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SAFETY

Before unpacking the product, read and learn all safety and handling information provided in this section. Whenever unpacking, handling, operating, moving, or storing the product, ensure all guidelines in this section are met.

References

- EN/IEC 60825-1 Ed.2 2007
- Laser Notice No. 50, dated June 24, 2007

SAFETY SYMBOLS

When handling a Voxtel laser product, the labels and hazard descriptions below apply. Due to size limitations, labels do not appear on the product.

With the exception of the ESD warning label, the following labels are provided for application by the assembler or end user of the product. Proper product labeling of the fully assembled product is required in order to meet FDA certification guidelines. Proper labeling provides the user with appropriate warnings and product information when applied in the following manner.

- Labels provided must be permanently fixed, legible, and visible according to their purpose.
- Labels provided must be read without the necessity for human exposure to laser energy in excess of the limits associated with Class 1.

Further explanation can be found in IEC 60825-1 Ed.2, sec 5.1

Explanatory Label

This product is a Class 1 laser product as defined by EN/IEC 60825-1 2007.

Non-Interlocked Protective Housing Label

CAUTION
CLASS 4 INVISIBLE LASER RADIATION
WHEN OPEN
AVOID EYE OR SKIN EXPOSURE TO DIRECT OR SCATTERED RADIATION

The eyesafe, microminiature DPSS laser contains a Class 4 laser diode. There are no user-serviceable parts on any of the items supplied. Do not attempt to open the laser to attempt maintenance, service, repair or reconfiguration of any kind.

Certification Label

This laser complies with U.S. FDA performance standards for laser products except for deviations pursuant to Laser Notice No. 50, dated June 24, 2007.

Manufacturer’s Identification Label

Manufacturer, address, product and serial number.
Handling this product requires ESD precautions.

**ESD Warning Label**

Handling this product requires ESD precautions.

**HANDLING PRECAUTIONS**

This section applies to all Voxtel LRF products.

**For all units equipped with a laser:**

In addition to the requirements below, adhere to the requirements of:

- “DPSS Lasers and Laser Driver Boards” section of this manual
- Safe use of laser protocols using ANSI Z136.1-2014
- ESD prevention protocols using ANSI-ESD-S20.20-2014 as a guide

**For units not equipped with a laser:**

In addition to the requirements below, adhere to the requirements of:

- ESD prevention protocols using ANSI-ESD-S20.20-2014 as a guide

⚠ **Warning**

- For all units equipped with a laser, failure to follow laser protocols and precautions when handling the product may result in personal injury and/or damage to the product.

⚠ **Caution**

- Failure to follow ESD protocols and precautions when handling the product may result in damage to the product. A single electrostatic discharge (ESD) event can cause catastrophic or latent device failure.

**ESD Precautions**

**For all units that have a standalone laser:**

- **When Not in Use:** Electrically short the laser anode and cathode electrical leads to prevent ESD damage.
  - For lasers with connectors attached, insert the shorting pin in the connector.
  - For lasers without connectors, twist the exposed conductive wires together.

- **When Making the Connections:** 1) do not connect the laser to a function generator, or other pulse generator, with the pulse generator emitting pulses; 2) connect 5V to the laser diode driver before attaching laser wires. Disconnecting and reconnecting the 5V with the laser wires attached to the anode and cathode may damage the laser.

**For all units (including those equipped with a laser):**

- **Clean, Static-free Environment:** Do not open the package in an unclean environment; handle the product only in a clean, static-free work environment, such as a grounded workbench or surface.
- **Continuous Grounding:** Ensure all persons and tools that may contact the product are continuously grounded.
- **ESD-protective Clothing/Accessories:** When handling the product, wear: 1) a grounded wrist strap; 2) ESD protection; and 3) ESD-safe (static-dissipative) lint-free (nonsheeding) gloves. If any oil or grease is apparent on the gloves, replace the gloves.
• **ESD-protective Container:** When transporting the product beyond the confines of the workbench, place it in an ESD-protective container that restricts product movement within the container, such as the original shipping container, an antistatic bag, or a grounded cart.

• **Powered-off for Connections:** When making connections, ensure the product power supply is off. Do not connect a product to a laser diode when the power supply voltage is on.

**Additional Handling Protocols and Precautions**

**For all units (including those equipped with a laser):**

- When placing or positioning the product, use a light touch.
- Except as described in “Appendix A—Unpacking, Inspection, and Cleaning,” do not allow anything to contact the transmit window of a laser or the receive window of a photoreceiver.
- Handle the product using thumb and forefinger as shown:

  ![Diagram of laser and photoreceiver handling](image)

  For lasers, hold the top of the laser casing—above the mounting flanges.

  For photoreceivers, receivers are best handled by holding with thumb and forefinger across the diameter of the TO-8 can.

  **Caution**
  - **Do not bend the laser mounting flanges.**
    The mounting flanges are designed as flexures to reduce torque effects during mounting. If not handled correctly, the mounting flanges may become bent.

  **Caution**
  - **Do not allow pins to bend**
    Take care when mounting, handling, or placing the product. If pins need to be straightened, use a standard pin-straightening tool.

- During handling, wear clean lint-free gloves to avoid contaminating the window.

  **Note**
  - **Do not touch the product with bare hands.**
    Any oil or grease that contacts the window can negatively impact performance; oil or grease that contacts the product casing can negatively affect cosmetic appearance.

**Additional Notes**

  **Note**
  - Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.

  **Note**
  - The product may look different than shown. Refer to the drawings on the datasheet.
INTRODUCTION

This user manual provides the information necessary to operate the ROXTM laser ranging photoreceivers, pulsed diode-pumped solid-state (DPSS) lasers, electronics, and rangefinding or lidar products.

CAUTIONS, WARNINGS, AND NOTES

In this handbook, the following conventions are used:

⚠️ Warning
• Failure to follow this guidance may result in injury.

⚠️ Caution
• Failure to follow this guidance may result in damage to the equipment.

⚠️ Note
• Failure to follow this guidance may result in sub-optimal performance of equipment.

ORGANIZATION

This manual is generally organized by product. For devices that integrate multiple products as components—such as the laser rangefinding (LRF) modules, which integrate ROX APD photoreceivers, DPSS lasers, and electronics—information is available about the integrated product and additional information is available by component. For example, while an integrated LRF module has its own section, specific information about the laser is provided in the laser section and specific information about the photoreceiver is provided in the photoreceiver section of this manual.

Information that is universal to all LRF products is provided in the following sections of this user manual:
• Safety
• Appendix A—Unpacking, Inspection, and Cleaning

For all products, before unpacking the product from the shipping package, ensure all safety and handling conditions are met.

RESOURCES

• Product Datasheets
  ○ Individual product datasheets are available via the relevant product links from http://voxtel-inc.com/products/.
• Mechanical drawings and solid models are available at http://voxtel-inc.com/voxtel-news/user-resources/.
• Latest LRF firmware and software are available at http://voxtel-inc.com/voxtel-news/user-resources/.
• Voxtel Technical Notes on Laser Rangefinding—These technical notes are to help users understand how to model, configure, integrate, and operate the laser-ranging products for specific applications. The technical notes are available via the Technical Papers link on the Resources page at Voxtel-Inc.com.
ROX APD PHOTORECEIVER PRODUCTS

References

- **ROX™ APD Photoreceiver Product Datasheet**—Contains required operational information for connecting and using the ROX APD photoreceivers, as well as information on the ROX APD Photoreceiver Evaluation Board.
- **Voxtel Technical Notes on Laser Rangefinding**—These technical notes are to help users understand how to model, configure, integrate, and operate the laser-ranging products for specific applications. The technical notes are available via the Technical Papers link on the Resources page at Voxtel-Inc.com.

PRECAUTIONS

APD photoreceivers are sensitive to damage by ESD or other voltage transients. ESD-mitigating procedures are required when handling the photoreceivers. Before handling the equipment, read and become familiar with the safety and handling information below and in the “Safety” section of this manual.

⚠ **Caution**

- Failure to follow ESD procedures when handling the photoreceiver may result in damage to or destruction of the photoreceiver.
- Do not connect the photoreceiver with the power-supply voltage powered on.
- Do not direct or focus laser light directly on the ROX APD photoreceiver. APD photoreceivers are sensitive to being damaged by large optical signals. For optical damage threshold limits, refer to the product datasheet.
- Do not direct high-pulse-energy lasers or high-average-power pulsed lasers directly onto the APD photoreceiver. For testing, a sufficient signal level can be achieved by pointing the laser source at a very diffuse source, so that only a diffuse reflection of the laser light reaches the photoreceiver. Alternatively, neutral density filters can be placed in front of the laser and photoreceiver to attenuate the optical signals at the photoreceiver.

⚠ **Note**

- Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.
SETUP AND OPERATION

1. Read and adhere to the safety and handling protocols described at the start of this product section and in the “Safety” section of this manual.

⚠ Warning
• Failure to follow the precautions and procedures in the “Safety” section of this manual may result in catastrophic damage to the system.

2. Unpack, inspect, and (if necessary) clean the product as described in “Appendix A—Unpacking, Inspection, and Cleaning.”
3. Consult the photoreceiver datasheet for electrical and optical interfacing to the photoreceiver.
4. Configure a printed circuit board to provide the electrical input and output signals shown on the datasheet.
5. APD photoreceivers are factory-configured to default on power up to Mode 1, which sets the APD to operate with a gain of $M = 1$. For a description of the photoreceiver operating modes, refer to the ROX APD Photoreceiver Product Datasheet.
6. Before integrating the photoreceiver in the circuit, verify that the electrical interfaces meet the specifications of the datasheet.
7. If the photoreceiver analog output is being used, verify that the termination of the output is 50 ohms.
8. Configure the controller to send start commands to the photoreceiver with the pulse-width encoding shown on the datasheet.
9. Adjust the voltage threshold ($V_{th}$) to 0.55V.
10. Power-off the circuit and insert the photoreceiver.
11. Darken the operating environment or place a shroud or other covering over the photoreceiver, so that ambient lighting will not increase the noise floor.
12. Power-on the circuit, monitoring the power lines.
13. Ensure the current draw of the supplies are within the expected values on the datasheet.

⚠ Note
• The APD photoreceiver output will not respond to DC light sources.

14. Send a START command for Mode 1 ($M = 1$) operation.
15. Continue to send START commands at regular time intervals (e.g., every few seconds) so that the APD bias is adjusted to accommodate temperature changes. Do not allow the temperature of the APD photoreceiver to lower more than a few degrees Celsius.

⚠ Caution
• Failure to monitor temperature and re-bias the APD by sending START commands can damage the product. If the temperature of the photoreceiver is changed by more than a few degrees Celsius, the change in the APD gain characteristics can cause the APD to go into sustained avalanche breakdown, resulting in permanent damage to the photoreceiver.

16. Test the photoreceiver to check if it is operational using one of the following methods:
• While operating without a pulsed light source, adjust the $V_{in}$ bias down until false hits begin to be returned from the digital outputs. This will occur between 0.4V and 0.5V; or
• Monitor the analog output and confirm there is a signal at the output when the laser source is firing.
17. Power off the laser source and reduce $V_{in}$ in small steps from 0.6V until desired false-alarm rate (FAR) is reached.
18. If using the optional evaluation board, setup and configure as described in “ROX APD Photoreceiver Evaluation Board,” later in this section.
ADJUSTING THE VOLTAGE THRESHOLD LEVEL

Proper management of the detector voltage threshold level is critical for optimal operation of the photoreceiver. The threshold settings, during the ranging event, set: the voltage level in the detector that determines the probability of detecting the return laser pulses; and the false-alarm rate (FAR) of the photoreceiver. Generally, low voltage threshold settings allow for a high probability of pulse detection with a higher FAR, and high voltage threshold settings allow for a lower probability of pulse detection, with a lower FAR.

To optimize the voltage threshold for various applications, refer to Voxtel’s Technical Notes on laser rangefinding.

CONFIGURING TIME-VARIABLE THRESHOLD (TVT)

While synchronizing to the outgoing laser pulse, reduce $V_{th}$ from a voltage bias level of $V_{th \_high}$ to a voltage bias level of $V_{th \_low}$. An RC circuit in the APD photoreceiver will drop the threshold with the decay time specified in the datasheet. The RC decay time is also user-configurable.

In the standard configuration, the photoreceiver includes an RC time delay circuit that allows the user to change the threshold level while ranging. This allows the photoreceiver detection probability to change as a function of range, so that probability of detection of a target is somewhat normalized as a function of range.

A time-variable threshold (TVT) can be achieved by changing the $V_{th}$ level from a high voltage level to a low voltage level. The threshold begins to lower immediately once the $V_{th}$ level is switched from the end system. This is typically done when the T0 pulse is detected.

The photoreceiver is designed to allow for TVT, which allows for the detection threshold to change over a decay time. The specific decay-time constant at which the detection threshold lowers as a function of time is included in the photoreceiver datasheet. RC delay circuits tailored to user-specific requirements can be accommodated (contact Voxtel for details).

To cause a TVT, set $V_{th}$ to the highest threshold voltage level ($V_{th \_high}$) optimal for detecting the near-field optical pulse returns. $V_{th \_high}$ is generally set to between 0.65V and 0.70V.

- $V_{th \_high}$ should be set so that the outgoing pulse can be detected.
- $V_{th \_low}$ should be set to the desired false alarm rate of the end system.

When $V_{th}$ is switched from high to low the voltage threshold is dropped to a lower voltage, $V_{th \_low}$. $V_{th \_low}$ determines pulse-detection probability and false-alarm probability at the end of the TVT decay time, which means it must be set specifically for the application requirements. The low voltage threshold, $V_{th \_low}$ is generally between 0.45V and 0.6V.

CHANGING THE DECAY TIME ON THE VOLTAGE THRESHOLD

The time constant changes the threshold as follows:

$$V_{th}(\tau) = V_{th \_high} - (V_{th \_high} - V_{th \_low}) e^{-\tau/R\cdot C}$$

When the external value of $V_{th}$ is changed from one value to another—e.g., from a high voltage level, $V_{th \_high}$, to a low voltage level, $V_{th \_low}$—as configured at the factory, the internal threshold $V_{th}(\tau)$ changes according to the RC time constant. The RC value can be found on the datasheet. It may be possible to modify the RC time constant by adding a resistor to the circuit, outside of the TO-8 package. For details, contact Voxtel.

CALIBRATING FOR RANGE WALK

Range walk is the systematic dependence of the range accuracy on the return pulse amplitude. The effects of range walk can be mitigated in the photoreceiver by approximating the pulse amplitude by recording the leading-edge and falling-edge threshold crossings of the return laser pulse. The difference between the times of the falling edge and
the rising edge is called the time over threshold and is used to estimate the pulse amplitude so that a range-walk-correction factor may be applied.

A description of range walk is provided in the datasheet and methods of calibrating for range walk are described in Voxtel Technical Notes on laser rangefinding.

**TROUBLESHOOTING**

No analog output:

- Ensure the optical source is pulsed, with a pulse width between approximately 0.1 ns and 100 ns. The photoreceiver will not respond to DC (non-modulated) optical sources.
- Make sure the analog output has a 50-ohm termination.
- Using an oscilloscope or voltage meter, verify that the input bias levels at the APD photoreceiver are as specified in the datasheet. In particular, monitor VAPD, VCMOS1, and VCMOS2 to confirm they are at the proper bias levels.
- Measured VAPD bias levels that are lower than expected indicate that:
  - The APD is being operated at signal levels above the specified dynamic range; or
  - The photoreceiver has short circuited or is otherwise damaged.
- Verify that there is not too much optical signal.
- After performing the above, power down the photoreceiver and contact Voxtel for further troubleshooting tips.

Noise on the digital output lines:

- Verify that the digital output lines are properly terminated.
- Adjust \( V_{th} \) up to about 1 V to verify that the photoreceiver is not triggering off the electronic noise.

The calculated range changes with the reflectivity of the target:

- Changes in range accuracy are generally due to range walk. A description of range walk is included in the datasheet and in Voxtel’s Technical Notes on laser rangefinding. The system must be calibrated to accommodate the amplitude-dependent detection timing offsets that will result in the desired range accuracy errors.

The calculated range changes with the voltage threshold:

- Changes in range accuracy are generally due to range walk. A description of range walk is included in the datasheet and in Voxtel’s Technical Notes on laser rangefinding. The system must be calibrated to accommodate the amplitude-dependent detection timing offsets that will result in the desired range-accuracy errors.
- Changes in range precision are generally caused by signal pulse amplitudes that are close in value to the voltage threshold levels. At low signal levels, jitter caused by electronic noise may result in range-precision errors, as evidenced by a large standard deviation in the timing measurements. A description of how to optimize the signal-to-threshold levels is included in Voxtel’s Technical Notes on laser rangefinding.

**ROX APD PHOTORECEIVER EVALUATION BOARD**

The ROX APD Photoreceiver Evaluation Board is an option (sold separately) that allows operation and rapid evaluation of the ROX APD photoreceivers. The evaluation board provides the control and signal conditioning necessary to operate the APD photoreceiver and to evaluate the various operating modes of the photoreceiver. The evaluation board is delivered with an AC-to-DC power adaptor that provides the power necessary to operate the photoreceiver and is shipped with hardware to allow it to be mounted on an optical table for evaluation. The photoreceiver operating modes can be chosen using a simple dual-in-line plug (DIP) connector. The threshold voltage
The setting is adjusted with a potentiometer. The evaluation board also accommodates time-variable threshold operation.

## INITIAL CONFIGURATION

⚠ **Caution**
- Do not aim the laser directly at the photoreceiver.
  
  Aiming lasers directly at the receiver may result in a power density exceeding the photoreceiver damage threshold. For the purposes of testing, use neutral density filters in front of the APD and photoreceiver and reflect the laser off of diffusely scattering targets—preferably at ranges of 50 meters or longer. Do not test the photoreceiver using lasers aimed at highly reflective or retro-reflectors.

⚠ **Caution**
- To avoid damage to the APD, return the evaluation board to Mode 1 ($M = 1$) when repositioning the laser or when the photoreceiver is not in active use.

1. Read and adhere to the safety and handling protocols described at the start of this product section and in the “Safety” section of this manual.

⚠ **Caution**
- Failure to follow the precautions and procedures at the start of this section and in the “Safety” section of this manual may result in catastrophic damage to the system.

2. Unpack, inspect, and (if necessary) clean the product as described in “Appendix A—Unpacking, Inspection, and Cleaning.”
3. Mount the evaluation board within an optical test apparatus.
4. Ensure the jumper on J7 is removed or is otherwise not connecting any of the three pins together. The jumper on J7 is used only to enable time-variable threshold (TVT) functions. For details of the jumper configuration, refer to “Triggering TVT with Optical Signal (T0 pulse detected by photoreceiver).”
5. Using a 50-Ω coaxial cable, connect the analog output to an oscilloscope channel configured for DC-coupled 50-Ω termination.

⚠ **Note**
- Failure to use a 50-Ω termination will cause the output buffer amplifier to oscillate.

6. Set the oscilloscope channel to 100 mV per division.
7. Using a second 50-Ω coaxial cable, connect the comparator output to a second channel of the oscilloscope, also configured for DC-coupled 50-Ω termination. Set the oscilloscope channel to 1V per division.
8. Plug the provided 5V power supply into the evaluation board.

9. Set the high threshold voltage level, $V_{th, high}$, as follows:
   a. When no optical signal is present, turn the R35 potentiometer counterclockwise until the digital channel reacts to electrical noise, which indicates the signal path is functioning.
   b. After verifying that the output is reacting to the electronic noise, turn the $V_{th, high}$ potentiometer back (about a half-turn clockwise), so that any digital output due to noise is rare. The threshold voltage level for the desired false-alarm rate (FAR) for $V_{th, high}$ can be set precisely using a digital counter.

10. Set the low threshold voltage level, $V_{th, low}$, as follows:
    a. Press and hold the SW5 switch (located adjacent to the potentiometers).
    b. Monitoring the digital output, turn the R20 potentiometer counterclockwise until the desired output FAR is achieved. The FAR can be measured using a digital counter.

The ROX APD Photoreceiver Evaluation Board is now configured for operation and is optical-signal ready.

---

**OPERATION**

For descriptions of the operating modes used in the various ROX APD Photoreceiver models, refer to the datasheet.

When power is applied to the evaluation board, it automatically configures the photoreceiver to operate in mode 1, which, for most standard factory configurations, sets the APD gain to $M = 1$.

Each of the four micro-pushbutton switches enables one of the four factory-calibrated photoreceiver operating modes (SW1 = mode 1; SW2 = mode 2; SW3 = mode 4; and SW4 = mode 3). The switches can be used to optimize photoreceiver performance for a particular application.

Each time an SW switch is pressed, the following sequence occurs:

1. The high-voltage supply is enabled.
2. A measurement of the temperature of the photoreceiver is performed.
3. The APD in the ROX APD photoreceiver is configured to the bias voltage that was factory calibrated. These calibrated operating voltages are stored in memory in the ROX APD photoreceiver.

While, a significant change in temperature is unlikely in lab-test scenarios, it is generally advisable to regularly set the APD gain by periodically re-affirming the photoreceiver operating mode. This can be achieved, for example, by pressing the SW switch prior to making a sequence of measurements, so that the APD bias is adjusted for the current ambient temperature. This achieves optimized performance and reduces the risk of damage due to breakdown avalanche currents.

When temperature changes are likely—e.g., during field testing—either manually set the various modes frequently, or automatically set the various modes using a temperature sensor and a controller.

The optical signal that results from an outgoing laser pulse—often referred to as a $T_0$ pulse—provides a precise reference for the beginning of a laser range sequence.

---

**CONFIGURING TIME-VARIABLE THRESHOLD (TVT)**

To adjust the high threshold voltage level ($V_{th, high}$) and the low threshold voltage level ($V_{th, low}$), adjust the potentiometers as described in “Initial Configuration,” earlier in this section.

**Disable Time-variable Threshold (TVT)**

To disable time-variable threshold operation, remove the J7 jumper.

**Operating Time-variable Threshold (TVT)**

To enable time-variable threshold (TVT), place a jumper between any two adjacent pins on the J7 connector so that they are electrically connected. When configured in this way, the threshold voltage of the pulse-detection comparator is set to $V_{th, high}$; during operation after the TVT circuit is triggered, the threshold voltage $V_{th}$ drops from $V_{th, high}$ to $V_{th, low}$ in a decay time specified in the datasheet.
The threshold voltage remains at the low setting for ~20 ms before automatically resetting to high. Note that this reset time limits the pulse-repetition-rate capabilities of the evaluation board to 50 Hz.

**Selecting T0 Trigger Source (Electrical or Optical)**

The J7 jumper setting determines if the TVT circuit has been triggered by an optical T0 pulse incident on the detector, or by an externally supplied 5V logic signal. If the jumper is removed, the TVT function is disabled.

- **Triggering TVT with Optical Signal (T0 pulse detected by photoreceiver)**
  The TVT will be initiated by the outgoing laser pulse (T0 pulse) when it is detected by the photoreceiver, if Pin 2 and Pin 3 of Jumper J7 are electrically shorted together. In this configuration, after the photoreceiver detects the laser pulse, the detection threshold voltage bias will lower from $V_{th\_high}$ to $V_{th\_low}$ over the factory-configured decay time.

- **Triggering TVT with Electrical Logic Signal (T0 pulse generated by external electronics)**
  To start the TVT using the rising edge of an external provided electrical trigger, place a jumper to electrically short Pin 1 and Pin 2 of J7. The trigger logic signal should be applied to the SMA connector labeled J6. The rising edge of the user-supplied T0 trigger signal will cause the voltage threshold level to decay from $V_{th\_high}$ to $V_{th\_low}$ over a factory-configured decay time.
PRECAUTIONS

Laser products described in this manual are Class 1. Before handling the equipment, read and become familiar with the safety and handling information below and in the “Safety” section of this manual. DPSS lasers are very sensitive to damage by electrostatic discharge (ESD) or other voltage transients. When storing, handling, or operating the laser, ensure all requirements are met.

⚠ Warning
- Use of controls or adjustments or performance of procedures other than those specified herein may result in hazardous radiation exposure.
  Voxtel's DPSS lasers are designated as a Class 1 laser product when used as described for all procedures and operations in the information accompanying the product.
- Do not attempt to open the laser for maintenance, service, repair, or reconfiguration of any kind.
  There are no user-serviceable parts. Users are not authorized to perform any maintenance—scheduled or otherwise—on any items supplied. Service, repair, or reconfiguration is only to be carried out by Voxtel-trained technicians and engineers.
- Do not operate if there is any mechanical damage to the base or cover, or if the cover is removed.
  The DPSS lasers contain a Class 4 laser diode.
- Do not attempt to view laser output directly with any external viewing aid such as magnifying lens or microscope.
  Any focusing of the beam directly into the eye may cause damage or blindness.

⚠ Caution
- Do not operate with a laser trigger pulse longer than 3.5 ms.
  The laser trigger pulse provides current to the pump laser diode while the signal is high. A laser trigger pulse with a duration longer than 3.5 ms can overdrive the laser and result in damage.
- Do not operate with a frequency above the maximum specified frequency.
  Each laser has a specified maximum pulse-repetition rate (refer to the product datasheet); exceeding it can overdrive the laser and cause damage.

⚠ Note
- Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.
References

- Voxtel’s DPSS Lasers and Laser Driver Boards datasheet contains electrical and mechanical interface information for Voxtel’s DPSS lasers and laser driver boards, as well as assembly options (such as collimating optics and integrated T0 detector).
- Mechanical drawings, solid models, and this user manual are available at voxtel-inc.com via the “Drawings, Solid Models, Software, Firmware, and Document” link on the Resources page.
- IEC 60825-1 Ed.2—Contains definition of laser classification
- ANSI Z136.1—Safe Use of Lasers

ASSEMBLY, CONFIGURATION, AND OPERATION

This section describes the setup and operation of Voxtel DPSS lasers used with a Voxtel-supplied laser driver board.

Equipment

Laser setup requires the following basic equipment:

- Laser driver board for use with the specific laser product (e.g., 100 µJ, 300 µJ, 750 µJ, etc. variant)
- User-provided mount for the laser driver board (for mounting hole size and spacing, refer to Voxtel’s mechanical drawings of the laser driver board)
- 5V power supply: 1.5A, center positive standard barrel plug
- Pulse generator with BNC cable: Laser trigger output—square pulse, max 2.5 V, min 0 V, max 10 Hz, pulse width max 3.5 ms
- Custom tri-furcated cable
- Mechanical mounting surface for orienting the laser (for mounting hole size and spacing, refer to Voxtel’s mechanical drawings of the laser base)

Procedure

1. Read and adhere to the safety and handling protocols described at the start of this product section and in the “Safety” section of this manual.

⚠ Warning

- Failure to follow the precautions and procedures at the start of this section and in the “Safety” section of this manual may result in personal injury and/or catastrophic damage to the system.

Unpack, inspect, and (if necessary) clean the product as described in “Appendix A—Unpacking, Inspection, and Cleaning.”

Shipping Box for Laser only (ESD-Protective Container)

Voxtel DPSS lasers are shipped in an ESD-protective box. The ~7 x 3½ x 1-in³ (18 x 9 x 25-mm³) box shown will contain up to four lasers. Each Voxtel DPSS laser includes:

- a cathode (black wire)
- an anode (red wire)
- (optional) an integrated T0 detector (white wire; 26 – 28 AWG)
- a laser certificate of compliance
Voxtel DPSS Lasers

All Voxtel DPSS lasers include a cathode (black wire) and an anode (red wire), as pictured below.

Voxtel DPSS Lasers with Optional T0 Detector

Some Voxtel DPSS lasers, such as pictured below, are configured with an optional T0 detector. The T0 detector may be used to detect the outgoing laser pulse.

The T0 detector consists of an InGaAs PIN diode integrated onto a printed circuit board, with passive filtering circuitry. The PIN diode is mounted directly over the laser cavity.

All lasers with the integrated T0 detector option have a coaxial cable and the laser lid has a mini-coaxial connector (T0 signal cable) and a white wire (26 – 28 AWG) connected as a 3rd pin to the laser connector (T0 bias). The white wire is used to bias (i.e., 5 VDC) the T0 detector located inside the laser. The output from the T0 detector is at the coaxial connector and is designed to be terminated to 50 Ω.

Assembly and operation of lasers with the T0 detector is otherwise identical to those without.

2. Ensure the pulse generator is set correctly to the voltage levels specified to trigger the laser and that the output (laser trigger) is off.

⚠ Note

- Laser wires may be soldered after mechanical mounting of laser and laser driver board.

  If desired, this step can be performed after performing the mechanical mounting of the laser and laser-driver board.
3. Solder the anode and the cathode to the laser-driver board. Solder the red and black wires to the board as shown below.

⚠ Note
• Instead of soldering the wires directly into the board, a user-provided terminal block may be used.
  A two-position terminal block that can be easily soldered into the anode and cathode holes on the board is recommended. A suitable part is TE Connectivity P/N 796911-2.

⚠ Note
• A laser and laser-driver board with custom connectors may be used.
  Contact Voxtel for this custom option.

⚠ Note
• For temporary use, the laser-driver board may be mounted using one mounting hole.

4. Mount the laser to a custom fixture and torque the screws to 1.0 in-lbs. (M2 x 3 mm or 2–56 x 1/8”).
  The recommended laser mounting is via two screws through the mounting flanges onto a flat surface using the recommended torque. Voxtel cannot guarantee laser performance will meet criteria if mounted otherwise.

5. Mount the laser driver board through the corner mounting hole(s) to a post to prevent shorting.

6. Connect the 2 x 5 IDC connector (J1) of the custom tri-furcated cable to the J4 connector of the laser driver board.

⚠ Caution
• Do not allow the pulse-repetition frequency to exceed the specification.
  The laser has been designed for a maximum pulse-repetition frequency, which is specified on the datasheet. Exceeding the specification can overdrive the laser and result in damage.

7. Connect the 5V supply to the 5V input receptacle (J2) of the custom tri-furcated cable.
  Connect the 5V to the laser diode driver before connecting the laser to the laser diode driver.

8. Connect the pulse generator output BNC cable to the BNC connector (J3) of the custom tri-furcated cable.
9. For models with an external integrated T0 detector (for all other models, skip this step):
   a. Connect the laser to the laser driver board using the 3-pin harness (already attached to the laser driver board).
   b. Connect one end of the coaxial cable with the coaxial connector to the T0 signal connector on the laser lid.
   c. If the laser is for use with the Voxtel System-Integrator Kit:
      i. Connect the other end of the coaxial cable to the J3 connector on the LRF system board.
      ii. Follow the additional “Assembly and Configuration” instructions provided in the “LRF System-Integrator Kit” section of this manual.
10. Configure the pulse generator to provide a laser trigger as follows:
    a. Set the duration of the laser trigger as follows:
       i. If the laser certificate of compliance is available: Set the duration of the laser trigger to exceed the laser delay time by 0.05 ms. The laser delay time can be found in the laser certificate of compliance.
       ii. If the laser certificate of compliance is unavailable: Set the duration of the laser trigger to 1.00 ms.
    b. Set the pulse repetition frequency of the laser trigger to 2 Hz.
11. Place the laser-pulse detection card about 4 inches from the exit window.
12. Enable the pulse generator output.
13. Verify the laser pulse can be observed on the laser-pulse detection card.

⚠ Caution
- Do not allow the laser trigger signal pulse width to exceed 3.5 ms.
  If the laser trigger signal pulse width is too long, permanent damage will occur to the laser.

14. If the laser pulse is not observed:
    a. Increase the duration of the laser trigger pulse time in increments of 0.01 ms until the laser is observed firing, then increase the laser-on time once more by 0.05 ms.
    b. If the laser-on time reaches 3.0 ms and the laser pulse is not observed, contact Voxtel.
15. Ensure the laser trigger (pulse generator output) is off before disconnecting laser from laser driver board.

USE OF NON-VOXTEL LASER DRIVER BOARDS

⚠ Note
- Voxtel is not responsible for the setup and operation of non-Voxtel-supplied equipment.

When using a user-supplied laser driver board to drive a Voxtel laser, ensure the driver board output meets the specification given in the “Electrical” section of the laser datasheet.
## DISASSEMBLY/STORAGE

⚠ **Caution**
- The laser trigger (pulse generator output) must be off before disconnecting the laser from the laser driver board.

1. Ensure the laser trigger (pulse generator output) is off.
2. Connect the anode and cathode contacts of the laser (this is an ESD precaution): For soldered connections, unsolder the wires and twist the wires together as shown. If unsoldering is not feasible, proceed to the next step.

3. Store the product in an ESD protective container (e.g., a nickel bag). The Voxtel shipping container may be used as an ESD protective container for storage.

## TROUBLESHOOTING

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Troubleshooting Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No light</strong></td>
<td>1. Verify the 5V DC supply using a digital multimeter (DMM).&lt;br&gt;2. Verify the laser anode and cathode are connected to the laser driver board.&lt;br&gt;3. Verify the polarity of the anode and cathode connections.&lt;br&gt;4. Verify the laser trigger signal with an oscilloscope.&lt;br&gt;5. Verify the laser trigger signal is at the TTL level.&lt;br&gt;6. Verify the laser trigger signal duration is between 1.00 ms and 3.0 ms.&lt;br&gt;7. Verify the laser trigger signal repetition rate does not exceed 2 Hz.&lt;br&gt;   Note: 2 Hz should be used for troubleshooting purposes.&lt;br&gt;8. Place the pulse detection card directly in front of the laser—about 4 inches from the exit window.&lt;br&gt;9. If the problem persists, contact Voxtel.</td>
</tr>
<tr>
<td><strong>Dim light, large area on laser-pulse detection card</strong></td>
<td>1. Verify that both mounting screws are torqued correctly to 1.0 in.-lb.&lt;br&gt;2. Verify the laser trigger pulse width by starting at a 1.00-ms duration and increasing to no more than 3.0 ms in 0.1-ms increments.&lt;br&gt;3. Loosen both mounting screws so there is zero torque on both and recheck for lasing as described above.&lt;br&gt;4. If no lasing is observed after trying the above steps:&lt;br&gt;   a. Carefully note the following:&lt;br&gt;       o Torque used to mount the laser screws&lt;br&gt;       o Laser trigger pulse-repetition rate&lt;br&gt;       o Temperature of operation&lt;br&gt;       o Reflective or other surfaces located in front of the laser&lt;br&gt;       o Potential ESD events&lt;br&gt;   b. Contact Voxtel with a message that includes the notes listed above.</td>
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</table>
LRF SYSTEM-INTEGRATOR KIT

This guide provides detailed instructions to assemble, power, update firmware, communicate, and range with the Voxtel LRF System-Integrator Kit.

References

- Safety and handling information is provided in the following sections of this user manual:
  - Safety
  - DPSS Lasers and Laser Driver Boards
- Assembly, configuration, and operation information for components of the LRF System-Integrator Kit is provided in the following sections of this user manual:
  - ROX APD Photoreceiver Products
  - DPSS Lasers and Laser Driver Boards
  - LRF Systems Operation
  - Appendix A—Unpacking, Inspection, and Cleaning
- Required electrical and mechanical information is provided in the following Voxtel datasheets:
  - LRF System-Integrator Kits Datasheet
  - Eyesafe DPSS Lasers Datasheet (including laser and laser driver board)
  - ROX APD Photoreceiver Datasheet
- For all products above, mechanical drawings, solid models, firmware, software, software ICD, and this user manual are available for download at voxtel-inc.com via the “Drawings, Solid Models, Software, Firmware, and Document” link on the Resources page.

PRECAUTIONS

Laser-equipped units described in this manual are Class 1. Before handling the equipment, read the safety and handling information in the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual.

⚠ Caution
- Do not fire the laser directly at the receiver or via a retro-reflector.
  Firing the laser directly into a close target or aiming the laser directly at the photoreceiver aperture may result in catastrophic damage to the receiver.

⚠ Note
- Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.
ASSEMBLY AND CONFIGURATION

1. Review and adhere to the safety and handling information provided at the start of this section, and in the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual.

⚠ Warning
- Failure to adhere to all safety and handling information provided at the start of this section and in the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual may result in personal injury and/or catastrophic damage to the system.

2. Unpack, inspect, and (if necessary) clean the product as described in “Appendix A—Unpacking, Inspection, and Cleaning.”

Shipping Box for the LRF System-Integrator Kit (ESD-protective Container)
Size a~ 8¾ x 6 x 1¼” (22.5 x 15.5 x 30mm

Components of the LRF System-Integrator Kit in Shipping Box
(Note: Actual parts received will depend on order.)

• Depending on the options purchased, the LRF System-Integrator Kit will include [qty. (1), unless otherwise stated]:
  o APD photoreceiver board
  o LRF system board
  o Laser driver board
  o DPSS laser (may include optional T0 detector and coaxial connector)
  o Flex cable used to connect the LRF system board to the ROX APD photoreceiver board.
  o PCB bracket
  o Assembly hardware kit
  o Interface support module (ISM) with USB cable and 5V power supply
  o (Optional) Auxiliary board with Bluetooth and attitude and heading reference system (AHRS)
3. Connect the APD photoreceiver board to the plug labeled “Receiver” on the flex cable.

⚠ Caution

- **Do not reverse the connection of the flex cable.**
  The flex cable is polarity sensitive. Reversing the connection of the cable may cause catastrophic damage.

- **Do not repeatedly bend or mate/de-mate the flex cable.**
  The 2-inch polyimide flexible ribbon cable between the receiver assembly and system board allows for separate mounting of the optical and electronic systems for ease of alignment and adjustment. The cable is not intended for repeated bending and mating/de-mating; bending and mating/de-mating may lead to cable failure.

- **Do not use excessive force when de-mating.**
  Excessive force may cause the connector to snap out suddenly and lead to cable failure or delamination of the connectors from the cable.

- **Do not twist the flex cable.**
  Twisting the cable can result in failure.

- **Do not bend beyond the minimum bend radius on the flex cable of 1.5 mm.**

4. Connect the plug labeled “System” on the flex cable to the LRF system board.
5. Connect the LRF system board to the laser driver board via the connectors and ensure the connectors for the laser driver board (2 x 5 connector) and the LRF system board (2 x 6 connector) are mated correctly, as below.

⚠ Note
• The boards can be used for initial temporary testing as shown.

6. If not already secured together, secure the boards together using qty. 4 x 5/16” long x 4-40 Standoffs and 8 x 4-40 screws.

7. Connect the laser to the laser driver board as provided in steps 6 – 8 of the “Assembly, Configuration, and Operation” subsection of the “DPSS Lasers and Laser Driver Boards” section of this manual.

⚠ Caution
• Do not reverse the connections.
  The wires are polarity-sensitive. Reversing the connections may cause catastrophic damage.

8. (If the Voxtel laser has an integrated T0 detector lid installed, perform this step).
  a. If using an external T0 pulse—either provided by a Voxtel laser with a T0 detector or by a non-Voxtel-supplied external T0 pulse—connect the T0 signal to the J3 connector on the LRF system board with a mini-coaxial cable.

⚠ Note
• This cable is provided if the Voxtel laser has a T0 lid.
b. Configure the LRF for operation with an external T0 signal using the proper software command syntax (refer to the Software ICD).

⚠ Note
- At a 1% duty cycle, the maximum T0 pulse amplitude into the LRF system board input is 3.3V logic level.

9. (If the unit is provided with a Voxtel laser, skip this step.)

The LRF system board is designed to operate with a user-provided laser. If the unit is not provided with a Voxtel laser, enable operation with a user-provided laser as follows:

a. Ensure the user-provided laser meets all requirements specified in the product datasheets.
   If unsure, contact Voxtel to help determine if a user-supplied laser would be compatible with a Voxtel LRF kit.

b. The laser must be triggered via the laser-gate signal output of the system board. This is found in 1 of 2 places:
   i. Pin 2 of the LRF system board P1 connector; or
   ii. Pin 7 of the LRF system board J4 connector.

c. (Optional) If connecting a T0 signal to the Voxtel system board:

   ⚠ Caution
   - At a 1% duty cycle, the maximum T0 pulse amplitude into the LRF system board input is 3.0V.
   - A DC logic level above 1.8V can damage the LRF system board.
   - Input signals above these levels may damage the LRF system board.

   ⚠ Note
   - The J3 input is terminated to 50 Ω and triggers on the rising edge of a logic level signal (nominally, a 1.8 V transition logic is required).

   i. Use a coaxial cable to connect the T0 output pulse to the J3 input on the LRF system board.
   ii. Ensure that the T0 pulse does not exceed 3 VDC.

10. Provide power and communications connection to the LRF system board set by connecting the necessary pins as detailed in the datasheet.

11. (Optional) To aid in alignment purposes, the analog output from the photodetector may be monitored. To enable this option:

a. Connect an oscilloscope or other instrument to the coaxial connector located on the APD photoreceiver board.

b. Verify that the analog output is terminated at the coaxial connector to 50Ω.

c. Configure the LRF for operation with an external T0 signal using the proper software command syntax (refer to the Software ICD).

12. All internal connections are now in place. For external communications, power, and operation, refer to “LRF Systems Operation.”

13. Command the LRF using serial software commands.

   The LRF is operated by inputting commands from a host processor or the terminal emulator of a graphical user interface.
   - For basic command sets, refer to “LRF Systems Operation.”
   - For detailed command sets, refer to the software ICD.

14. Discontinue LRF operation when complete.

   To discontinue LRF operation:
   a. Set the APD photoreceiver to mode 1 (M = 1).
   b. Select the Disconnect button from the main page tool tray.
   c. Disconnect the power jack from the LRF.
LRF OEM MODULE

This section provides detailed instructions to assemble, power up, and connect the Voxtel LRF Original Equipment Manufacturer (OEM) Module. For operational and communication details and examples, refer to the “LRF Systems Operation” section of this manual.

References

- Safety and handling information is provided in the following sections of this user manual:
  - Safety
  - DPSS Lasers and Laser Driver Boards

- Assembly, configuration, and operation information for components of the LRF OEM module is provided in the following sections of this user manual:
  - ROX APD Photoreceiver Products
  - DPSS Lasers and Laser Driver Boards
  - LRF Systems Operation
  - Appendix A—Unpacking, Inspection, and Cleaning

- Required electrical and mechanical information is provided in the following Voxtel datasheets:
  - LRF OEM Module Datasheet
  - Eyesafe DPSS Lasers Datasheet (including laser and laser driver board)
  - ROX APD Photoreceiver Datasheet

- For all products above, mechanical drawings, solid models, firmware, software, software ICD, and this user manual are available for download at voxtel-inc.com via the “Drawings, Solid Models, Software, Firmware, and Document” link on the Resources page.

PRECAUTIONS

- For laser safety information, refer to the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual.
- For handling and ESD guidance, refer to the “Safety” section of this manual.

⚠ Note

- Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.
1. Review and adhere to the safety and handling information provided in the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual.

⚠ Warning
• Failure to adhere to all safety and handling information provided at the start of this section and in the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual may result in personal injury and/or catastrophic damage to the system.

2. Unpack, inspect, and (if necessary) clean the product as described in “Appendix A—Unpacking, Inspection, and Cleaning.” The LRF OEM Module consists of:

- Transmitter and receiver optical assembly mounted onto the faceplate, comprising:
  - ROX APD photoreceiver
  - Collimated DPSS laser
  - Laser markers (optional)
- Electronics Board Stack comprising:
  - LRF system board (top)
  - Laser driver board (bottom)
- Interface support module (ISM) comprising:
  - Interface board with a USB-to-serial conversion chip, 8-pin mating connector (P2) for the LRF, and USB (P3) and power jack (P4)
  - Micro-USB communication cable for USB communication
  - 5.0 V/2.0 A power supply with (5.5/2.1 mm O.D./I.D.) barrel connector
  - Extension cable (optional) provided for LRFs with mechanical enclosure
- Auxiliary board (optional) with Bluetooth and attitude and heading reference system (AHRS)
  The auxiliary board augments the LRF capabilities with the ability to measure rotational orientation. The auxiliary board mounts above the LRF system board. Further details are provided in “Appendix C—Auxiliary Board.”
- Connectors
  - Flex cable: A 2-inch polyimide flexible ribbon cable connects the receiver side of the faceplate to the LRF system board. This cable is delicate and care must be taken when handling the components of the OEM module to prevent the cable from breaking.
  - Anode and cathode cables: The anode and cathode cables of the laser transmitter are directly soldered to the laser driver board.
  - (Optional) T0 pulse detector connections: Some units include a T0 pulse detector that generates an electronic pulse when the laser is fired. Units that include the T0 pulse detector include a wire directly soldered to the laser driver board that provides the 5.0 V bias supply to the T0 detector. These units also include a coaxial cable that connects the T0 detector output signal (and ground) to the J3 connector on the LRF system board.
3. Carefully remove the shipping plate, handling the cabling and connectors with care:

⚠ Caution
- Do not use the shipping plate during normal operation.
  During transit, the shipping plate protects the unit and prevents stress on the cabled connections.
  During operation, the shipping plate is removed, such that there is no support between the electronic board stack and the metal faceplate.

⚠ Caution
- After removing the shipping plate, there is no support between the electronic board stack and the metal faceplate. To prevent damage to the cabling and connectors, both must be handled carefully.

4. Mount the LRF OEM Module as follows:
   a. Secure the LRF faceplate and electronics board stack to an optical bench or electro-optic assembly for operation.
      For mounting specifications, refer to the mechanical drawings.
   b. Ensure the transmit and receiver apertures are clean and clear of any obstructions.
      Coatings on the optics are present so only lint-free lens cloth or paper should be used to clean them.
   c. Handle/route the cable as described below:

⚠ Caution
- Do not repeatedly bend or mate/de-mate the flex cable.
  The 2-inch polyimide flexible ribbon cable between the receiver assembly and system board allows for separate mounting of the optical and electronic systems for ease of alignment and adjustment. The cable is not intended for repeated bending and mating/de-mating and may lead to cable failure.
- Do not use excessive force when de-mating.
  Excessive force may cause the connector to snap out suddenly and lead to cable failure or delamination of the connectors from the cable.
- Do not twist the flex cable.
  Twisting the cable can result in failure.
- Do not bend beyond the minimum bend radius on the flex cable of 1.5 mm.

- If it is necessary to disconnect the flex cable:
  o Note the orientation of the cabling.
    The cable is labeled with a designated receiver end and a designated system end; however, the connection is not keyed.

      ![Flex Cable Orientation Image]

              APD Photoreceiver End       LRF System Board End

      o Ensure the hard backer behind the connector is supported while applying a constant and gentle removal force between the board and connector.
• If it is necessary to bend the flex cable:
  o Ensure the flex is perpendicular to the cable.
  o Ensure the cable does not twist.
  o Preform the bend on the flex.

  To form a bend on the flex cable, wrap the cable around a cylinder with a diameter of 3 mm or greater. The cable has shape memory and will retain the shape of the bend as shown:
  ▪ Fold flex tightly around a surface with diameter at least 3 mm (e.g., a screwdriver).
  ▪ Allow the flex to form into a U-shape.
  ▪ Open the flex to the required angle.
5. Perform the interface support module (ISM) connections shown:

6. All internal connections are now in place. For external communications, power, and operation, refer to “LRF Systems Operation.”

7. Command the LRF using serial software commands.
   The LRF is operated by inputting commands from a host processor or the terminal emulator of a graphical user interface.
   • For basic command sets, refer to “LRF Systems Operation.”
   • For detailed command sets, refer to the software ICD.

8. Discontinue LRF operation when complete.
   To discontinue LRF operation:
   a. Set the APD photoreceiver to mode 1 (M = 1).
   b. Select the Disconnect button from the main page tool tray.
   c. Disconnect the power jack from the LRF.
This section describes the operation of:

- Voxtel LRF System-Integrator Kits
- Voxtel LRF OEM Modules

**References**

- Datasheets: LRF OEM Module Datasheet, LRF System-Integrator Kit Datasheet, Eyesafe DPSS Lasers Datasheet (including Laser and Laser Driver Board), and APD Photoreceiver Datasheet. These datasheets are available via the relevant product link on the Products page at Voxtel-Inc.com. A single pdf containing the datasheets for all Voxtel LRF products is also available.
- Mechanical drawings, solid models, firmware, software, software ICD, and this user manual are available at voxtel-inc.com via the “Drawings, Solid Models, Software, Firmware, and Document” link on the Resources page.

**PRECAUTIONS**

- For laser safety information, refer to the “Safety” and “DPSS Lasers and Laser Driver Boards” sections of this manual.
- For handling and ESD guidance, refer to the “Safety” section of this manual.

⚠ **Note**

- Voxtel is not responsible for the setup and operation of non-Voxtel supplied equipment.

**CONNECTIVITY**

Power and communication are provided through the LRF system board’s 8-pin, 2-mm-pitch, P1 receptacle (Hirose PN DF3-8P-2Ds).

1. Ensure the product is secured in its intended system as per the assembly and configuration instructions provided in the relevant product section of this user manual.
2. Connect the product to a PC/controller using a direct cabled connection to LRF or the interface support module (ISM) as described below. For pinout and specifications, refer to the product datasheet(s).
DIRECT CABLED CONNECTION TO LRF SYSTEM BOARD

This method is useful for minimizing the connection footprint

Requirements
User-supplied cabling

Guidance

Pin 1 (P1) is on the LRF system board, as shown in the preceding figure. With the recommended +5.0 V input (pin 8 is power input and pin 5 is ground), the system should not draw more than 0.5 A (during active ranging); however, a 2.0 A supply minimum is recommended to handle any in-rush currents during power up and range initialization.

⚠ Caution
• Using a 5V level logic may damage the LRF system board.

System communication is through +3.3 V level logic serial UART (pin 6 UART transmit out and pin 7 UART receive in).

ISM CONNECTION TO LRF SYSTEM BOARD

1. Connect the P2 connector on the ISM board to the P1 receptacle on the LRF system board.
2. Using the micro-USB communications cable, connect P3 on the ISM board to the controller/PC.
3. The power supply connects between P1 on the connector board and the main power.

COMMUNICATION

⚠ Caution
• To avoid damage to the APD, return the ROX APD photoreceiver to Mode 1 (low gain) at the start of operation, when commencing tests, or when repositioning the LRF OEM Module.

1. Ensure all required connections are complete.
2. Open a communications port.
   To open a communications port, identify and/or set the serial COM port used for communication. This can be done via the device manager in a windows PC. Using an FTDI USB-to-serial IC or cable, it should be identified as a USB Serial Port as shown.

Example COM port setting in the PC device manager.
3. Configure the communication software for the specified COM port.

⚠ **Note**
- Any communication terminal that supports the UART serial protocol may be used. This document uses the open-source terminal software PuTTY (www.putty.org) as an example.

If using PuTTY, communication settings are accessible via the **Serial** tab.

PuTTY serial comm port settings.

4. (Optional) For ease of use, it is recommended to turn on **Local Echo** and **Local Line Editing** if your terminal supports them. If using PuTTY, this is accessible via the **Terminal** tab.

PuTTY settings for configuring a local echo.
5. Open a connection to the LRF. In PuTTY, clicking the **Open** button opens the connection.
6. To confirm communication is working properly, perform a query and verify that the expected response is returned. The example below uses two queries—the serial number query (\: SN) and the firmware version query (\: VE).

![Example initial communication test.](image)

**RECEIVER GAIN CONFIGURATION**

LRF configuration depends on the desired range distances and current environment. Specifically, the receiver’s gain mode and comparator threshold must be set for optimal performance. Select the APD gain mode using the list of standard gain modes below. Command examples follow.

<table>
<thead>
<tr>
<th>Mode</th>
<th>Command Syntax</th>
<th>Typical Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mode 1</td>
<td>:GN 0</td>
<td>To provide maximum damage threshold (low gain)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Indoor/Shorter range</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Safe mode for bore-sighting/alignment, or when there is potential for retro-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>reflections of laser.</td>
</tr>
<tr>
<td>Mode 2</td>
<td>:GN 1</td>
<td>To provide optimum sensitivity (high gain) optimized for a 60 Hz FAR</td>
</tr>
<tr>
<td>(factory</td>
<td></td>
<td>• Long-range single-pulse operation</td>
</tr>
<tr>
<td>default)</td>
<td></td>
<td>• Ideal signal-to-noise ratio (SNR) for &lt;1% FAR over a 5 km range</td>
</tr>
<tr>
<td>Mode 3</td>
<td>:GN 2</td>
<td>To provide optimum sensitivity (high gain) for 15 kHz FAR</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Long range multi-pulse operation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Ideal SNR for higher FAR</td>
</tr>
<tr>
<td>Query</td>
<td>:GN</td>
<td>To query the current gain mode of the receiver</td>
</tr>
</tbody>
</table>

![Example gain mode query, maximum damage threshold (low gain) and 60Hz FAR optimum sensitivity (high gain) mode commands.](image)
POSITION LRF SYSTEM

Ensure the LRF is aimed at the desired field of view and the photoreceiver optics are unobstructed.

⚠ Caution
  • To avoid damage to the APD, return the ROX APD photoreceiver to Mode 1 (low gain) at the start of operation, when commencing tests, or when repositioning the LRF OEM Module.

⚠ Caution
  • Do not allow the laser to be fired or reflected directly into the receiver. Firing or reflecting the laser directly into the receiver may result in catastrophic damage to the receiver.

⚠ Note
  • Using the external T0 input may require optical baffling and isolation between the laser and receiver elements of the LRF. Using the external T0 input does not preclude the possibility of the LRF receiver directly detecting the outgoing laser light. The LRF uses the timestamp of the first received signal, either from the receiver or the external T0 input. Inadvertently using the wrong signal will affect the accuracy of the system.

RECEIVER THRESHOLD CONFIGURATION

With the gain set and system positioned, the next step is to configure the receiver detection threshold voltage. For a background on this process, refer to “Appendix B—LRF Detection Threshold.” Set the pulse-detection threshold using one of the two methods described in this section.

False Alarm Rate (FAR) Calibration (command syntax “ :CL”)

The false-alarm-rate calibration command automatically sets the receiver low-voltage threshold \( V_{th,\, low} \) to achieve the desired false alarm rate. By default, \( V_{th,\, low} \) is set to a target 300 Hz FAR. If a different FAR is desired, the “ :CL” command can be followed by the desired rate. The LRF system will respond with an acknowledgement of both the current and previous \( V_{th,\, low} \) settings. The threshold voltage is displayed in digital number (DN) format and can be converted to a voltage level via the software ICD specifications. Command examples follow.

Example of a FAR calibration command—first at the default FAR, then at a specified 50 Hz FAR calibration.

If the system is unable to adjust to the target FAR, \( V_{th,\, low} \) will be unchanged and the system will return the response “not set,” as shown below. This may indicate a problem with the receiver, the receiver connector, or the flex cable. To troubleshoot, adjust the voltage threshold manually [(see Manual Setting of the Low Threshold Voltage (command syntax “ :TL”)]. When the voltage threshold is lowered, the measured false-alarm rate should increase;
when the voltage threshold is raised, the measured false-alarm rate should increase. If this is not the case, contact Voxtel for further information.

Example of an unsuccessful FAR calibration command with an unchanged threshold voltage.

Manual Setting of the Low Threshold Voltage (command syntax “: TL”)

Manual adjustment of $V_{th,\text{low}}$ sets the voltage level via the user determined DN level following the command. Sending the threshold level command (: TL) without threshold setting (in DN) returns the current threshold setting.

Check the FAR once $V_{th,\text{low}}$ is set via the “: FL” command as per the example below.

Example of a $V_{th,\text{low}}$ threshold query and check of the current FAR followed by a resetting of the threshold and FAR check.

⚠ **Note**
- Ideal settings may vary from system to system; however, setting $V_{th,\text{low}}$ outside the range of 950 – 1500 DN (0.48 – 0.73 V) will prevent the receiver from properly acknowledging any returns.

### RANGING COMMANDS

⚠ **Caution**
- To avoid damage to the APD, return the ROX APD photoreceiver to Mode 1 (low gain) at the start of operation, when commencing tests, or when repositioning the LRF OEM Module.

This section provides an operational description of each range command. For more-detailed specification of ranging commands, refer to the software ICD.

Before using the commands in this section to execute a range, ensure that the following two steps have been completed as instructed in this manual:
- The photoreceivers gain mode is set.
- The photoreceivers detection threshold is set.
**Single Pulse Range [command syntax ":RR"]**

In this range mode, a single laser pulse is emitted and non-zero returns are reported.

![Example of a single-pulse range response with a 337-meter return.](image)

**Single-Pulse Range with Automatic Calibration [command syntax ":AS"]**

Prior to executing a range request, a threshold calibration is executed and $V_{th\_low}$ is set to a target 300 Hz FAR.

![Example of a single pulse with automatic calibration range response with a 337-meter return.](image)

**Multi-Pulse Range [command syntax ":ER"]**

In this command, multiple ranges are executed sequentially and any coincident returns between these ranges are returned. When first setting $V_{th\_low}$ to a >10 kHz FAR, (i.e., via a calibration command) this can provide an extended range beyond the system’s single-pulse range limit. To change configuration parameters for multi-pulse operation, refer to the software ICD.

![Example a multi-pulse range response for a 337-meter return.](image)

**Multi-Pulse Range with Automatic Calibration [command syntax ":AM"]**

Prior to executing a multi-pulse range, the low threshold voltage is set to a target 40 kHz FAR and sets the photoreceiver gain to mode 3 (equivalent to ":CL 40000" and ":GN 3" commands).

![Example of a multi-pulse range with automated calibration with a 371-meter return.](image)
Continuous Single-Pulse Range [command syntax “:CR”]

Repeatedly performs a single-pulse range measurement at a specified range period in digital range units (1 DN = 34.13 µs.) Sending a “:CR” command without a range period terminates the continuous ranging. For the default configuration, ranging will not be effective below a 7400 DN range period. For continuous ranging above 4 Hz, refer to the software ICD for up to 10 Hz operation.

⚠ Note
When a range request is initiated, the microcontroller powers up the time-to-digital converter and initiates the laser pump. For each range request, the timing calculation is initiated by detection of the outgoing T0 laser pulse and the laser pump is turned off. If a T0 laser pulse is not observed within the configured laser delay time (per the datasheet), a “No T0” error message is reported and the range request is aborted.

OPERATIONAL EXAMPLES

This section provides a few operational examples for both single-pulse and multi-pulse ranging.

⚠ Caution

• Do not fire laser directly at a reflective surface (e.g., mirror) or aim laser directly at the photoreceiver aperture. Firing the laser directly into a close target or aiming the laser directly at the photoreceiver aperture may result in catastrophic damage to the receiver.

• When operating the LRF OEM Module at ranges less than 100 meters (recommended range for system-integrator kits will vary on optics), keep the receiver set to Mode 1 (low gain).

In case of a direct illumination or reflection, when initially configuring/integrating the LRF, maintaining the receiver in low gain mode will prevent potential damage.

SINGLE-PULSE RANGE OPERATION

1. Set the photoreceiver gain mode (command :GN [0|1]).
   • Use low gain mode 1 (“:GN 0” command) for initial testing and short range or indoor use.
   • Use high gain mode 2 (“:GN 1” command) for maximum range performance.

2. Position the LRF to the desired field of view or target.

3. Calibrate the LRF detection threshold (command :CL) using one of the following options:
   • The detection threshold is set automatically to target 300 Hz FAR level in this example. This FAR setting can be user specified by providing a number after the calibration command; i.e., commanding “:CL 50” will set the threshold to a 50 Hz FAR; alternatively
   • The detection threshold can be manually set via the “:TL” command, which is described in the software ICD.
4. Execute range requests (command :RR).
   • A single range is shown in the example.
   • Alternatively, the detection threshold can be calibrated to a 300 Hz FAR prior to every range request when using the “:AS” command.

5. (Optional) Save the configuration settings (command :SV).
   • If ranging is expected to be repeated under conditions similar to current conditions, save the configuration to ensure the LRF will power up in this state after any power down.

Example single-pulse operation as per steps above: 1) Initial gain setting; 2) not displayed in the terminal; 3) threshold calibration; 4) ranging; and 5) saving the configuration settings.

⚠ Note

About Detection Threshold Calibration
As environmental conditions change (i.e., temperature or light level) significantly, recalibrating the detection threshold may be required. It is recommended while ranging to recalibrate the threshold on a regular basis to account for gradual changes in ranging conditions. In the example code below, an increase in the background noise floor has increased the false-count frequency. Recalibration resets $V_{\text{th,low}}$, minimizing the false counts.

Example single pulse ranging case where changing conditions has increased the FAR. Threshold recalibration resets the false count rate to the requested level.
MULTI-PULSE RANGE OPERATION

To set the receiver for multi-pulse range operation, the process is similar to single-pulse operation. This mode is designed to be used to resolve weak and/or obscured targets.

⚠ Caution
- To avoid damage to the APD, do not operate in multi-pulse mode for targets closer than 100 m.

1. Set the photoreceiver gain mode (command \texttt{:GN 3}).
   - Use gain mode \texttt{3} ("\texttt{:GN 3}" command) to allow for high gain optimized for a higher FAR.
2. Position the LRF to the desired field of view or target.
3. Calibrate the LRF detection threshold (command \texttt{:CL 40000}).
   - For optimal-pulse operation, set the detection threshold to a high FAR (i.e., > 10 kHz); in the example below, a target FAR of 40 kHz is used.
4. Execute range requests (command \texttt{:ER}).
   - Multiple ranges will be taken in succession and only recurring returns will be reported.

Example multi-pulse ranging code: Once configuration is complete and two multi-pulse ranges are executed, an additional set of single-pulse returns are taken to show the typical false-count rate observed in this configuration setting.

⚠ Note
The preceding example code shows the process and typical responses. For contrast, following the multi-pulse ranges, single-pulse range returns are shown at the given configuration settings. The returns are dominated by randomly timed false counts with an actual return observed at 337 meters.

AUXILIARY BOARD

If using an auxiliary board, refer to “Appendix C—Auxiliary Board” for operation instructions.
**UPDATING MODULE SOFTWARE AND FIRMWARE**

The LRF system board has the ability to update its system firmware via its serial UART. This can be done via a Windows 10 PC and Voxtel’s *LRF Commander* evaluation software.

**INSTALLING THE LRF COMMANDER SOFTWARE**

Download the *LRF Commander* software from the *Additional Product Resources* section on Voxtel’s [rangefinder product page](#). Once downloaded, extract and run the *LRF Commander* setup program.

Double-click the `LRFCmdrSetup_<version>.exe` setup program.

When prompted by the UAC dialog box, click *Yes*.

Click *Next*.

If Microsoft.NET 4.5 has not yet been installed, follow the installation prompts: review and accept the license terms; select the *Create a desktop icon* check box; and click *Next*.

A notification will indicate when the installation is complete.

Click *Finish*. 
When prompted to restart the computer, click **Restart Later**.

Click **Install**.

If Java Runtime has not already been installed, click **Install**.

Upon review, **Accept** the Java Runtime license agreement.

Click **Finish** to close the Java installation complete dialog.

Click **Next** to install Atmel Flip software.

Check the accept box and click **Next**.

Click **Next**.

Click **Install**.

Click **Next**.

Unselect **Create desktop shortcut** and **Show Readme**, then click **Finish**.

A new window will appear that will allow you to update the LRF device drivers. Click **Next**.
To install the ATMEL device software, click **Install**.

At this point, the first of the two drivers will have been loaded.

Use the LRF Commander application to continue loading the other driver, then click **Finish**.

Run LRF Commander. Double-click the LRF Commander desktop icon.
LOADING THE DEVICE FIRMWARE

Download the latest LRF Module Firmware from the User Resources available at Voxtel-Inc.com. [https://voxtel-inc.com/voxtel-news/user-resources/](https://voxtel-inc.com/voxtel-news/user-resources/). If the LRF has the auxiliary board option installed, use the LRF Module with AHRS Firmware option. Confirm the firmware version of the hex file, “Voxtel_LRF_Firmware_2.3.[X].hex,” is greater than the firmware currently installed, which can be queried via the “:VE” command.

Open LRF Commander software.

From the File menu, select Update Device.

Select the new version of firmware to load into the LRF device when the open dialog appears.

Select Yes to confirm the HEX file is the intended file for updating the LRF device.

The process should take about 2 minutes. After the LRF firmware has been successfully updated, a successfully updated LRF firmware dialog will appear.

Close the LRF Commander application.

A cycle-power reminder appears.

Cycle the power on the LRF device. Click OK.

The LRF device firmware is now updated and ready to use. The version of the firmware is shown in the upper-right corner of the application.
If the LRF device fails to upload the new firmware, the following error dialog will appear.

![Error Dialog]

For more details about the update process, select the **Communication Tab**.

![Communication Tab]

After correcting the problem, cycle power on the LRF and restart the LRF Commander and try again.

⚠ **Note**
- For a driver installation using a PC that has an operating system with a language that uses a non-Latin alphabet, issues may arise.

After completing the above steps and addressing any issues in the error dialog box above, if the firmware update remains unsuccessful, contact Voxtel.
APPENDIX A—UNPACKING, INSPECTION, AND CLEANING

UNPACKING

Unpack the product as follows:

1. Read all information provided in the “Safety” section of this manual; adhere to all information provided therein.

   ⚠ **Caution**

   • Failure to follow the information provided in the “Safety” section of this manual may result in personal injury or catastrophic product failure.

2. Place the package on the work surface.
3. Verify that the serial number on the product matches the serial number on the box label.
4. Verify that all product items are present. Product items are listed on the packing slip and are pictured and/or described in the relevant section(s) of this manual.
5. If desired, save the shipping box. Shipping boxes can be used as ESD-protective storage boxes.

   ⚠ **Note**

   • Proper product labeling of the fully assembled product is required in order to meet FDA certification guidelines.

6. For units equipped with a laser, verify the laser safety label pack contains the following four labels as described in the “Safety Symbols” section of this manual:
   a. Explanatory Label
   b. Non-Interlocked Protective Housing Label
   c. Certification Label
   d. Manufacturer’s Identification Label

Labels are provided for application by the assembler or end user of the product. Proper labeling provides the user with appropriate warnings and product information when applied in the following manner:

• Labels provided must be permanently fixed, legible and visible according to their purpose.
• Labels provided must be read without the necessity for human exposure to laser energy in excess of the limits associated with Class 1.

Further explanation can be found in IEC 60825-1 Ed.2, sec 5.1.
INSPECTION AND CLEANING

INSPECTION

⚠ Caution

- Whenever possible, use clean dry air or nitrogen to clean the receiver window.
- If necessary, use only lint-free optical wipes to clean the receiver window.

1. If the kit is equipped with a standalone laser, it will be mounted to another surface. Verify the mating surface has no raised imperfections that could prevent flush contact with the mounting surface.

2. Inspect any windows on the product(s) under 10x magnification:
   a. For lasers, inspect the laser exit window.
   b. For photoreceivers, inspect the detector window.

3. If excessive particulates or grease/smearing are observed, clean the window per the techniques below.

⚠ Note

- The exit window can tolerate some level of contamination without affecting performance.

4. Between steps, reinspect the window to determine if further steps or repeat steps are needed.

WINDOW CLEANING TECHNIQUES

⚠ Caution

- If using higher pressures/flow rates, ensure the product is secured.
- If using a canned source, do not allow any liquid spray to expel and deposit on the window.

⚠ Note

- When repeating steps, always use a new, clean, dry mini cotton bud or lens tissue.

⚠ Note

- The window can tolerate some level of contamination before performance is affected.

If the window requires cleaning, use the techniques below in the order provided, as required. These cleaning techniques require the following user-provided equipment:

- Air gun with pressurized CDA or clean nitrogen
- Clean, dry, lint-free mini cotton bud (when repeating steps, do not reuse)
- High-grade IPA
- Lens tissue (when repeating steps, do not reuse)
1. Removing Particulates
   a. Use the air gun so it blows both directly at the window and at a narrow angle across the window.
   b. Re-inspect the window.

2. Removing Grease, Oil, and Smearing
   a. Use the dry-wipe technique as follows:
      ii. Use the air gun at a narrow angle so it blows across the window.
      iii. Lightly touch a cotton bud in the center of the window and slowly spiral it outward, toward the outside edge of the window.
      iv. Use the air gun at a narrow angle so it blows across the window.
   b. If the problem persists, use the solvent-wipe technique as follows:
      i. Lightly dampen a cotton bud with high-grade IPA.
      ii. Lightly touch the dampened cotton bud in the center of the window and slowly spiral outward, toward the outside edge of the window.
      iii. After the IPA has evaporated, use the air gun at a narrow angle so it blows across the window.
   c. If the problem continues to persist and/or smearing is observed, use the smear-removal technique as follows:
      i. Wrap a piece of lens tissue around the end of a cotton bud.
      ii. Lightly touch the tissue in the center of the window and slowly spiral outward, toward the outside edge of the window.
This section provides an overview of the pulse/return detection process for Voxtel LRF systems. For more detailed specifications of the photoreceiver’s threshold, refer to the “ROX APD Photoreceiver Products” section of this manual.

The analog front end of the receiver is sent into a digital comparator along with a user-configurable detection threshold setting. The resulting digital output is used by the LRF system board to report range events.

The receiver typically has a DC offset of 0.5 V and a maximum output level of 1.0 V; the detection thresholds should not be set above or below these levels respectively. By default, a time-variable threshold starts the range cycle at a high threshold level, \( V_{th\text{, high}} \), for stronger near range signals, and it transitions down to a low threshold level, \( V_{th\text{, low}} \), for maximum sensitivity at longer ranges. The decay between \( V_{th\text{, high}} \) and \( V_{th\text{, low}} \) occurs via an RC time constant of 2.6 µs.

The factory set value of the high threshold value should not need to be changed by the user, but as ranging conditions change, the low threshold value should be changed manually via the “:TL” command or set to a specified false-alarm-rate (FAR) via the calibration, “:CL”, command. By default, the calibration command will set the low threshold to a target 300 Hz FAR, which is equivalent to a change of less than 1% for the reporting of a false return over a 5-km range.

Examples of the threshold setting levels superimposed with a receiver’s analog signal and the reported digital output are shown at right (not too scale):

- The first figure shows an optimal threshold setting for ranging while minimizing any false returns.
- The second figure shows a threshold setting that is too high, so weaker returns are missed.
- The third figure shows a threshold setting that is too low, and false returns are reported.

**Optimal threshold setting where the low threshold setting is at a high sensitivity without false counts.**

**Threshold setting where the low threshold is set too high and weaker returns are missed.**

**Threshold setting where the low threshold is set too low and multiple false counts occur.**
APPENDIX C—AUXILIARY BOARD

This appendix provides detailed instructions to setup, configure, calibrate, and operate the optional Voxel Auxiliary Board, which includes Bluetooth communications and attitude and heading reference system (AHRS) capabilities.

The auxiliary board augments the LRF capabilities with the ability to measure rotational orientation. The auxiliary board contains a sensor-fusion coprocessor that runs a sensor-fusion algorithm using the output of a 9-axis IMU to generate an estimation of the system’s attitude and heading.

The magnetometer is designed to sense the magnetic field of the earth. The main impediments to successful operation of the magnetometer are:

1) Presence of ferrous metals (iron or iron alloys)—Ferrous metals distort the Earth’s magnetic field lines and can become permanently magnetized, causing a large-magnitude distortion.
2) Active power electronics—Electromagnetic interference from active power electronics can cause changing disturbances due to magnetic flux from inductors.

For systems that have been configured with an auxiliary board, inertial measurement unit (IMU) data are available through the user UART interface. The IMU uses solid-state accelerometer, gyro, and magnetic sensors combined with a sensor-fusion processor to filter and combine sensor data to form the inertial frame reference in a quaternion representation of the IMU orientation.

Terminology

- **Attitude and heading reference system (AHRS):** Attitude refers to a rotation about one or more axes relative to a fixed reference; heading refers to a geomagnetic compass heading.
- **Inertial measurement unit (IMU):** A collection of sensors capable of measuring the linear or rotational acceleration along or about one or more axes of motion, commonly inclusive of magnetometers, although magnetometers do not measure acceleration.
- **Local magnetic declination:** The local difference between magnetic and true north, which changes depending on geographic location and drifts over time according to geologic processes.
- **Sensor fusion:** Refers to integrating the output of multiple discrete sensors according to an algorithm or mathematical relationship. In this case, the sensor-fusion coprocessor runs a proprietary Kalman Filter that generates attitude and heading estimates from the combined output of individual three-axis accelerometers, gyroscopes, and magnetometers.

Further Reading

To better understand how micro-electro-mechanical system (MEMS) inertial and magnetic sensors work, some resources include:

- Magnetometer Calibration Methods and Why they are Necessary: https://www.sensorsmag.com/components/compensating-for-tilt-hard-iron-and-soft-iron-effects
- MEMS Rate Gyroscopes: https://en.wikipedia.org/wiki/Vibrating_structure_gyroscope
- MEMS Accelerometers: http://www.sensorwiki.org/doku.php/sensors/accelerometer

Additional References

- **Software ICD: Laser Rangefinder Modules, Kits, and Components:** This document contains extended command set used by the auxiliary board and is available at http://voxtel-inc.com/files/LRF-Software-ICD.pdf.
**Note**

- The auxiliary board is configured using the same interface and command structure as the base LRF. The auxiliary board parameters can be configured at any time prior to use. For more information on commands and command syntax for the auxiliary board, refer to the software ICD.

- Do not operate an auxiliary board-equipped LRF device in the presence of ferrous metals and active power electronics. This includes (but is not limited to), permanent magnets, large steel mounting brackets and hardware, steel file drawers, computer power supplies, high-power switch-mode power supplies on printed circuit boards. The magnetometer is the sensor in the IMU that is most sensitive to unwanted outside influence. Failure to meet these operating conditions will result in inaccurate or erroneous estimates for compass heading.

- Do not use large steel screws or steel mounting hardware; do not encase an auxiliary board-equipped device within a steel enclosure. The magnetometer is able to compensate for local distortions in the magnetic field, so small steel screws or mounting hardware may be acceptable. However, if an auxiliary board-equipped device is encased within a steel enclosure, the magnetometer will not operate correctly. Also, the presence of too much ferrous metal near the auxiliary board will cause degraded performance when estimating compass heading.
MOUNTING AND ENCLOSURE
Mount as per the markings shown in the product mechanical drawing. For auxiliary board-equipped devices, follow these additional guidelines:

- For best results, use plastic or aluminum mounting hardware, which does not affect the magnetometer.
- For best results use a durable hard plastic enclosure. If a plastic enclosure is not practicable, use a thin aluminum encasing.

SENSOR INITIALIZATION AND DE-INITIALIZATION
The sensor package receives regulated power from the main LRF unit. The sensor fusion coprocessor on the auxiliary board continuously updates the calibration as long as it is powered and initialized, then stops calibrating upon deinitialization.

Initialization
To initialize the sensor:
1. Power on the device.
2. Enable the LRF (LRF_ENABLE pin).
3. Send an initialization command. To send an initialization command, input “:F8”.

De-Initialization
To de-initialize the sensor:
1. If the LRF is still streaming sensor fusion output, issue an “:ST” command to stop streaming.
2. Once AHRS output from the LRF ceases, input “:F9”. The :F9 command limits power consumption by the auxiliary board sensors while they are not in use.

SENSOR CONFIGURATION
1. Configure the sensor package for common use conditions as follows:
   - Initialize the sensor (refer to “Sensor Initialization and De-initialization”).
2. Configure the sensor parameters as follows:
   - **Local Magnetic Declination**: Set this parameter according to the geographical location where the device is used. The National Oceanographic and Atmospheric Administration provides an online table and calculator of local magnetic declination. Refer to https://www.ngdc.noaa.gov/geomag/declination.shtml.
   - **Sensor Orientation**: Set this parameter according to the device orientation. For information regarding device orientation, refer to “AHRS Software Commands,” below. The parameter values represent different rotations about the longitudinal axis of the device, in increments of 90 degrees. For more information about parameter values, refer to the software ICD.
   - **Output Axis Bias Settings**: Set the programmable bias or offset for each output axis. These parameters are used to virtually boresight or align the sensor output. Bias settings are added to their respective axis. For example, a pitch bias setting of 1.23 would add 1.23 degrees to the pitch output. The heading output bias operates identically to the magnetic declination parameter but is programmed separately.
3. De-initialize the sensor (refer to “Sensor Initialization and De-initialization”).
4. Calibrate the magnetometer (refer to “Magnetometer Calibration”).

AHRS Software Commands
For IMS software commands, refer to the software ICD. From the factory, the IMU is programmed with the default orientation shown.
Magnetometer Calibration

The magnetometer must be calibrated to compensate for the effects of ferrous metals and active electronics, which can distort the local magnetic field. Perform calibration in a magnetically neutral environment after the device has been mounted in its final operating position. If this is not possible, calibrate the device separately, attached to as much of its proximate enclosure as possible. As long as the device is powered on, the sensor fusion coprocessor on the auxiliary board continuously updates the calibration; this includes de-asserting the LRF_ENABLE pin and initializing the :F8 command.

To calibrate the magnetometer:

1. Perform the Initialization sequence (refer to “Sensor Initialization and De-initialization”).
   - If desired, load the last saved calibration. To load the last saved calibration, input the :F2 command.

   **Note**

   - Loading a previously valid calibration does not result in immediate setting of the calibration done status bit. To set the calibration done status bit, the complete Calibration procedure must be performed.

2. Perform calibration as follows:
   a. Rotate the device and any proximate enclosure through complete rotations in all axes.
   b. Stream the sensor fusion output and observe the result of the calibration in real time.
c. To stream the sensor fusion output to the serial output of the LRF, send an \texttt{:RN} command to the LRF.

d. Verify that the device has been sufficiently calibrated. The status parameter included in the result string for sensor fusion measurements is an 8-bit unsigned integer. The fourth bit of this integer is set (equal to 1) if calibration has been completed successfully. For example, if the result string from \texttt{:RN} returns an 8 (binary 0000 1000) for the status parameter, the calibration bit has been set, and the device is ready to use.

e. Stop streaming the sensor fusion output.

f. To stop streaming, send an \texttt{:ST} command. (Sensor fusion samples are streamed to the serial output of the LRF at about 33 Hz.)

g. Save the current device magnetometer calibration.
   To save the current calibration, input the \texttt{:F1} command.

\textbf{Calibration Tips}

An example of the calibration flow is charted below:

- To save the neutral calibration, use the \textit{Save Calibration LRF} command; input \texttt{“:F1”}.
- To restore calibration after device power up, use the \textit{Load Calibration LRF} command; input \texttt{“:F2”}.
- For best results, recalibrate periodically, particularly when entering a new magnetic environment. If this is not possible due to device mounting or enclosure, use a saved neutral calibration. The neutral calibration will be iteratively refined as your device moves relative to the Earth and its local magnetic environment.

\begin{center}
\includegraphics[width=\textwidth]{example_calibration_flow_chart.png}
\end{center}

\textbf{Example Calibration Flow Chart}
⚠ Note

- The magnetometer in the auxiliary board is very sensitive to external magnetic fields. Common sources of magnetic interference are listed below.
- Do not operate an auxiliary board-equipped device in the presence of ferrous metals and active power electronics, including (but not limited to):
  - Permanent magnets
  - Large steel mounting brackets and hardware
  - Steel file drawers
  - Computer power supplies
  - High-power switch-mode power supplies on printed circuit boards

The magnetometer is the sensor in the IMU that is most sensitive to unwanted outside influence. Failure to meet these operating conditions will result in inaccurate or erroneous estimates for compass heading.

To obtain attitude and heading estimates from the LRF, follow the operational flow chart shown below. For the extended command set used by the auxiliary board, refer to the software ICD.