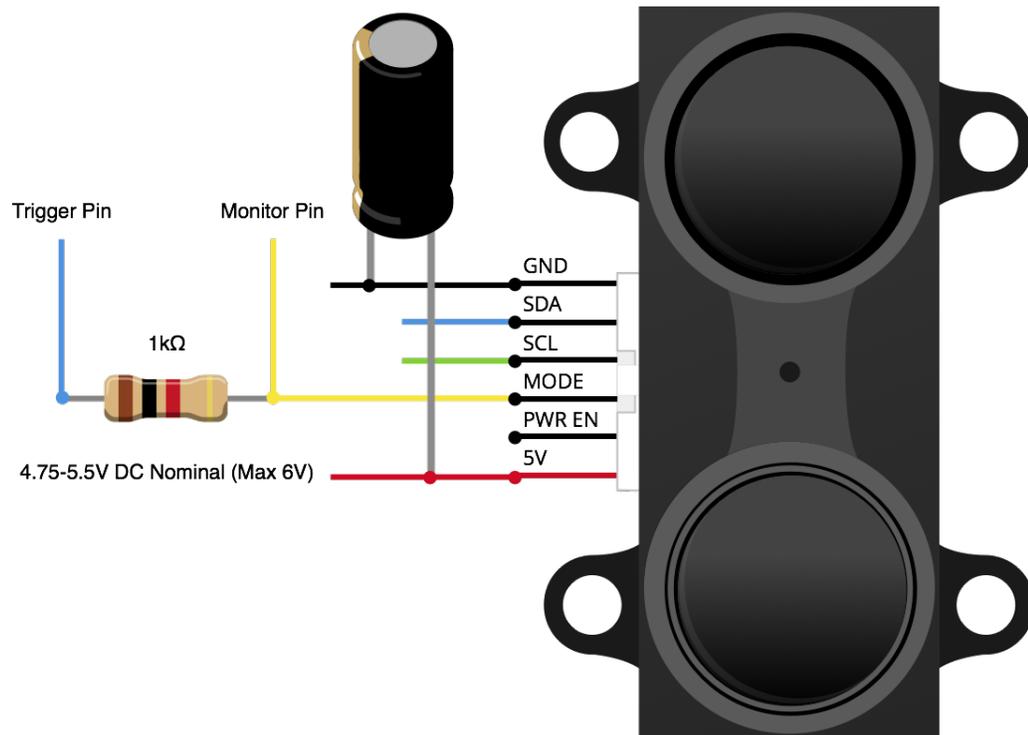
Connect the Arduino like the image below. *Be sure that the polarity of the electrolytic capacitor is correct.*

# Continuous Mode Wiring



# PWM Wiring

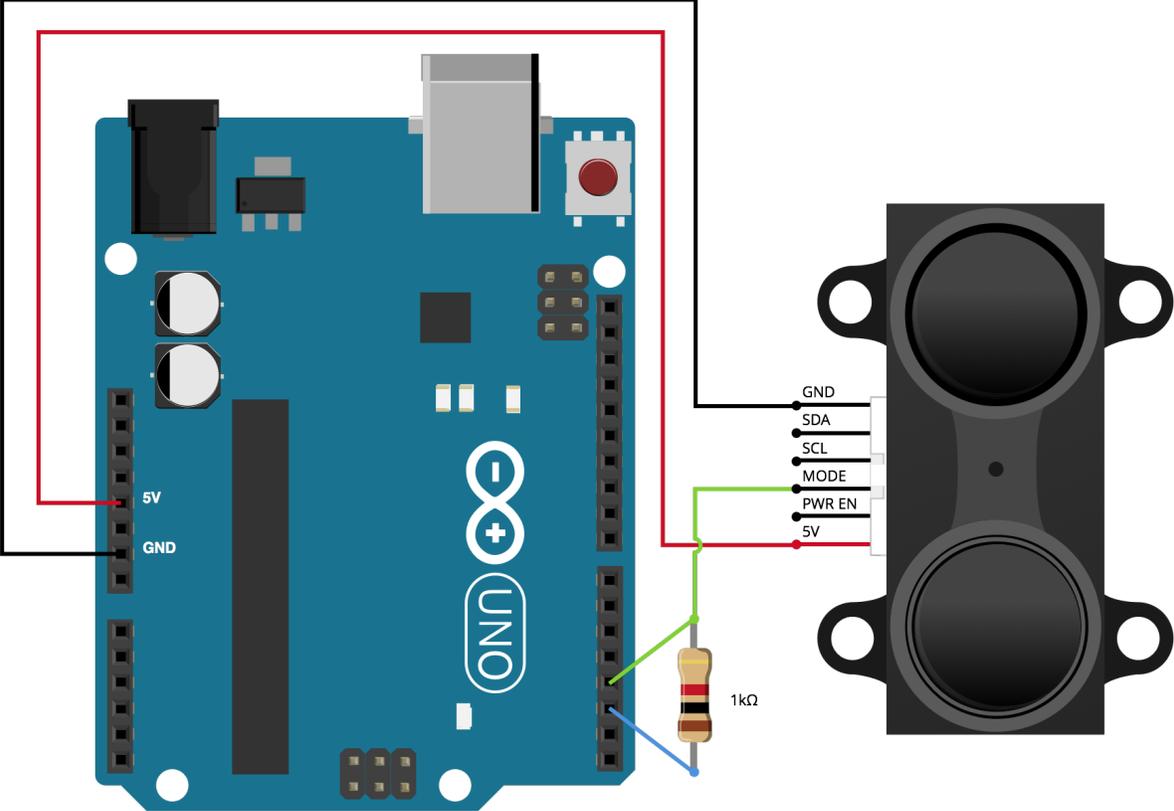
## PWM Wiring



1. Connect power and ground pins. The sensor operates at 4.75-5.5V DC Nominal, Maximum 6V DC.
2. Connect the MODE pin to a 1kΩ resistor and the monitor pin
3. Connect the other side of the 1kΩ resistor to the trigger pin

## Arduino PWM Connection

Connect the Arduino like the image below. Pin #2 is the Trigger Pin and Pin #3 is the Monitor Pin.



# Frequently Asked Questions

# What is the Accuracy of LIDAR-Lite?

We get asked this a lot and the answer can get somewhat complicated... so here we go:

- **Resolution:** LIDAR-Lite measures distance with centimeter (cm) resolution.
- **Accuracy in the manual:** In the LIDAR-Lite operating manual and data sheets we report the accuracy as  $\pm 0.025\text{m}$  ( $\pm 2.5\text{cm}$ ) or in other words 5%. This is the worst case scenario. (see below)
- **Accuracy in testing:** In our testing, we've found the actual accuracy of LIDAR-Lite is typically better than 1% (see below)

## Resolution vs Accuracy

Resolution should not be confused with accuracy. It is simply the smallest measurement increment that LIDAR-Lite is capable of reporting. It's the same as the smallest increment of measurement on a tape measure or ruler.

Accuracy, on the other hand, is how repeatable a reading is to a fixed target. In other words, if a target is 10m from the sensor, how close to 10m will the sensor read? And if you take 100 measurements, what range window do the minimum and maximum readings fall into?

## How did we get the $\pm 2.5\text{cm}$ (or 5%) accuracy?

The clock internal to the Signal Processing Core (the FPGA) we use has a reported accuracy of 5% by its manufacturer. Since this clock is the basis for all the calculations that happen during the processing of a signal (measurement), we've used that as the basis for our statements of accuracy for LIDAR-Lite.

That 5% number should be considered the worst case scenario. When a measurement is taken by LIDAR-Lite, the distance reported is the result of an accumulation of up to as many as 255 individual readings. In our testing, we've found the actual accuracy of LIDAR-Lite is typically better than 1%.

## LIDAR-Lite's signal processing algorithm

LIDAR-Lite's signal processing algorithms provide an advantage in accuracy when taking measurements to

distant or less reflective targets. Since a single distance measurement is an accumulation of many readings, the resulting signal processing gain improves accuracy. The longer the sensor can look at a target, the more accurate the reading. The time spent taking the readings is called the "integration" time. This can be as long as 20 milliseconds in some cases. If shorter integration times are desired, the sensor can be programmed to take fewer readings in a measurement. Reducing the number of readings can have an effect on the maximum range of the sensor.

If a target is close or highly reflective, LIDAR-Lite will accumulate fewer readings, resulting in a shorter integration time. In this case, even though we are accumulating fewer readings, the higher return signal strength still allows the accuracy of LIDAR-Lite to be maintained.

## So, if that's the case, why do we still report accuracy as 5% or +/- 0.025m?

We do this because until we can collect enough data to validate the better accuracy numbers we are seeing in our testing, we feel it is better to be conservative with our performance claims.

## Is there anything that can affect the accuracy of LIDAR-Lite?

If it is operated at too low a voltage, the power regulation may not be able to maintain the proper operating voltage for the Signal Processing Core or the laser may not be able to operate at peak efficiency. And, of course, attempting to take measurements beyond the maximum operating range of the sensor will also result in erratic readings.

---

# What kind of connector does LIDAR-Lite have?

- Board Connector: Molex part #5023860670 (DigiKey Part #: WM3917CT-ND)
  - Mating Connector: Molex # 5023800600 PLUG HSG 6POS (DigiKey Part #: WM2271-ND)
-

# Does the LIDAR-Lite run on 5V? Can it run on 3.3V?

LIDAR-Lite requires 5V to run properly and this is what we recommend and support.

However we have heard anecdotally that under certain and specific circumstances a lower voltage may work, you will want to experiment to see what works. Because this is an edge case for the sensor, we don't have any specific information of the conditions under which less than 5V works. Besides simply not powering up, the sensor can also power-up but return poor data or only good data at really short distances.

---

# What voltage can the LIDAR-Lite pins handle?

**I2C:** The I2C lines are 3.3v. They're setup for 3.3v and 5v operation (5v is converted to 3.3v and the sensor has an internal 4.7K ohm pullup resistor). If you're using a 5v system with only our sensor on the I2C then the 4.7K pullup may be adequate, however if you have multiple sensors on the I2C you may want to use a lower resistance pullup.

**MODE Pin:** The MODE pin has a 3.3v drive voltage, so it will only pull a load high up to 3.3v. It is diode isolated so 5v won't damage it, but it will not be able to drive a low high unless it's 3.3v.

---

# What is the spread of the laser beam?

At very close distances (less than a meter) the beam is about the size of the aperture (lens), at distances longer than that you can estimate it using this equation:

Distance/100 = beam size at that distance (in whatever units you measured distance in).

The actual spread is ~8 milli-radians or ~1/2 degree.

---

# How do I "Zero" the LIDAR-Lite?

LIDAR-Lite is not "zeroed" at the factory but we have a register (0x13) for zeroing the unit. If you want to offset the readings simply write a calibration offset value to 0x13.

We have sample Arduino code for v1 of the sensor here: [https://github.com/PulsedLight3D/LIDARLite\\_Zeroing](https://github.com/PulsedLight3D/LIDARLite_Zeroing)

## Notes:

The calibration offset is a two's complement.

For positive offset... i.e. to add a constant to the distance output... simply convert the decimal number to hex.

- Example... if i want to add 5 to all distance readings... the CalibrationOffsetValue would be 0x05

For negative offset... i.e. to subtract a constant from the distance output, you need to subtract the value from 256 and convert that to hex.

- Example 1... if i want to remove 5 from all distance readings:  $256-5 = 251$  so the CalibrationOffsetValue would be 0xFB.
  - Example 2... if i want to remove 12 from all distance readings:  $256-12 = 244$  so the CalibrationOffsetValue would be 0xF4
-

# Returned Signal Strength: Effect of Distance, Target Size, Aspect, and Reflectivity

The LIDAR-Lite sensor transmits a focused infrared beam that reflects off of a target, with a portion of that reflected signal returning to the receiver. Distance can be calculated by taking the difference between the moment of signal transmission to the moment of signal reception. But successfully receiving a reflected signal is heavily influenced by several factors.

These factors include:

- Target Distance
- Target Size
- Aspect
- Reflectivity

The relationship of distance (D) to returned signal strength is an inverse square. So, with increase in distance, returned signal strength decreases by  $1/D^2$  or the square root of the distance.

Additionally, the relationship of a target's Cross Section (C) to returned signal strength is an inverse power of 4. The LIDAR-Lite sensor transmits a focused near-infrared laser beam that spreads at a rate of approximately  $.5^\circ$  as distance increases. Up to 1 meter it is about the size of the lens. Beyond 1 meter, approximate beam spread in degrees can be estimated by dividing the distance by 100, or  $\sim 8$  milliradians. When the beam overfills (is larger than) the target, the signal returned decreases by  $1/C^4$  or the fourth root of the target's cross section.

The aspect of the target, or its orientation to the sensor, affects the observable cross section and, therefore, the amount of returned signal decreases as the aspect of the target varies from the normal.

Reflectivity characteristics of the target's surface also affect the amount of returned signal. In this case, we concern ourselves with reflectivity of near infrared wavelengths. Refer to our article on Reflectivity for additional information.

So you can see, a small target can be very difficult to detect if it is distant, poorly reflective and its aspect is away from the normal. In such cases, the target's returned signal strength may be improved by attaching infrared reflectors to the target, increasing the size of the target, modifying its aspect or reducing distance from the sensor.

# Special Topics

# Reflectivity

Does your LIDAR-Lite unit sometimes return an unexpected result?

There are several variables to consider if your LIDAR-Lite fails to return a valid measurement or seems not to recognize an object at all. These can be categorized into the following areas:

A. Reflectivity of the object B. Distance of the object from the sensor C. Size of the object relative to the transmitted infrared beam D. Direct or reflected sunlight finding its way into the receiver E. Atmospheric conditions F. Obstruction of the receiver lens F. Failure of the LIDAR-Lite unit

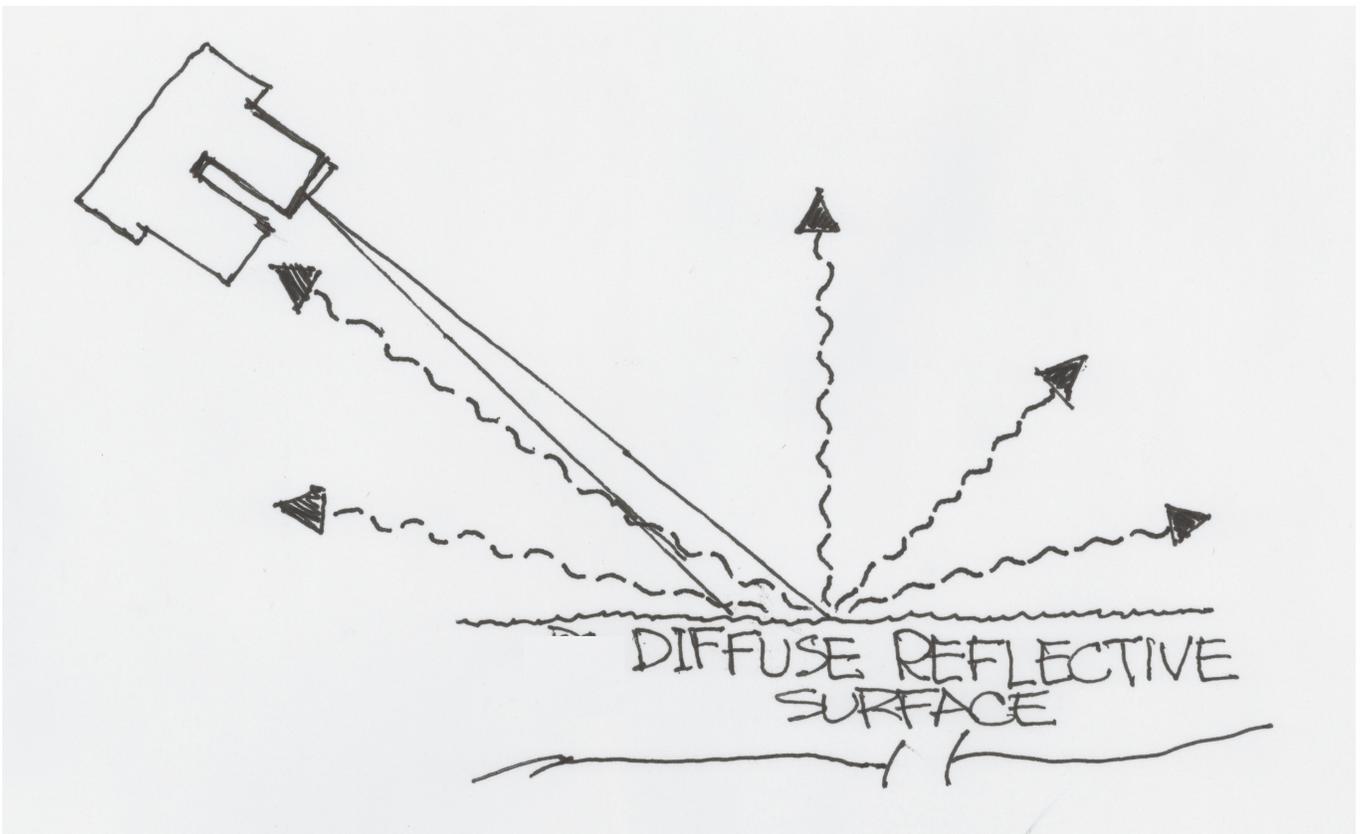
We'll consider reflectivity here:

## Reflectivity

Reflective characteristics of an object's surface can be divided into three categories (in the real world, a combination of characteristics is typically present): A. Diffuse Reflective B. Specular, and C. Retro-reflective

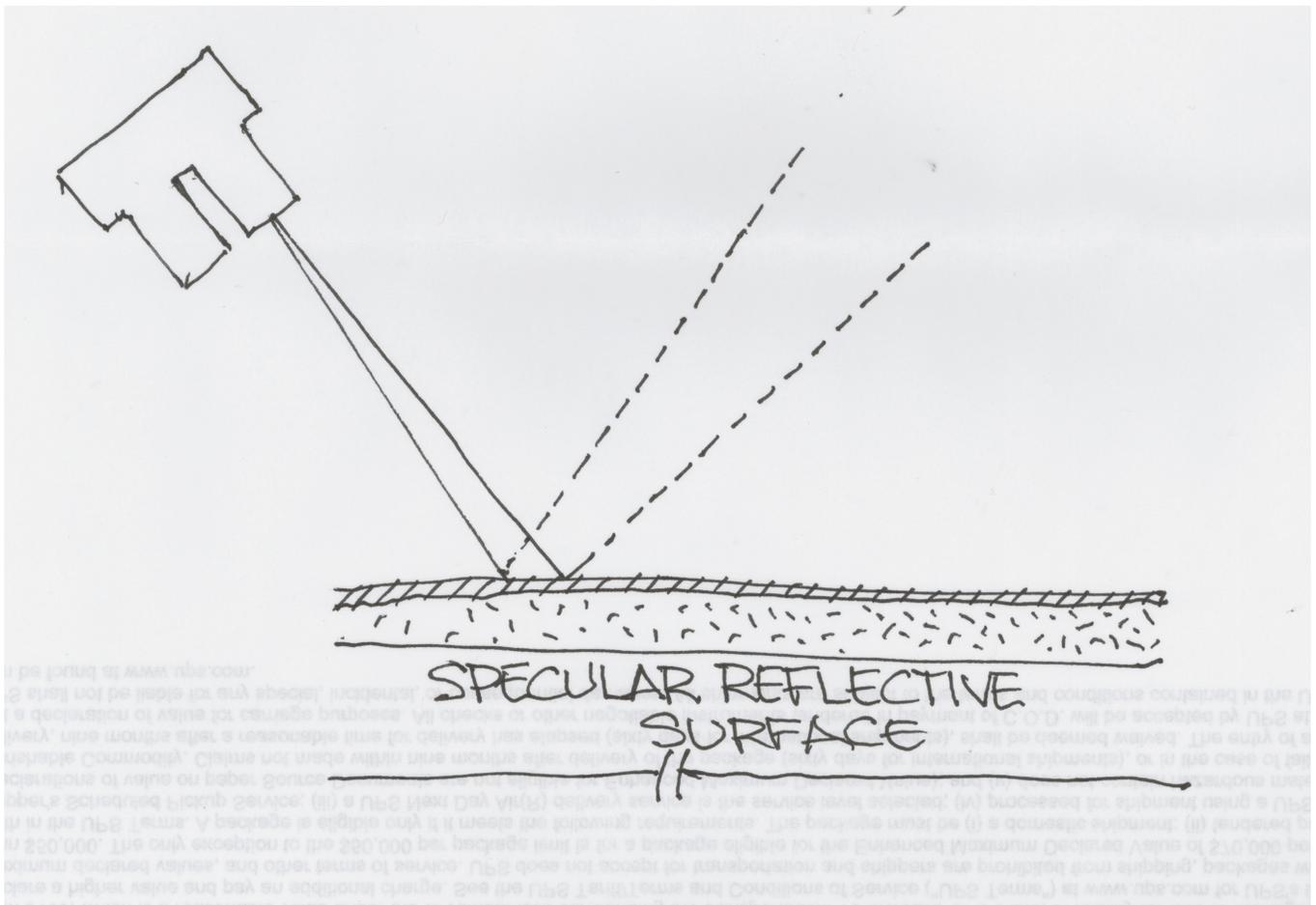
## Diffuse Reflective

In the case of purely diffuse surfaces, we are talking about materials that have a textured quality that causes reflected energy to disperse uniformly. This tendency results in a relatively predictable percentage of the dispersed laser energy finding its way back to the LIDAR-Lite receiver. As a result, these materials tend to read very well. Materials that fall into this category are paper, matte walls, and granite. It is important to note that materials that fit into this category due to observed reflection at visible light wavelengths may exhibit unexpected results in other wavelengths. The near infrared range used by the LIDAR-Lite transmitter may detect them as nearly identical. A case in point is a black sheet of paper may reflect a nearly identical percentage of the infrared signal back to the receiver as a white sheet.



## Specular

Specular surfaces, on the other hand, are difficult or impossible for the LIDAR-Lite to recognize because radiated energy is not dispersed. Reflections off of specular surfaces tend to reflect with little dispersion which causes the reflected beam to remain small and, if not reflected directly back to the receiver, to miss the receiver altogether. The LIDAR-Lite may fail to detect a specular object in front of it unless viewed from the normal. Examples of specular surfaces are mirrors and glass viewed off-axis.



## Retro-reflective

Retro-reflective surfaces return a very high percentage of radiated energy to the receiver due to their reflective properties. Light hitting a retro-reflective surface will return to the receiver without much signal loss so retro-reflective surfaces are typically very good targets for the LIDAR-Lite. Paint used to mark roadways, animals' eyes, license plates and road signs are examples of retro-reflective surfaces. Some bicycle reflectors are retro-reflective in the visible spectrum but are not easily detected by LIDAR-Lite due, in part, to their failure to reflect infrared wavelengths as efficiently as they do light in the visible spectrum.

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# Bathymetry

There are a few considerations to take into account if your application requires measuring distances to, or within, liquids.

These include:

1) Reflectivity and other characteristics of the liquid itself, 2) Reflectivity characteristics of particles suspended in the liquid, 3) Turbidity, and 4) Refractive characteristics of the liquid

Reflectivity of the liquid is important when measuring distance to the surface of a liquid or if measuring through liquid to the bottom of a container.

It is important to note that measuring distance with the LIDAR-Lite depends on reflected energy from the transmitted signal being detected by the receiver in the sensor. For that reason, the surface condition of the liquid may play an important role in the overall reflectivity and detectability of the liquid. In the case of a flat, highly reflective liquid surface, the laser's reflected energy may not disperse adequately to allow detection unless viewed from the normal. By contrast, small surface ripples may create enough dispersion of the reflected energy to allow detection of the liquid without the need to position the sensor so that the transmitted beam strikes the liquid's surface from the normal.

Reflectivity of suspended particles is a characteristic that may help or hinder depending on the application. Turbidity, or the clarity of a liquid created by the presence or absence of suspended particles, can similarly help or hinder measurement efforts. If the application requires detecting the surface of the liquid, then suspended particles may help by reflecting more of the transmitted beam back to the receiver, increasing detectability and permitting measurements to be taken.

On the other hand, attempting to measure through suspended particles in a liquid will only be successful if the transmitted beam is allowed to reflect off of the desired target without first being absorbed or reflected by the suspended particles.

When the near infrared energy transmitted by the LIDAR-Lite transitions from the atmosphere to a liquid, the energy may be bent, or refracted, and absorbed in addition to being dispersed. The degree to which the transmitted beam is refracted and absorbed is defined by its Refraction Index. That being said, the most important criteria impacting successful measurement through a liquid is the amount of dispersion of the transmitted beam and whether any of the dispersed beam makes its way back to the LIDAR-Lite receiver. Remember that electromagnetic energy travels slower through a liquid and may affect accuracy of the final measurement output.

You can read more about Reflectivity as it relates to using your LIDAR-Lite in the section above.

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# Strategy to Minimize Power Consumption

Our Operating Manual has a section on Power Management that describes register settings which allow you to turn the FPGA and pre-amp on and off as desired. But if you want to minimize power consumption as much as possible, you will need to employ the following steps. We anticipate the approximate power consumption at 1Hz to be in the range of <2 mA.

1. Initiate full power up with power enable line.
  2. Wait 3 to 4 ms, then initiate power savings (shut down FPGA and pre-amp per Power Management procedure section of Operating Manual).
  3. Wait 30 ms while clock loops synchronize, then power up FPGA and pre-amp.
  4. Wait 12ms, then initiate acquisition.
  5. Read measurement and turn sensor off using power enable line.
  6. Repeat above sequence
-

# Technology Patents

## US Patent, Patent No.: US 8,125,620 B2

**Abstract:** A method and apparatus for the acquisition of repetitive signals in a sensing device comprising a transmitter, a receiver and an object. The transmitter repetitively emits a modulated electromagnetic signal into a transmission medium, with the emitted signal interacting with the object producing a counter propagating return signal. The return signal may contain properties that reflect all, or a portion, of the initial signal or may be correlated with said signal through a process of absorption and reemission, in which reflected signal characteristics are governed by the object's physical material characteristic. The return signal is detected and converted into digital signals by a receiver via a reception channel through the use of edge transitions rather than logic levels from one or more computer outputs to reconstruct the return signal waveform. A several waveform acquisition and reconstruction methods are disclosed for use with an edge sampling detection apparatus. When directed towards the time-of-flight distance measurement the invention also discloses a useful method to profile optical feedback using a moving waveguide.

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## US Patent, Patent No.: US 8,994,925 B2

**Abstract:** Optical range finders are configured to transmit optical bursts toward a target and detect a corresponding received burst. DC offset in the received burst due to square law detection can be offset based on a difference between high pass and low pass filtered portions of the received burst. Edge records associated with bursts can be obtained and correlated with a reference signal or waveform to obtain a range estimate.

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# Connecting LIDAR-Lite v1 to Pixhawk

[Here](#) is some information from the folks at ArduCopter about connecting the LIDAR-Lite v1 to Pixhawk. It may work for LIDAR-Lite v2.