IMPLEMENTATION OF THE REAL-TIME TRANSVERSE PAVEMENT PROFILE MEASUREMENT SYSTEM: COMPREHENSIVE REPORT

THE UNIVERSITY OF TEXAS AT ARLINGTON
TRANSPORTATION INSTRUMENTATION
LABORATORY

REPORT 5-1782-01-1
Project Number 5-1782-01

Roger S. Walker, Ph.D., P.E.

Performed in Cooperation with the Texas Department of Transportation and the Federal Highway Administration

Date: December 2004

Technical Report Documentation Page

1. Report No. FHWA/TX-06/5-1782-01-1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Implementation of the Real-Time Transverse Pavement Profile Measurement System: Comprehensive Report		5. Report Date December, 2004
		6. Performing Organization Code
7. Author(s) Dr. Roger Walker Ph. D, P.E.		8. Performing Organization Report No. 5-1782-01-1
9. Performing Organization Name and Address The University of Texas at Arlington, Transportation Instrumentation Laboratory		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. 5-1782-01
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office P.O. Box 5080 Austin, TX 78763-5080		13. Type of Report and Period Covered Technical Report 9/1/02 – 8/31/04
		14. Sponsoring Agency Code

15. Supplementary Notes
Project performed in cooperation with the U.S. Department of Transportation, Federal Highway Administration.

16. Abstract
The Texas Department of Transportation (TxDOT) has been using a five-sensor rut bar system, implemented with ultrasonic sensor technology, to automatically collect estimates of pavement rutting for PMIS purposes. A number of problems occur when using the acoustic sensors for this purpose. During TxDOT Project 1782 a set of procedures (see Research Report 0-1782-1) were developed for using the Acuity AccuRange 4000 laser system for measuring rut. At the end of the project it was recommended that the use of the system be implemented on a larger sample of roads. Following this project, TxDOT initiated an implementation project with the University of Texas at Arlington in December of 2002. This current report discusses the implementation effort.

17. Key Word Acuity Scanning Laser, Rut measurements, Transfers Profile	18. Distribution Statement No restrictions. This document is available to the public through the National Technical Information Service, Springfield, Virginia 22161, www.ntis.gov

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 64	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

IMPLEMENTATION OF THE REAL-TIME TRANSVERSE PAVEMENT PROFILE MEASUREMENT SYSTEM: COMPREHENSIVE REPORT

THE UNIVERSITY OF TEXAS AT ARLINGTON
TRANSPORTATION INSTRUMENTATION
LABORATORY

REPORT 5-1782-01-1
Project Number 5-1782-01

Roger S. Walker, Ph.D., P.E.

Performed in Cooperation with the Texas Department of Transportation and the Federal Highway Administration

Date: December 2004

Notice **–** The United States Government and the State of Texas do not endorse products or manufacturers. Trade or manufacturers' names appear solely because they are considered essential to the object of the report.

DISCLAIMER(S)

The contents of this report reflect the views of the author(s), who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation.

There was no invention or discovery conceived or first actually reduced to practice in the course of or under this contract, including any art, method, process, machine, manufacture, design or composition of matter, or any new useful improvement thereof, or any variety of plant, which is or may be patentable under patent laws of the United States of America or any foreign country.

ACKNOWLEDGEMENTS

The author would like first to acknowledge Carl Bertrand and Brian Michalk of the Texas Department of Transportation. Without their support, this research project would not have been possible. Acknowledgements are also due the students and staff personnel, in particular Eric Becker at the Transportation Instrumentation Laboratory facility at the University of Texas at Arlington.

Table of Contents

List of Figures

Introduction

This report discusses an implementation project between the Texas Department of Transportation and The University of Texas at Arlington. The Texas Department of Transportation (TxDOT) has been using a five-sensor rut bar system, implemented with ultrasonic sensor technology, to automatically collect estimates of pavement rutting for PMIS purposes. A number of problems occur when using the acoustic sensors for this purpose. TxDOT Project 1782 was initiated to investigate the possibility of using scanning laser technology for measurement of rut that would alleviate some of the problems of the acoustic sensor systems. The scanning laser system was based around the Acuity AccuRange 4000 laser system and is described in Research Report 1782F. Following this project, TxDOT initiated an implementation project with the University of Texas at Arlington in December of 2002. This current report discusses the implementation effort.

The report first briefly reviews the scanning laser system developed during Project 1782 followed by the implementation efforts. The system is currently being used during the 2004 PMIS data collection activities. It is also being used in TxDOT Research Project 4463, Using Profile Measurements to Locate and Measure Grind and Fill Areas to Improve Pavement Ride. The appendix, AR4000 Operational Manual, includes the operational (P2) and troubleshooting (P3) manuals for the scanning laser as specified in the proposal. Additional such information can be obtained from the TxDOT Texas Modular Vehicle (TMV) operational and training material.

Background – Research Project 1782

As mentioned above during Project 1782, a functional scanning laser system was developed to scan the full width of the paving lane and to report and store the rut condition of each wheel path. The principle components of the measurement process are illustrated in Figure 1. The AccuRange laser is a laser diode based distance measuring system with 0.1 inch static resolution for distances to 50 feet. When used with the accompanying scanning mirror system, it provides a means for making multiple scans over a surface. The High Speed Interface module, in addition to providing an interface between the laser and an embedded

PC, also contains a circuit to control the speed of the Scanning Mirror Motor. The theory of operation of the AR4000 Laser is available at the Internet site, http://www.acuityresearch.com. When the system is mounted on the back of a vehicle it can provide transverse measurements of the road surface as the vehicle travels down the road.

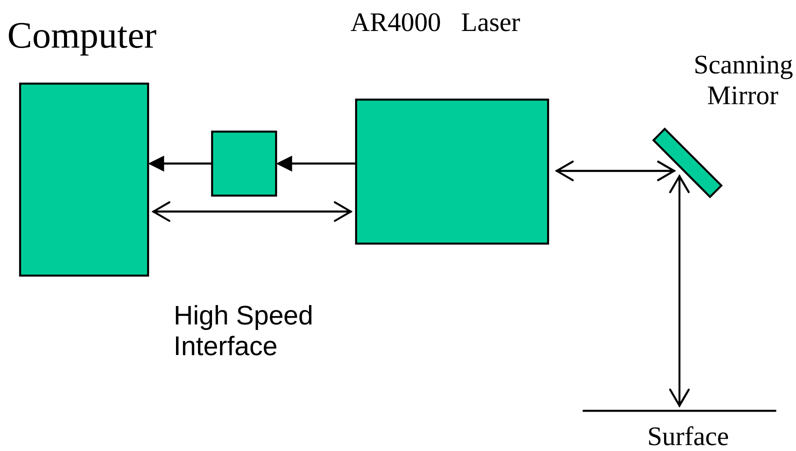


Figure 1 The Acuity Scanning Laser System

During the project it was found that significant noise problems occurred with the laser system during high speed measurements. This noise was found to be caused from the laser beam as it is swept across the pavement surface. The laser sensor, in a stationary configuration, met the technical specifications as indicated by the manufacturer. However, when scanning the laser across a pavement or other non-smooth surface, noise spikes much greater than the profile signal would occur. Thus much of the effort during the project was focused on developing a means to distinguish the signal from the noise, and to address a means by which measurement methods could be done at highway speeds. The raw laser data are first converted into distance readings and then put through a multi-step process to produce results that can then be used to compute rut and provide transverse surface scans. This process which is discussed in detail in the 1782 Research Project report consists of the following steps for each scan: Coordinate transformation, histogram clipping, spike suppression, scan comparison, and curve fitting. Rut detection is accomplished by using the European "string line" method. Figure 2 illustrates a processed scan after applying the string line rut procedure on a processed rut measurement taken from a section in Granger, Texas during 2003.

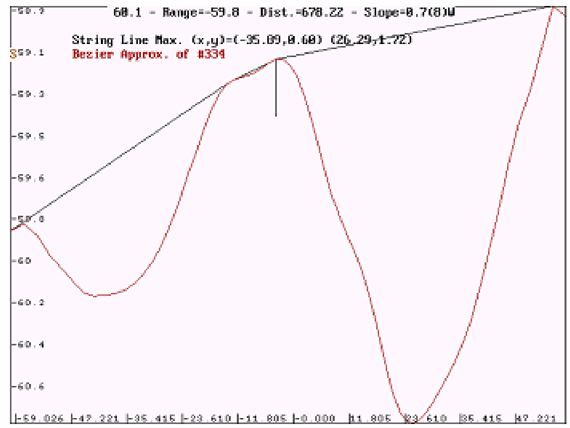


Figure 2 Processed Scan with String Line Rut Procedure

Until the last year of the project, it appeared as though the noise problems resulting from the AccuRange laser and rotating mirror would prevent further use of the system. However, during the last year of the project the multi-step process applied to each scan provided valid rut measurements that were verified from measurements at the Ride/Rut Calibration facility, and at sites in Austin and Granger, Texas. Thus it was decided to proceed to implementation of the system, acquiring 16 scanning laser systems for network and project level data collection.

Implementation

The implementation project was initiated in December, 2002. As specified in the implementation plan, during the first year of the project, five Acuity systems were purchased. The remaining 11 systems were purchased during 2004. At the beginning of Research Project 1782 in 1999, the platform used for TxDOT data collection activities was based around a dedicated DOS system. By the time Research Project 1782 ended in August, 2002, the platform used for data collection had changed to a Windows/Linux based network system. The Pavement Branch of Construction Division designed and developed a vehicle network system (VNET) for coordinating the data collection activities. Since the system developed in Research Project 1782 was based around the DOS system, the implementation would require modifying the software so the system could integrate with the VNET concept.

The original implementation plan called for the use of the real-time scanning and analysis programs developed during Research Project 1782 for collecting and processing the scanned data. In order to implement network level operations, the plan also called for a TxDOT 'wrapper' program that would permit the use of the UTA developed multi-step data acquisition and processing software. The processed data would then be sent to the TxDOT developed network application software. TxDOT software would use the algorithms developed by UTA for obtaining rut estimates. In addition it was originally planned to use the UTA designed signal interface for encoding of the start and distance signals into the measurement process, and an embedded PC for reading and storing the raw laser scans. These plans were changed during the first project meeting in January, 2003. At this meeting several key decisions were made by TxDOT project personnel that altered the original implementation plans. First it was decided that TxDOT project personnel would rewrite the scanning laser data acquisition and processing software since they were developing the VNET concept and wanted the system to work directly with the network without the use of the 'wrapper'. Secondly, TxDOT project personnel also decided that this system would run totally in the Linux environment. During the implementation efforts, TxDOT also made a number of other changes in processing the raw laser readings and distance measurements. As a result, many of the processing and analysis methods developed in Research Project 0-1782 were not used. The new processing procedures are discussed in the TxDOT in-house operational manuals.

TxDOT project personnel designed and implemented a compact package and mounting system for the implementation. The TxDOT scanning laser package is illustrated in Figures 3 and 4. Figures 5 and 6 illustrate the system mounted on the back of the TMV measuring vehicle. As illustrated the packaging and mounting process also included external cooling for the scanning laser components. Figure 7 illustrates an example of the TxDOT VNET TPP project level data file. Each scan contains the x coordinate of the starting position (nearest distance) followed by a series of y-z coordinate readings. The TMV utilizes an Ethernet LAN to connect pavement management data collection subsystems such as profile, ride, rut, and texture.

The TxDOT Scanning Laser System has been incorporated with the TxDOT Texas Modular Vehicle (TMV) system. Because valid scanning laser data was not available until the end of the implementation project it was not possible to perform any of the originally planned resolution and accuracy tests. However, the data from the scanning system is currently being evaluated and used in Project 4463 for 3-D surface measurements. The system was recently taken to the Ride/Rut Calibration Section at College Station. The Rut Calibration Section includes four sets of three beams placed along the section as shown in Figure 8. The beam height differs for each set, beginning at three inches for the first set to 0.25 inches for the last set. Figure 9 provides three consecutive scans from the TPP records illustrating laser output. Figure 10 provides a 3-D display of multiple scans over the first set of bars.

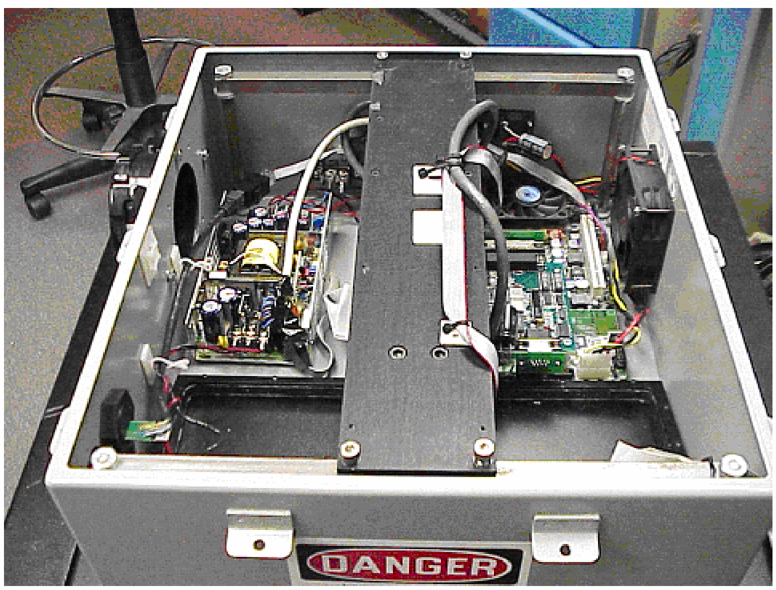


Figure 3 TxDOT Compact Packaging of Scanning Laser System

Figure 4 TxDOT Scanning Laser System Ready To Install on Vehicle

Figure 5 Scanning Laser System Mounted on TxDOT TMV

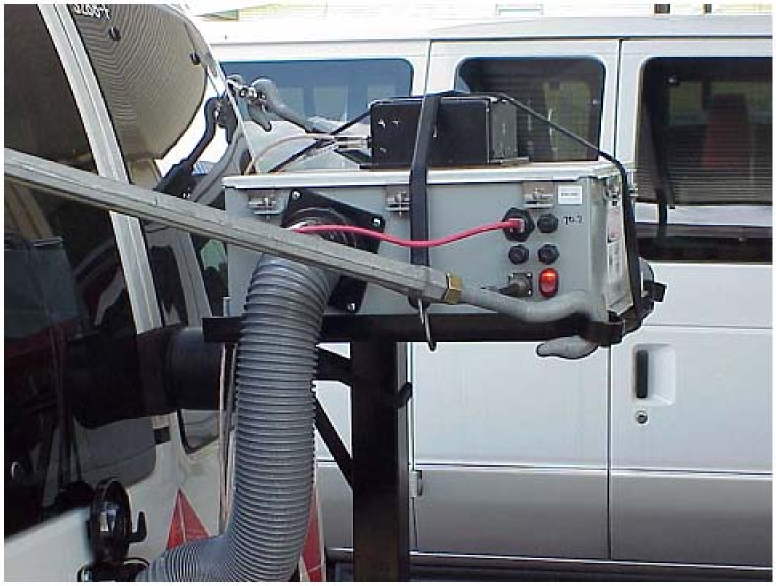


Figure 6 Scanning Laser System Shown with External Cooling on TxDOT TMV

META1,VID04,0.0,0.0,1,Rel 11.29.04,TXDOT Software,AxisCamera,1,640x480,75
HEAD4,,0.0,0.0,20041203173832.413,PROJ,,00,000,RutTest,0000 +00.000,K1
TPP00,,0.00020,0.00020,-57.24:-60.43,-55.97:-65.38,-53.82:-69.49,-48.63:-69.58,-39.67:-62.93,-36.97:-65.80,-31.25:-62.45,-27.52:-62.77,-23.83:-62.57,-20.16:-62.37,-16.74:-62.15,-13.32:-62.01,-10.27:-62.95,-06.94:-62.77,-03.71:-62.15,-00.47:-61.76,+02.67:-62.29,+06.30:-65.21,+09.27:-62.80,+12.50:-62.77,+15.86:-62.62,+19.41:-62.93,+23.05:-63.10,+26.78:-63.11,+30.94:-63.70,+34.90:-63.67,+39.10:-63.30,+43.93:-63.85,+49.06:-63.96
TPP00,,0.00032,0.00032,-59.92:-62.30,-53.01:-60.84,-50.90:-64.51,-47.42:-66.79,-40.23:-62.79,-35.51:-61.91,-32.01:-62.80,-28.22:-62.82,-25.52:-65.54,-20.94:-62.82,-17.45:-62.56,-13.94:-62.08,-10.76:-62.35,-07.47:-62.37,-04.34:-62.96,-01.05:-62.34,+02.10:-62.38,+05.35:-62.34,+09.06:-65.54,+11.94:-62.94,+15.39:-63.22,+18.96:-63.47,+22.30:-63.08,+26.09:-63.35,+29.91:-63.25,+33.99:-63.57,+38.19:-63.29,+42.58:-63.30,+47.88:-63.74,+53.03:-63.87

Figure 7 Example VNET TPP Scan Readings

Figure 8 Rut Section at Ride/Rut Calibration Center

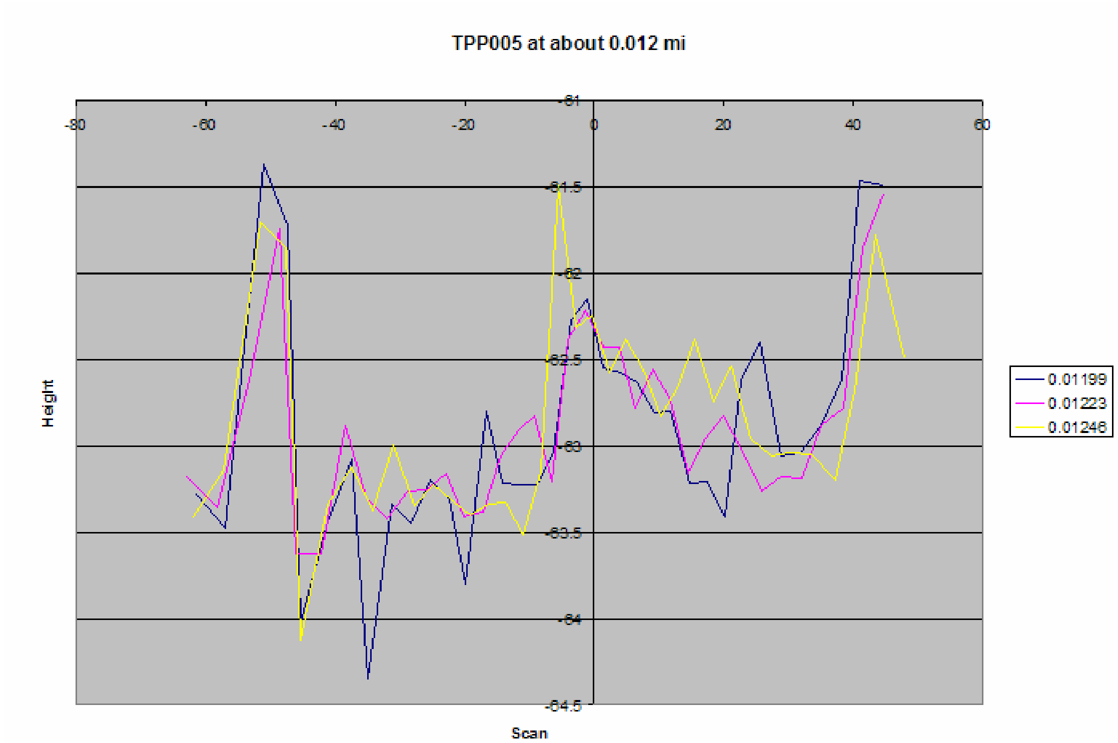


Figure 9 Three Scans of Data at TTI RUT Calibration Facility TPP05 at About 0.012 Mile

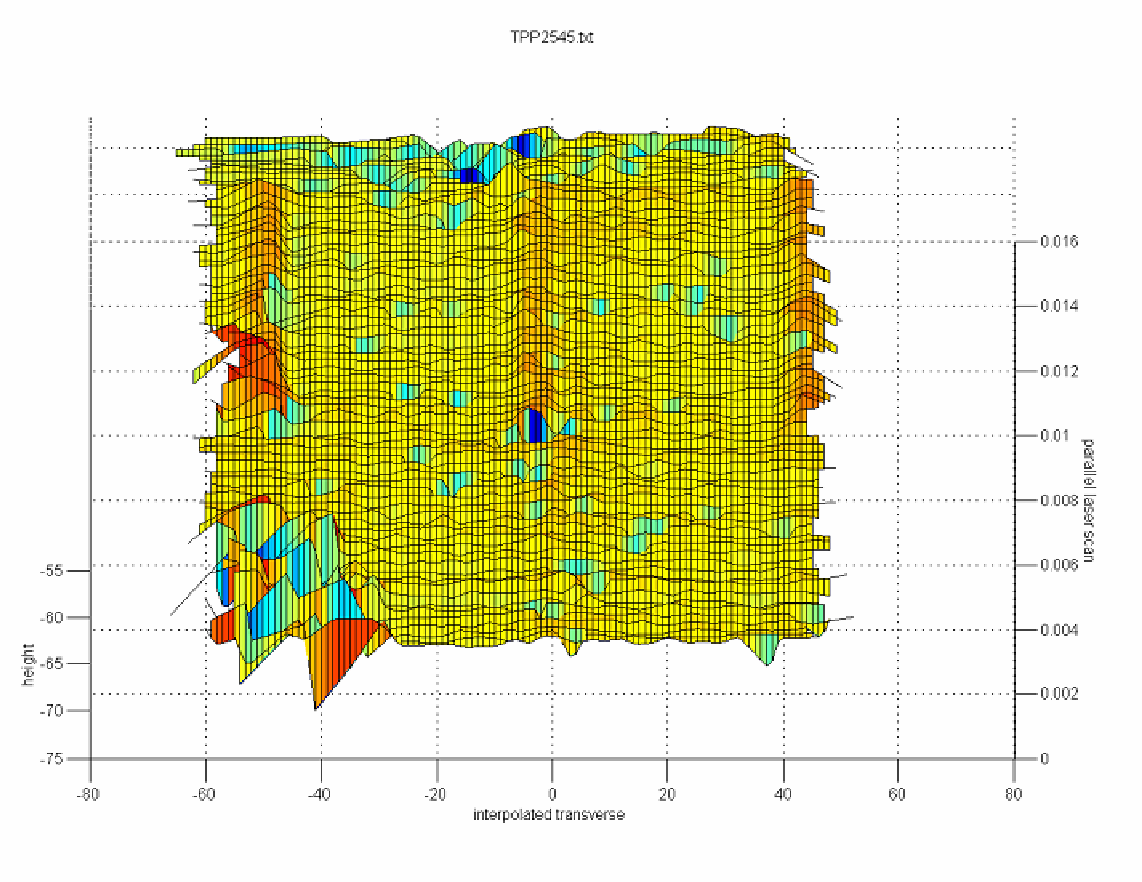


Figure 10 3-D Plot at Beginning of Rut Section

Recommendations and Conclusions

During the project, 16 scanning laser systems have been purchased and 7 have been installed on TMVs. They are currently being used during the 2004 PMIS data collection activities. TxDOT has a compact mounting system for the scanning laser which includes the acuity laser, rotating mirror, power and embedded system components. Each package includes facilities for external cooling from the vehicle. The system includes laser mounting and installation procedures. The user operations were designed and implemented by TxDOT project personnel and are included in the TxDOT Data Collection Operations Manuals. The system is currently in use.

APPENDIX:

AR4000 User's Manual

The Acuity AR4000 User's Manual is available from the Acuity website and is included here for the convenience of the user. The website for the Acuity AR4000 User's Manual is:

http://acuityresearch.com/pdf/ar4000-users-manual.pdf

The websites for the Acuity Scanner Manual and HSIF Card Manual, respectively, are:

http://www.acuityresearch.com/pdf/line-scanner-users-manual.pdf

http://www.acuityresearch.com/products/ar4000/options-accessories-high-speed-interface.shtml

Acuity is a product line of Schmitt Measurement Systems, Inc., Portland, Oregon, USA

AccuRange 4000™ Laser Rangefinder

AccuRange™ Line Scanner

User's Manual

Rev. 2.4
For use with AR4000™ and Line Scanner
September 5, 2003

Acuity
A division of Schmitt Measurement Systems, Inc.
2765 NW Nicolai St.
Portland, OR 97210
www.acuityresearch.com

Limited Warranty

Acuity, a division of Schmitt Measurement Systems, Inc., makes the following limited warranties. These limited warranties extend to the original purchaser and to no other purchaser or transferee.

Limited One Year Parts and Labor Warranty

Acuity warrants this product and its parts against defects in materials or workmanship for a period of one year after the date of original retail purchase. During this period, Acuity will, at its option, repair or replace a defective product or part without charge to you.

Warranty Conditions

The above LIMITED WARRANTIES are subject to the following conditions:

1. Warranties extend only to products manufactured by Acuity.

2. Warranties extend only to defects in materials or workmanship as limited above. Warranties extend only to defects which occur during normal use and do not extend to damage to products or parts which results from alteration, repair, modification, faulty installation or service by anyone other than an authorized Acuity service center, damage to products or parts caused by accident, abuse, misuse or maintenance, mishandling, misapplication, or damage caused by acts of God.

3. You must retain your bill of sale or provide other proof of purchase.

4. Any replacement parts furnished at no cost to the purchaser in fulfillment of this warranty are warranted only for the unexpired portion of the original warranty.

ALL WARRANTIES REQUIRED TO BE IMPLIED BY STATE LAW ARE EXPRESSLY LIMITED TO THE DURATION OF THE LIMITED WARRANTIES SET FORTH ABOVE. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. **WITH THE EXCEPTION OF ANY WARRANTIES REQUIRED TO BE IMPLIED BY STATE LAW AS HEREBY LIMITED, THE FOREGOING EXPRESS WARRANTY IS EXCLUSIVE AND IN LIEU OF ALL OTHER WARRANTIES.**

IN NO EVENT SHALL ACUITY BE LIABLE FOR SPECIAL, INCIDENTAL, CONSEQUENTIAL OR PUNITIVE DAMAGES, INCLUDING, WITHOUT LIMITATION, INJURY OR DAMAGE TO PERSONS OR OTHER PROPERTY, INCONVENIENCE, LOSS OF GOODWILL, LOST PROFITS OR REVENUE, LOSS OF USE OF THIS PRODUCT OR ANY ASSOCIATED EQUIPMENT, COST OF SUBSTITUTIVE EQUIPMENT DOWNTIME COSTS OR CLAIMS OF ANY PARTY DEALING WITH PURCHASER FOR SUCH DAMAGES, RESULTING FROM THE USE OF THIS PRODUCT OR FROM DEFECTS IN THIS PRODUCT, OR ARISING FROM BREACH OF

WARRANTY OR CONTRACT, NEGLIGENCE OR ANY OTHER LEGAL THEORY. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation may not apply to you.

Procedures for Obtaining Warranty Service

1. Contact your Acuity distributor or call Acuity to obtain a return merchandise authorization (RMA) number within the applicable warranty period. Acuity will not accept any returned product without an RMA number.

2. Ship the product to Acuity, postage prepaid, together with your bill of sale or other proof of purchase. your name, address, description of the problem(s). Print the RMA number you have obtained on the outside of the package.

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

(1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Note: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this device in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at their own expense.

Table of Contents

1. Introduction

This section is a guide to getting started with the AccuRange 4000 and this manual. The AR4000 has a number of configurable parameters, but many applications can use it in its default configuration.

The first sections of the manual that should be read are the General Description and the Operating Guidelines. After that Installation, with reference to the Signal and Power Interface section for specific cable descriptions, should provide the information necessary to connect the sensor and verify its operation, either with a serial terminal program at 9600 baud, or by connecting the current loop interface.

To understand more about the format of the serial data, read the Serial Communications chapter. For details on the current loop and pulse width outputs, read the chapter titled Current Loop and Pulse Width Outputs.

For custom configuration, the AccuRange Command Set section provides information on setting up the AccuRange for specific application requirements. The remaining sections deal with specifics of the outputs and interfaces and with general performance characteristics of the sensor.

2. General Description

The AccuRange 4000 is a laser diode based distance measurement sensor for ranges up to 50 feet, with 0.1 inch accuracy. There are three models, the 4000-LV, 4000-LIR, and 4000-RET. The 4000-LV emits visible light (red, 670 nm wavelength), while the 4000-LIR and 4000-RET uses near infrared light (780 nm wavelength). The 4000-LIR is a Class IIIb laser product, available in power levels of 8 mW (standard), or up to 20 mW with the High Power Laser option. The 4000-LV is a Class IIIa laser product. The 4000-RET is a Class I eye safe product for use with retroreflective tape. The labels shown below appear on the AccuRange 4000-LV and 4000-LIR.

4000-LIR: Emitter: 780 nm IR laser diode
Optical power 20 milliwatts max.
Effective Range: 50 feet

4000-LV: Emitter: 670 nm red laser diode
Optical power: 5 milliwatts max.
Effective Range: 40 feet

The 4000-LIR and 4000-RET have lower measurement noise and greater sensitivity and maximum range. The 4000-LV features visible light output. See the relevant descriptions in the Performance and Measurement Accuracy section for noise and range information. Custom configurations of the AccuRange 4000 are also possible.

The AccuRange 4000 operates by emitting a modulated, collimated beam of laser light and converting the distance to the target surface to an RS-232 or RS-422/485 output. The range may be read via the serial cable as digital data, or from the optional analog current loop output. A second cable supplies power to the AccuRange 4000 and brings out other signals, which include reflected signal strength, sensor temperature, and background light level. When configured for use with the AccuRange 4000 High-Speed Interface and host-resident calibration software, uncalibrated pulse-width modulated output is also available on this cable.

2.1 Mechanical Dimensions

Figure 1 shows the mechanical dimensions for the AccuRange. The laser beam is emitted from the center of the front panel, and the central 2.5 inch diameter of the front panel is a collector for return light. The bottom of the sensor has 4 blind holes which are threaded for 6-32 bolts for mounting the sensor. The back of the sensor has a switch for configuration and reset, LED, and two 6 foot cables. The first is for serial communication, the second contains power and analog signals. The weight of the AccuRange 4000 is 22 ounces.

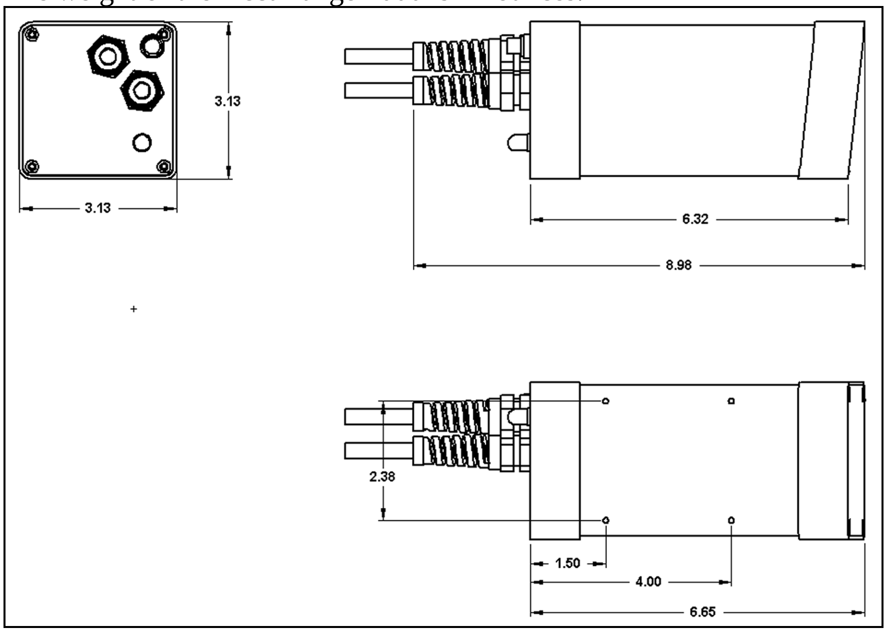


Figure 1. Mechanical Specifications

The outer case of the sensor is .125" aluminum. The acrylic front window and the back panel are sealed to the case, creating a watertight enclosure.

3. Operating Guidelines

Use protective eyewear whenever there is a risk of being exposed to the output beam of the 4000-LIR or 4000-LV. Use eyewear specifically designed to block laser radiation of the frequency used by the sensor.

Do not point the sensor at any person, particularly a person's eyes or face. Laser radiation can damage the eyes without sensation or warning.

Do not attempt to disassemble the sensor. Improper disassembly will destroy the optical alignment of the sensor and necessitate factory repairs.

Do not operate the sensor in areas where the sensor case is exposed to direct sunlight for more than a minute or where the air temperature is more than 45°C (113°F). If the sensor is to be used in temperatures below 0°C (32°F), apply power to the heater power supply lines. This will allow the sensor to maintain a constant internal temperature, ensuring optimum operation.

Do not point the sensor at the sun or other intense heat sources. The sensor will operate when pointed at sunlit areas, although sensitivity is reduced. The optional optical filter is recommended for use on sunlit target areas.

Avoid excessive vibration and shocks. The sensor contains securely mounted but precisely aligned optical components. These components are isolated from the case with shock mounting, which protects them from all but severe shocks to the case.

Do not scratch the front face of the sensor, particularly in the central area. Keep the front face clean with a damp cotton cloth. The face is acrylic with an anti-abrasion coating. Avoid the use of cleaning solvents other than alcohol.

4. Signal and Power Interface

The 4000 has 2 cables. In the default configuration, the cable with the 9 pin connector is a standard RS-232 serial port. If the 4000 is ordered with the RS-422 option, this cable is used for that. The other cable is an 8 pin power/signal cable. If the 4000 is ordered with a power supply, the power/signal cable will pass through the power supply. All wires are passed through the power supply except the red, orange, and brown power lines which are connected only between the power supply and the sensor. Connection and termination according to the instructions is essential for correct sensor operation. Read the wire descriptions for connection information.

4.1 8 Wire Power and Signal Cable

The table below shows the wiring on systems ordered without power supplies. See the section on power supplies and safety interlocks for the wiring on systems ordered with power supplies.

Wire	Function	Direction
Red	Power, +5V (5-6V)	In
Black	Ground	
Orange	Heater Power, +5V (4.5-7V)	In
Brown	Heater Power Return	
Yellow	Temperature, 0-5 V	Out
Blue	Pulse Width Range or Optional Current Loop Range	Out
Green	Ambient light signal, 0-5 V	Out
Purple	Amplitude signal, 0-5 V	Out
Shield	Ground at Supply End	

Power and Signal Cable Wiring

4.1.1 Power and Signal Cable Wire Descriptions

Line 1: +5V power at 300 milliamps. Maximum noise: 10 millivolts p-p.
Color: Red

Power supplies from 5 to 6 volts may be used. Higher voltages will result in excessive current drawn by the overvoltage protection circuitry and may cause permanent damage. Voltages less than 5.0 Volts at the cable end may result in inaccurate range readings.

Line 2: Ground
Color: Black
Return for the 5V supply.

Line 3: Heater Power, 5 to 7 volts at 0-2 amperes, temperature dependent.
Color: Orange
Heater power and return may be optionally connected to supply power for temperature regulation within the sensor. The current drawn by the heater power circuitry depends on the difference between the ambient temperature and the hold temperature for which the sensor is configured. It may be as high as 2 amperes in extreme cases. The sensor power and ground lines should only be connected to the heater power and ground at the source of a low impedance power supply, to prevent high heater current from causing significant voltage drops in the supply lines for the sensor electronics. This line should be left disconnected if heater power is not used.

Line 4: Heater Power Return
Color: Brown
Return for the optional heater power. If heater power is used, connect to the sensor electronics ground at the power supply. This line should be left disconnected if heater power is not used.

Line 5: Temperature output: 0 to 4 volts. 5 mA max.
Color: Yellow
The temperature output is a linear indication of internal sensor temperature. This may be used to monitor the internal temperature and to make range corrections due to changes in temperature, although the temperature dependence of the indicated range is typically small. The temperature output will change approximately 29 millivolts for each 1° F change in sensor temperature, and should read about 2.5 volts when the sensor is at 85° F. This output should be left open when not in use.

Line 6: Pulse Width Range Signal: Pulse width square wave
OR: Optional Current Loop Range Output: 4-20 milliamps, 10 V max output
Color: Blue
In the standard AccuRange 4000 configuration, this output provides an uncalibrated measure of range. The period of the pulse is the sample interval for which the sensor has been configured with the Sample Rate command. The duration of the low portion of the pulse is proportional to measured range, scaled by the sample rate and maximum range for which the sensor is configured. See the Current Loop and Pulse Width Outputs section for details. The pulse width signal is used by the AccuRange High-Speed Interface to make range measurements at high sample rates. It may be timed by sampling hardware to determine indicated (uncalibrated) range.

If the sensor was ordered with the optional current loop output, this line will deliver a current proportional to the measured range. The zero range current, offset of the zero range point, and the span (point of full scale output) may be set using the appropriate commands. If calibrated output mode is enabled, the output will be the actual distance to the target. Otherwise, the output will be the raw sensor range, uncompensated for temperature, signal strength, and other effects. Best accuracy is obtained by loading the line with a 500 ohm resistor to ground at the measurement point.

Line 7: Ambient light output: 0 to 4 volts. 5 mA max.
Color: Green
This output provides a measure of the total optical energy received by the sensor, which is a combination of external illumination and the laser beam energy. This may be used to make range corrections due to changes in ambient light levels at the target location, although range dependence on ambient light is small unless high ambient light levels such as sunlight are encountered. This output should be left open when not in use.

Line 8: Amplitude output: 0 to 4 volts. 5 mA max.
Color: Purple
This output provides a measure of the strength of the signal received by the sensor,
the amount of output laser light reflected back and collected by the sensor. This may be used to make corrections to variations in the range reading caused by changes in reflectance of the target. This output should be left open when not in use.

Outer shield: Not connected. Should be grounded at supply end.

4.2 Power Supplies and Safety Interlocks

4.2.1 LIR and LV Power Supplies

The optional AC to DC power supplies for the AccuRange 4000-LV and 4000-LIR supply operating power and temperature stabilization heater power to the sensors. They are housed in NEMA-4 polycarbonate enclosures and are permanently attached to the AccuRange 4000 power/signal cable, with 6 feet of cable between the sensor and power supply. An additional 4 feet of cable extends beyond the power supply for reading the sensor's optional current loop and other outputs.

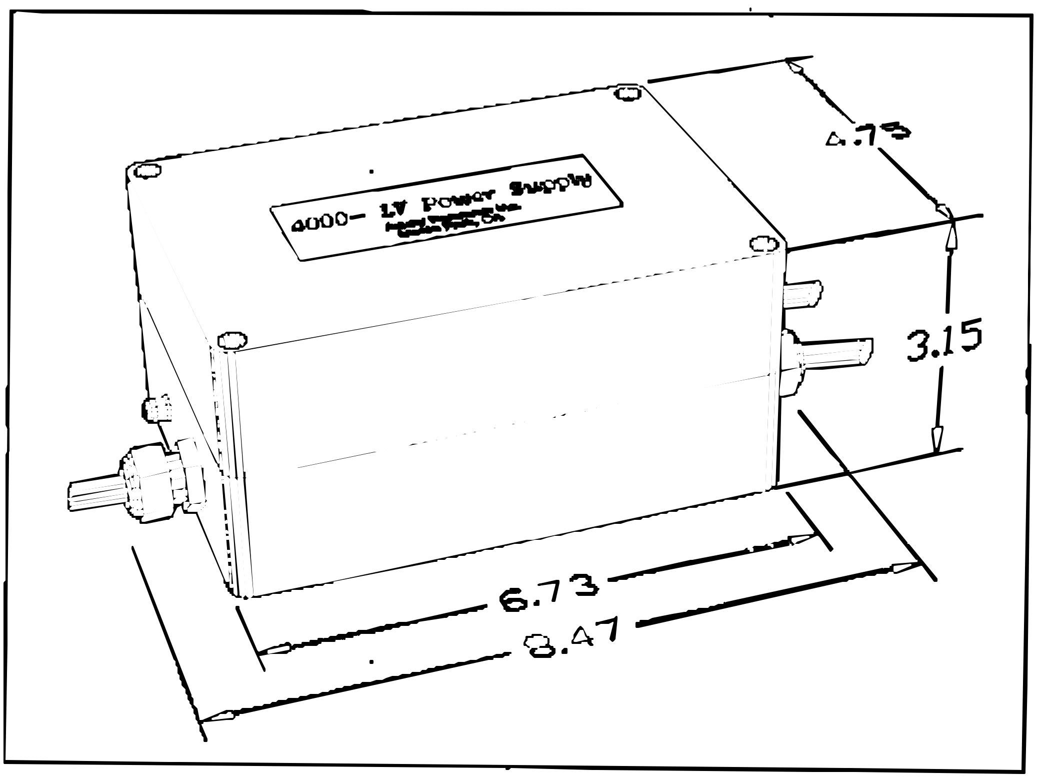
The LIR Power Supply also includes the keyswitch and interlock jack required for CFR certification for Class IIIb lasers. In the LIR Power Supply the keyswitch and interlock jack located inside the box must be turned on and installed to complete the laser power supply circuit.

To access the switch and jack, remove the four screws in the power supply case and lift the top half of the case. When the circuit is complete, the indicator lamp on the box will light, and power is applied to the sensor. After a 5 second delay, the 4000-LIR laser will come on.

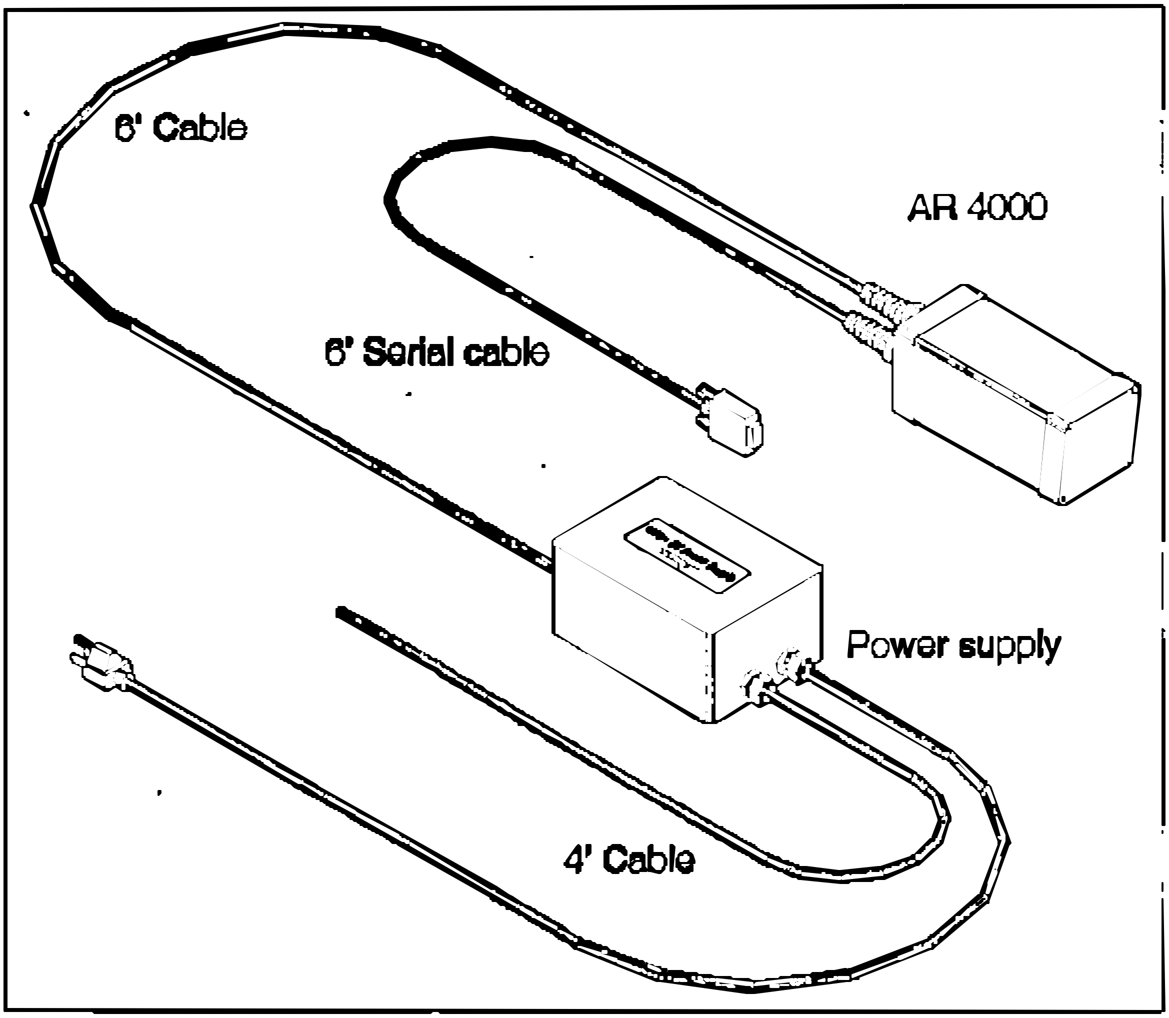
The wiring for the 8 line power and signal cable extending from the power supplies is the same as for the AccuRange 4000LV and LIR, except that the 5 volt power and heater lines, and the heater return line, are not connected. The table below shows the wiring for the 8 wire cable extending from the LIR and LV power supply boxes.

Wire	**Function**	**Direction**
Red	No Connection	
Black	Ground	
Orange	No Connection	In
Brown	No Connection	
Yellow	Temperature, 0/5 Volt	Out
Blue	Pulse Width Range	
	or Optional Current Loop Range	Out
Green	Ambient light signal, 0-5 V	Out
Purple	Amplitude signal, 0-5 V	Out
Shield	No Connection	

LIR and LV Power Supply Signal Cable Wiring



AR4000 Power Supply Dimensions

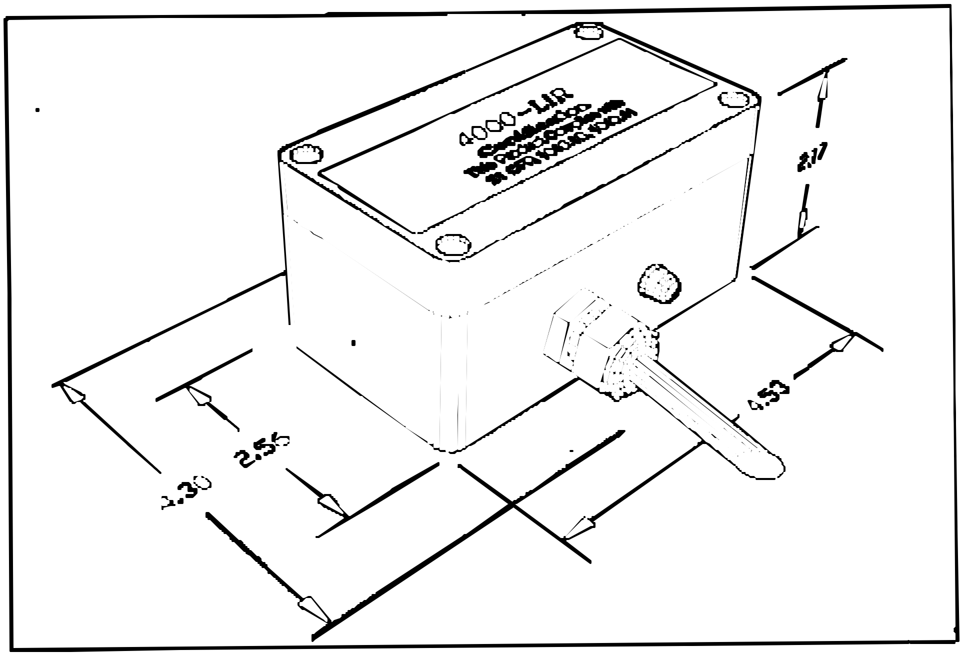


AR4000 With Power Supply

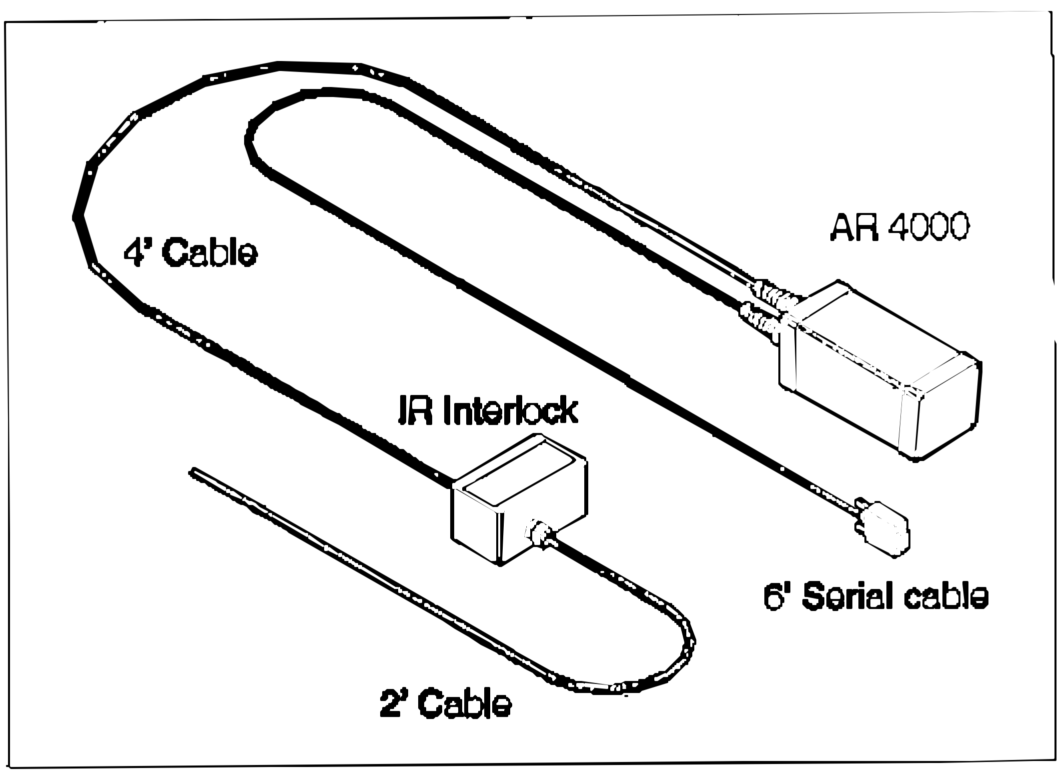
4.2.2 IR Interlock Box

The IR Interlock box contains the same keyswitch and removable jack as the IR Power Supply. To access the switch and jack, remove the four screws in the power supply case and lift the top half of the case.

All of the lines in the AccuRange Power and Signal cable are connected straight through, except that the red power line passes through the keyswitch and jack before powering the laser. Removing either the key or the jack or turning off the key breaks the sensor power circuit. When the circuit is complete, the indicator lamp on the box will light, and power is applied to the sensor. After a 5 second delay, the 4000-LIR laser will come on.



IR Interlock Box Mechanical Dimensions



4000 LIR with Interlock Box

5. Serial Interface Specification

5.1 Hardware Port

The default serial port in the AccuRange 4000 is a standard RS-232 port, which can be connected to an IBM or compatible 9 pin serial port. If the 422/485 option is ordered, the serial cable contains the wire pairs for point-to-point full duplex RS-422 communication. Data can be transferred at any of several baud rates, in binary or ASCII format.

Pin #	RS-232 Function	RS-422 Function
1	NC	TxData-
2	TxData	TxData+
3	RxData	RxData+
4	DTR	RxData-
5	GND	GND
6	DSR (Connected to CTS)	NC
7	NC	NC
8	CTS	NC
9	NC	NC

RS-232 and RS-422 Serial Port Wiring

5.1.1 Output Flow Control

If configured for RS-232, The interface board responds to two types of flow control: Ctrl-S/Ctrl-Q and hardware CTS/DTR. If configured for RS422, only Ctrl-S/Ctrl Q can be used, since wire pairs for CTS-DTR are not included. The interface will always stop transmission if Ctrl-S is received, and will resume when Ctrl-Q is received. RS-232 interface response to the DTR flow control input is controlled by the Flow Control configuration parameter. If flow control is enabled and the host computer sets DTR false, the sensor will stop transmitting. If flow control is disabled, DTR will be ignored. If output is suspended in the middle of a sample, the remainder of the sample will be transmitted when DTR is asserted by the host, but subsequent samples may be lost.

5.1.2 Input Flow Control

The sensor does not transmit Ctrl-S/Ctrl-Q. In the RS-232 configuration, if the input buffer is in danger of overflowing, the CTS line will be brought false. To assure no loss of command string data, the host system should respond to this signal if transmitting command strings of more than 10 bytes, or allow 0.1 seconds between commands for command completion. The Flow Control configuration parameter has no effect on the interface's assertion of CTS.

6. Installation

6.1 Cabling

6.1.1 Standalone Cabling

To use the AccuRange 4000 without a serial connection to a host computer, the only connections necessary are the power and ground lines, and the pulse width or current loop signal connection to your data display or recording equipment. See the Signal and Power Interface for wire connections. In its default configuration, the AccuRange 4000 will begin measuring and transmitting range on power-up (following a 6 second laser power-on delay for the 4000-LIR).

Depending on the configuration ordered, the range output line will have either the current loop or pulse width output on it. The best accuracy and linearity for the current loop is obtained with a 500 ohm load to ground at the measurement point.

The signal strength, background light, sensor temperature, and/or the optional current loop range output may be connected to analog input hardware. Use of a temperature stabilization power supply is also recommended for maximum accuracy. If you want to use temperature stabilization, attach the heater power lines to a 5 volt supply.

The AR4000 requires at least 5 volts for sensor power, so if the same supply is used for the sensor power as for the heater power, make sure that the lines are connected together at the supply. Tying them together at a distance from the supply may cause voltage drops in the power lines due to the heavy currents (up to 4A in cold conditions) drawn by the heaters.

6.1.2 Connection to a Host Computer

Unless ordered with the RS-422 option, the cable with the 9 pin connector is the RS-232 serial connection to the sensor. This may be directly connected to an IBM-PC compatible serial port. Connect a 5 to 6 volt power supply to the power and ground lines of the Power/Signal cable. See the Signal and Power Interface for wire connections. Only the power and ground need be connected for operation with the serial interface. Temperature stabilization power may also be connected, as described above. For testing use a terminal emulation program such as the Windows terminal, set to 9600 baud, 8 bits, no parity, 1 stop bit. Sensors configured with the RS-422 option behave identically in software, and any of several commercially available RS-22 cards may be used to support the sensor on a PC communcations port.

7. Initial Checkout

7.1 4000-LV

When power is applied the green LED on the back panel should flash briefly and then stay on, and a bright red beam should be emitted from the center of the front aperture. The sensor should give reasonable range information immediately, although it will take 5-10 minutes for the internal temperature and range readings to stabilize fully.

7.2 4000-LIR

When power is applied the green LED on the back panel should come on. After approximately 6 seconds, the LED will flash briefly and the laser will come on. The beam will be invisible or just barely visible. Use an IR viewing card in the path of the beam for viewing. The sensor should give reasonable range information after the 6 second delay has passed and the laser turns on, although it will take 5-10 minutes for the range readings to stabilize fully.

7.2.1 Verifying Operation

In its default configuration, the 4000 transmits 5 samples per second at 9600 baud over the serial line, and transmits measured distance over the current loop output (if installed) with the same update rate. The frequency of the pulse width output will be higher: See the Pulse Width Output section. The current loop should put out 4 mA at zero range, and 20 mA at 650 inches. Check either or both of these signals to verify basic sensor operation.

7.3 Troubleshooting

If the LED does not come on, then blink once and stay on, check the power supply wiring. If the laser does not come on (after 6 seconds for the 4000-LIR), or the LED blinks rapidly (several times a second) check the power supply voltage. If the LED blinks continuously about once a second after power-up, the EEPROM has lost its configuration and/or calibration data. Pressing the switch will allow power-up to continue, but configuration information and measurement accuracy may have been affected. Messages will be transmitted over the serial port describing the failure (see the section on Configuration and Non-Volatile Storage). Configuration information may be restored by re-entering the desired configuration. Contact Acuity in the event of calibration data loss.

In the event of slightly low voltage from the power supply, the sensor will stop transmitting data and the LED will blink rapidly (several times a second) until the power supply level is restored.
If the power supply falls below 5 volts for more than 100 microceconds, the sensor will be reset to avoid unreliable operation that could damage it. If this occurs, the quality of the power supply and its ability to provide a constant voltage when there is noise on the AC line. If the power supply output voltage can be increased to 5.5 volts, this may provide enough margin to prevent resets, unless the supply has very poor line regulation.

7.3.1 Serial Communications Check

If no information is received over the serial port, check the power supply and serial cable connection. The sensor may in a configuration that prevents serial communication, such as being set at the wrong baud rate. Turn the power off, press the button on the back panel of the 4000, and turn the power on with the button held down. The LED should stay off until the button is released, and then flash briefly (after a 5 second pause on the 4000-LIR). This will reset the sensor to the factory default configuration (9600 baud, 8 bits, no parity, 1 stop bit), and should enable serial communication with the host system.

If no serial data is being received and the LED is blinking several times a second, the power supply voltage is low. It should be at least 5.0 volts at the end of the 6 foot sensor cable.

7.3.2 Range Output Check

If the range output is in error, check that the sensor and target are stationary and stable, that the target is about 8 feet from the sensor as an initial test range, and that the beam is hitting the target. The sensor may need to warm up before reaching full accuracy: leave it on for a few minutes and re-check the range accuracy.

One way to check the basic ranging operation of a sensor configured with pulse width output is with an oscilloscope. Check the waveform on the pulse width output. It should be a square wave swinging from 0.4 to 0.9 volts, with at rise/fall time of about 20 nanoseconds. The duration of the low portion of this signal should increase as the distance to the target surface increases. The signal repeats approximately 200 times per second at low sample rate settings, depending on the maximum range configured. For high sample rate settings, the signal will repeat once per sample interval.

7.3.3 Analog Output Check

The analog signal outputs can be tested with a voltmeter or oscilloscope. Each should be between 0 and 5 volts. Amplitude should change as the target is moved, or as the target color changed. The ambient light output will also change, to a lesser degree. Pointing the sensor at a brightly lit surface should raise the ambient light output. Temperature should rise gradually for the first 15 minutes or so from a cold start, or more rapidly if the heater power is applied.

7.3.4 Range Measurement Quality Check

The quality of a range measurement depends on many variables, some of which are discussed in the section on performance and measurement accuracy. Generally, the quality of the signal can be measured by taking a set of samples of a stationary target over a fixed time interval and computing the standard deviation of that set of samples. For example, a set of 10 samples taken at a 100 Hz sampling rate over a total elapsed interval of 0.1 second on a stationary white target at a range of 8 meters can be expected to have a standard deviation of about .02 in. for the 4000-LIR and .08 in. for the 4000-LV. Note that sampling much faster than 100 Hz will result in greater standard deviations due to detector thermal noise effects, and sampling over much longer intervals will result in larger deviations due to long term drift.

8. Performance and Measurement Accuracy

This chapter is a general discussion of factors that affect the sensor's performance and is intended as background information to help with demanding applications. It is not needed for basic installation and configuration.

The 4000-LIR and 4000-LV will detect diffuse reflections from objects of any color with the greatest sensitivity falling at about 8 feet, although short distances right up to the front face of the sensor can be measured. If the sensor is configured with the close focus optics options, the greatest sensitivity will be 3 to 4 feet from the sensor unless adjustments have been made for a specific application. The sensor has no trouble picking up walls, floors, carpets, and even surfaces such as CRT screens from almost any angle. Shiny surfaces such as glossy plastic or paint can be more difficult to detect, depending on the angle at which the beam hits them.

The 4000-RET will detect only returns from retroreflective materials or mirror-like surfaces, including glass. Retroreflective tape can be detected over incidence angles of about +/- 40 degrees, while mirror surfaces must be oriented to reflect the beam back into the sensor to allow detection.

The sensor is calibrated with the temperature control active and set to 95^{o} F. Lower laser settings and operation at other temperatures may reduce the accuracy of the measurements taken.

There are three types of noise that will affect the measurement accuracy in different ways. They are described below, but each has a range of sample rates at which it is the predominant source of noise. Figure 2 shows the accuracy limit imposed by each type of noise for a given sample rate. The first type is detector thermal noise, which originates in the signal detection photodiode, and is proportional to the square root of the sample rate. The second type is laser diode noise, and the third type of "noise" is the resolution limitation imposed by the sampling method. Detector thermal noise is not a factor with the 4000-RET, as the signal from the retroreflector is strong even at the eye safe power level.

The vertical scale in Figure 2 is the attainable accuracy, while the horizontal scale is sample rate. Each line represents a different constraint on accuracy due to noise or sampling resolution. For any sample rate, the highest line at that rate represents the limiting factor and the attainable accuracy. At low sampling rates (below 10,000 samples per second) the limiting factor is the laser diode noise, shown as a horizontal line. At higher sampling rates the limiting factor becomes the detector thermal noise, shown as the curved line proportional to the square root of the sample rate. At the highest sampling rates, the sampling resolution becomes a factor, and the diagonal line shown in Figure 2 represents the limitations of the AR4000 sampling resolution with a maximum range of 30 feet.

8.1 Detector Thermal Noise

Range measurement accuracy at high sample rates is limited by thermal noise in the sensors' detector. Typically, a range measurement will be made by timing a number of cycles of the output. The greater the number of cycles timed, the better the averaging or filtering of this noise will be. Without going into the theory of noise power and noise bandwidth, the effect is that the standard deviation of the measurement error increases proportionally with the square root of the signal bandwidth, or in this case the sample rate. The noise in this sensor is 0.0005 in/($Hz^{1/2}$). Multiplying this value by the square root of sample rate will give the rms. noise value (approximately the same as the standard deviation) for the measurement. Thus a sample rate of 10,000 Hz gives readings with a standard deviation of about .05 inches.

8.2 Laser Diode Noise

There is another source of measurement error that needs to be considered when taking high accuracy measurements, caused by noise in the laser diode. This noise is characterized by random changes in the range reading that tend to increase as the time over which the readings are taken increases, when the sensor and target are stationary. This becomes noticeable over times of about 0.3 seconds or more, and increases up to times of several hours. The standard deviation of this drift is about 0.01 in. at 1 second, and .05 in. at 10 hours for the IR version and up to .1" in 10 hours for the visible model. Much of this noise shifts to higher frequencies (up to several kilohertz) if the target is moving or vibrating, even slowly. This fact can be used to filter out this noise if low frequency sampling is being done on a moving target. The motion effectively dithers the range reading, and an average value can be obtained that is more accurate than is possible if the target is stationary.

8.3 Maximum Range Specification

One of the configuration options for the AccuRange 4000 is the maximum range expected. This is to allow the sensor to obtain readings with the best possible resolution and accuracy. Internally, the time required to take a single sample depends on the distance being measured and the resolution used to take the measurement, If the ranges are known to be short, better resolution and accuracy at high sample rates may be obtained by reducing the maximum range. For most applications the default of 650 inches should be adequate. If you are measuring ranges greater than this, or ranges much shorter in situations where maximum resolution and high sample rates are required, your maximum should be specified using the Set Maximum Range command.

8.4 Sampling Resolution

The diagonal line shown in Figure 2 is an accuracy limit due to sampling resolution, assuming that the ranges to be measured are 30 feet or less. This becomes the limiting constraint above 15,000 samples/second. For ranges up to

60 feet, the limitation would be a similar line with twice the slope. This is due to the fact that longer ranges make more time to resolve to the same precision.

8.5 Other Factors Affecting Performance

In addition to noise, there are other factors that affect the indicated range output. The most significant of these is the amplitude of the return signal, or the reflectivity of the target. Indicated range can vary as much as 3 inches between very weak signals and very strong ones. The sensor has a signal strength output, which is an analog signal that ranges from 0 to 4 volts and is approximately logarithmic with received light intensity. The calibrated output compensates for varying reflectivity. The amplitude output can also be used to create grayscale images of objects over which the beam is scanned, and to determine whether a signal is valid or too weak to be reliable.

Temperature and the ambient light level also affect the measurement slightly. Analog temperature and ambient light outputs allow these effects to be compensated for in software, but typically they are not significant unless the sensor is used in an environment where they vary widely.

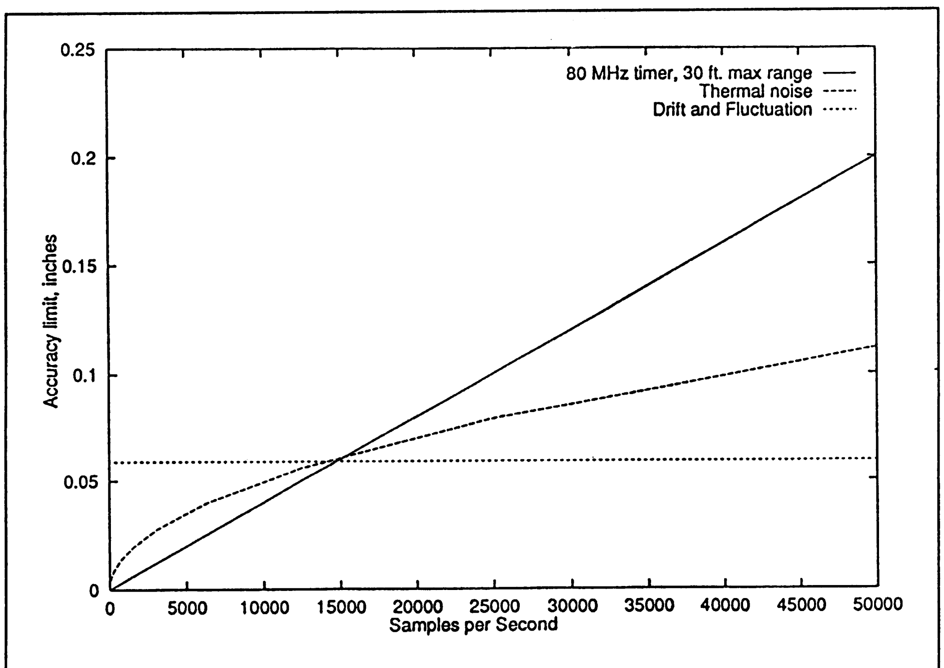


Figure 2. Attainable Accuracy vs. Sample Rate

8.6 Sensor Linearity

If the sensor is being operated in uncalibrated output mode, the nonlinearity of the sensor must be considered to accurately obtain actual distance from the indicated range. The sensor's calibrated output compensates for nonlinearity, but since this varies from sensor to sensor it must be individually measured and accounted for when operating the sensor in uncalibrated mode.

9.0 Serial Communications

9.1 Output Data Formats

Data is transmitted from the AccuRange 4000 as 8 data bits with no parity and 1 stop bit. The data sent may consist of calibrated distance readings, uncalibrated sensor data, or both together in each sample. Data may be sent in ASCII or binary format. Thus there are 6 data format combinations that can be transmitted by the 4000: ASCII calibrated only (the default), ASCII uncalibrated only, ASCII calibrated plus uncalibrated, binary calibrated only, binary uncalibrated only, and binary calibrated plus uncalibrated.

If calibrated output is enabled, the range information is the measured distance obtained by the sensor's internal calibration process. This is then transmitted as ASCII characters or binary bytes, depending on whether the ASCII or binary mode has been selected. In binary, all multibyte range and distance measurements are transmitted most significant byte first.

If uncalibrated mode is selected, the data transmitted by the sensor consists of a raw (uncorrected) range reading in sensor count units, the reflected signal strength, background light level, and sensor temperature. The size of the sensor count units in uncalibrated mode will depend on the maximum range and sample rate specified.

If both calibrated and uncalibrated outputs are enabled, the calibrated data is transmitted first, followed by the uncalibrated information. Each combination is detailed below.

The location of the zero point may be changed for either calibrated or uncalibrated output with the Set Zero Point command. The direction of increasing output serial values from the zero point may be reversed by issuing the Set Span command with a distance closer than that used in a previously issued Set Zero Point command.

9.1.1 ASCII Data format, Calibrated Distance Only

[DD]D.DD<CR><LF>
In this configuration, each sample consists of a string of characters as follows: 4 to 6 distance followed by <CR><LF>. characters (possible values from 0.00 to 999.99 inches in 1/100ths of an inch in English output, or 0 to 99999 mm metric) Values enclosed in [] will not appear if they consist only of leading zeros.

9.1.2 ASCII Data format, Low Level Sensor Outputs Only

[RRRRRR]R<TAB>[SSS]S<TAB>[AAA]A<TAB>[TTT]T<CR><LF>
In this configuration, each sample consists of characters as follows: 1 to 7 range characters (possible values from 0 to 4.19 million, decimal format), SPACE, 1 to 4 signal strength characters (0 to 1023), SPACE, 1 to 4 ambient light level characters (0 to 1023), SPACE, 1 to 4 sensor temperature characters (0 to 1500 in 0.1°F per unit), <CR><LF>.

9.1.3 ASCII Data format, Distance plus Low Level Sensor Outputs

[DD]D.DD<TAB>[RRRRRR]R<TAB>[SSS]S<TAB>[AAA]A<TAB>[TTT]T<CR><LF>
In this configuration, each sample consists of characters as follows: 4 to 6 distance characters (possible values from 0.00 to 999.99 inches or 0 to 99999 mm), TAB, 1 to 7 range characters (possible values from 0 to 4.19 million), SPACE, 1 to 4 signal strength characters (0 to 1023), SPACE, 1 to 4 ambient light level characters (0 to 1021), SPACE, 1 to 4 sensor temperature characters (0.1°F per unit), <CR><LF>. Values enclosed in [] will not appear if they consist only of leading zeros.

9.1.4 Binary Data format, Calibrated Distance Only

DD<FF>
In this configuration, each sample consists of 3 bytes: 2 distance bytes representing the range in 1/100ths of an inch in English output, or mm in metric ouput, followed by one byte with value FF Hex for framing. The maximum value of the distance word is FEFF Hex, to prevent framing ambiguity. The distance is transmitted low byte first. Synchronization should be performed by halting the serial output and then restarting it after flushing the serial input to the host, or by verifying that only one byte in 3 is of value 0xFF.

9.1.5 Binary Data format, Low Level Sensor Outputs Only

RRRSAT<FF><FF>
In this configuration, each sample consists of 8 bytes as follows: 3 range bytes, 1 signal strength byte, 1 ambient light level byte, 1 sensor temperature byte (0 to 255 in units of 0.5 °F), and two bytes with value 255 (Hex FF) for framing. The range is transmitted high byte first.

9.1.6 Binary Data format, Distance Plus Low Level Sensor Outputs

DDRRRSAT<FF><FF>

In this configuration, each sample consists of 10 bytes as follows: 2 distance bytes representing range in units of 1/100 of an inch or in mm, 3 range bytes, 1 signal strength byte, 1 ambient light level byte, 1 sensor temperature byte, and two bytes with value 255 (Hex FF) for framing. The maximum value of the distance word is FEFF Hex, to prevent framing ambiguity. The distance is transmitted low byte first. The uncalibrated range is transmitted high byte first.

10. Current Loop and Pulse Width Outputs

One of the lines in the power/signal cable, not used in the base configuration, carries the optional current loop output or, if the sensor is configured for use with a High Speed Interface, the same line will have an uncalibrated pulse width output signal.

10.1 Pulse Width Output

If the AccuRange 4000 is configured for use with a High Speed Interface, this output provides an uncalibrated measure of range. The period of the pulse is the sample interval for which the sensor has been configured with the Sample Rate command. The high level of the pulse is about 0.9 volts, and the low level is about 0.4 volts. The duration of the low portion of the pulse is proportional to measured range, scaled by the sample rate and maximum range for which the sensor is configured.

The pulse width output is actually a direct indication of the range as measured by the sensor electronics, before any firmware averaging or calibration. The scaling of the pulse width output depends on the sample rate and the maximum anticipated range for which the sensor is configured. The pulse will repeat once per sample interval down to a sample rate of about 200 samples per second. At lower sample rates the pulse will repeat one or more times per sample.

The width of the low portion of the pulse is proportional to range plus a constant offset: Zero range does not give zero pulse width. The pulse duration is also scaled each time a new Sample Rate or Maximum Range command is issued. The scaling is by factors of 2, and is set so that pulses will complete before the start of the next sample, but will take up most of the pulse period when measuring a distance at maximum range. Therefore, the max. range and sample time should be set before using the pulse width output, as changing them may re-scale it.

10.2 Current Loop Output

If the sensor was ordered with the optional current loop output, this line will deliver a current proportional to the measured range. The zero range current, offset of the zero range point (the starting distance), and the span (point of full scale output) may be set. See the Set Zero Point and Set Span Commands. Either calibrated or uncalibrated range may be selected for this output. If calibrated output mode is enabled, the output will be the actual distance to the target. Otherwise, the output will be the indicated sensor range, uncompensated for temperature, signal strength, and other effects.

In the default configuration, the current output is updated 5 times per second. This may be increased or reduced with the Set Sample Rate Command, using either the pushbutton on the back of the sensor or the 'S' command over the serial port.

Best accuracy and noise immunity is obtained by loading the line with a 500 ohm resistor to ground at the measurement point. The default configuration is for calibrated output, with the zero current set to 4 milliamps, the zero point at zero distance, and the span at 650 inches.

The minimum current loop span is approximately 9 inches. Attempts to set a smaller span will result in a span of about 9 inches.

The direction of increasing current output can be reversed by setting the span to a value closer that the previously set zero point.

The current loop output is a single line: The return portion of the "loop" is through ground.

11. Serial and Analog Output Performance Specifications

11.1 Sample rate

Maximum of 770 samples per second for calibrated output, 3300 samples per second for uncalibrated output. The sample rate is programmable to any rate below this, down to one sample per 10 seconds, with a resolution of 1 microsecond. Valid arguments for the sample rate command are 20 (microseconds per sample) to 9999999 (microseconds per sample).

Sample rate has a slightly different meaning for serial output and for the optional current loop output. For serial output, one sequence of characters is transmitted at each sample interval. The sample rate may be limited by the time required to obtain and calibrate a range measurement in calibrated output mode. It may also be limited by the time required to transmit each sample at the specified baud rate. If the baud rate is the limiting factor, data will be transmitted continuously. For calibrated output, the maximum sample rate is 1400 microseconds per sample if only the serial output is enabled.

For current loop output, the current transmitted is updated once per sample interval up to the limits of the sensor's sample rate capability. If a low sample rate is specified the resolution of the output will be 1 part in 4000 over 0 to 20 milliamps, the limit of the output converter. If only the current loop output is enabled, the maximum obtainable sample rate is 1300 microseconds per sample.

If both the serial and current loop outputs are enabled, the maximum output rate is 1500 microseconds per sample for calibrated output.

For uncalibrated output, the maximum serial output rate is 400 microseconds per sample, and the maximum current loop update rate is 300 microseconds per sample.

11.2 Resolution

Range resolution is limited by the sample rate selected and the maximum range to be measured. Specifying faster sample rates or longer maximum ranges will result in poorer resolution. Calibrated range output is always transmitted in units of .01 inches. However, resolution will show up as "steps" in the output values transmitted by the sensor. For the current loop output, resolution may also be limited by the resolution of the digital to analog converter used. This may become noticeable for large span settings, since the inherent sensor resolution for low sample rates is better than 1 part in 10,000. The table below shows the resolution that will be obtained for a variety of sample rate and maximum distance settings.

Maximum Attainable Sample Rates, samples/second

Resolution, inches	Range 6 Feet	30 Feet	55 Feet
.0062	2304	677	390
.0125	4609	1355	781
.0250	9218	2711	1562
.0500	18346	5422	3125
.1000	36873	10845	6250
.2000	50000	21691	12500
.4000	50000	43382	25000
.8000	50000	50000	50000

Current loop output is generated with a resolution of 1 part in 4000, and is linear with respect to measured range to 1 part in 1000. Selectable zero and span allow full resolution over any distance span.

Sensor amplitude, ambient light, and temperature are 10 bit samples and are internally updated at the same frequency as the range measurement up to 10,000 samples per second.

12. Configuration and Non-Volatile Storage

12.1 EEPROM Operation

The AccuRange 4000 stores its configuration settings in non-volatile memory (EEPROM). Factory configuration values are stored in the EEPROM upon shipment and may be restored at any time using the Reset Configuration command, or by holding the push-button down while powering up the interface.

The configuration commands do not automatically store the changes to the EEPROM. The Write command is used to make these changes permanent. The Write command stores all configuration information, so it can be used once after making several changes. The Read command is used to restore the values from EEPROM and will overwrite any changes not saved with the Write command.

If the interface is unable to read the configuration data on power up or when the READ command is used, the message "EEPROM VALUES INVALID". is sent over the serial port as the present baud rate, or at 9600 baud if the failure occurs on power-up. This will happen if the data has been corrupted due to a power failure during EEPROM write or some other reason. The sensor will then halt, with the indicator lamp flashing, until the switch is pressed. When operation continues, the sensor will be configured with the factory default settings.

The Write command should not be issued repeatedly under computer control in the course of normal operation, since the EEPROM's expected lifetime is 100,000 data changes.

Calibration data is also stored in the EEPROM, but cannot be changed by user commands. If the calibration data becomes corrupted, the message "EEPROM CALIBRATION DATA READ FAILED" is sent over the serial port. The sensor will then halt, with the indicator lamp flashing, until the switch is pressed. When operation continues, the calibrated range output will likely be incorrect, and sensor operation will be impaired. Contact Acuity for assistance.

13. AccuRange 4000 Command Set

All configuration of the sensor may be done via commands sent over the serial port or by using the push-button switch and acknowledgment LED on the back panel. The serial port commands are ASCII commands that may be entered under computer control or from the keyboard of a terminal connected to the port. Configuration information may be stored in nonvolatile EEPROM with the Write command, and is then retained through power cycling.

Each ASCII command is one character, which for some commands must be followed by one or more parameter value characters. Multiple commands may be grouped together in a single serial transmission, as there are no terminator characters used, but sending more than 10 characters without pauses at high baud rates may result in loss of input if the CTS serial line signal is not respected.

Commands such as Set Sample rate have parameters that may be variable length. A command is accepted and executed when any character other that a digit ('0'-'9') is received, or when the maximum acceptable length of the command is reached.

Example: To execute a set sample rate command: S50<CR> or S0000050 or S50F100<CR>. The last example also sets the maximum range to be measured. Any character that is not a valid command or a numeric parameter is ignored and will have no effect other than to terminate numeric parameter entry. It is advisable to always terminate single commands or the last command in a sequence with a character such as <CR> or '.' to ensure immediate command execution regardless of the length of numeric parameters entered.

All commands sent over the serial line are alphanumeric ASCII characters, allowing terminal keyboard entry. Command characters may be upper or lower case.

To enter commands with the switch and LED on the interface, press and hold the switch. The LED will go out for one second, and then will flash once per second as long as the switch is held. Hold it for the number of flashes given as the input switch code for that command. If a parameter is required, release the switch briefly as the command code flash count is reached (until the LED comes on after being released), then press and hold the switch for the number of flashes as required by the parameter value. The switch may be released any time after the start of a flash, before the next one starts. After the switch is released and the command entry is complete, the LED will flash in acknowledgment for a number of flashes equal to the total in the command, with a hesitation between the command and parameter. Commands take effect after the acknowledgment flashes.

Remember to make the changes permanent with the Write command (9 flashes) if desired, before turning off the power.
Example: To set the baud rate to 2400 baud, press and hold the push-button and wait for the LED to go out and then flash 10 times. Release the button. The LED

will stay out, indicating that a parameter value should be entered. Press and hold the button until the LED has flashed 4 times. Release the button. The LED will flash 10 times, pause, flash 4 times, and the baud rate will be set to 2400.

13.1 Command Quick Reference

One byte commands are shown below as ASCII Code:<Commandcharacter>.
Multiple byte commands are shown as:
ASCII Code: <Commandcharacter:> <<Parametername>>.

If the command may also be entered using the push-button, the number of LED flashes for that command is also given below.

Bracketed numeric parameters [...] are optional. Omitting an optional numeric parameter will set the value to the present internally measured value of that parameter. When using the switch and LED to enter commands, many optional parameters may only be set to their present values, since high resolution entry is not possible with the switch as an input device.

Default settings are for the factory configuration.

The notation (Serial Entry Only) indicates that the command cannot be given using the pushbutton on the back of the sensor.

Command Name	Length	Command Code	Default Setting
Set Sample Interval	3-8 bytes	ASCII Code: S<Interval> (20 <= Interval <= 9999999) Input switch code: 8<Rate Code>	5 samples/second (S200000)
Set Maximum Range	1-6 bytes	ASCII Code: F [<MaxRange>] (0 <= MaxRange <= 99999) Input switch code: 5	650 inches
Set Zero Point (Calibrated)	1-6 bytes	ASCII Code: Z[<ZeroPoint>] (0<=ZeroPoint <= 99999) Input Switch code:1	Zero range
Set Zero Point (Uncalibrated)	1-8 bytes	ASCII Code: Y[<ZeroPoint>] (0<=ZeroPoint <= 9999999) Input Switch code:16	

Command Name	Length	Command Code	Default Setting
Laser Power On	1 byte	ASCII Code: H Input switch code: 6	Laser on
Laser Power Off	1 byte	ASCII Code: L Input switch code: 7	
Enable Serial Data Output	2 bytes	ASCII Code: A<Mode> (Mode: 1=English, 2=low level, 3=flowctl, 4=Metric(mm)) Input switch code:11 <Mode>	English output enabled, uncalibrated outputs disabled, flowctl disabled
Disable Serial Data Output	2 bytes	ASCII Code: T<Mode> (Mode: 1=calibrated, 2=low level, 3=flowctl, 4=Metric(mm)) Input switch code: 12<Mode>	English output enabled, uncalibrated outputs disabled, flowctl disabled
Set Baud Rate	2 bytes	ASCII Code: B<Baud Rate Code> 1=300, 2=600, 3=1200, 4=2400, 5=4800, 6=9600, 7=19200, 8=38400 Input switch code: 10<Baud rate Code>	9600 baud
Set Serial Output to ASCII (Serial Entry Only)	1 byte	ASCII Code: D	ASCII Output
Set Serial Output to Binary (Serial Entry Only)	1 byte	ASCII Code: N	
Set Analog Zero Current	1-5 bytes	ASCII Code: J[<Current Output>] (Current Output, microamps) Input Switch Code: 3<Operation Code> Operation Code: 1:Set to 0. 2:Set to present current.	4 milliamps
Set Span	1-8 bytes	ASCII code: U[<Span] (0<=Span<=9999999) Input switch code:2	650 inches
Set Analog Output Mode	2 bytes	ASCII Code: X[<Mode>] (Mode:1=calibrated, 2=uncalibrated, 3=off) Input switch code:4	Calibrated Output

Command Name	Length	Command Code	Default Setting
Read Configuration Data From EEPROM	1 byte	ASCII Code: R Input Switch Code:18	
Write Configuration Data To EEPROM	1 byte	ASCII Code: W1234 Input Switch Code:9	
Reset Configuration to Factory Defaults	1 byte	ASCII Code: I Input Switch Code:15	
Set Temperature Hold Level	1-3 bytes	ASCII Code: C[<Temp To Hold>] (Temp. To Hold: 32-99 in ^{o}F). Input Switch code:13	95^{o}F
Take Single Sample (Serial Entry Only)	2 bytes	ASCII code: E[<Cal/Uncal.] (1=calibrated, 2=uncalibrated, 3=both)	
Set Minimum Valid Amplitude	1-4 bytes	ASCII Code: P[Amplitude] Input Switch Code: 17	0
Set Maximum Valid Amplitude	1-4 bytes	ASCII Code: M[Amplitude] Input Switch Code: 18	1023 (ASCII fmt) 0FFH (Binary fmt)
Show Version Number	4 bytes	ASCII Code: V1234	

13.2 Command Descriptions

The notation (Serial Entry Only) indicates that the command cannot be given using the pushbutton on the back of the sensor.

Set Sample Interval 2-8 bytes ASCII Code: S <Interval>
(20 <= Interval <= 9999999)
Default: 200000 (5 Samples/second) Input switch code: 8<Sample Rate Code>

Applies to serial and current loop output. When invoked as the "S" command over the serial port, sets the output rate of the sensor to the specified sample interval in microseconds. Interval must be 7 characters or less. Leading zeros may be included. Samples will not be sent unless corresponding output is enabled. For serial data, if the interval is less than the time required to transmit the data at the selected baud rate, samples will be sent continuously. Maximum rate will be limited by processor capacity when producing calibrated output.

To set with the pushbutton: The sample rate may be set to 1, 10, 100, or 1000 samples per second. The command code is 8, followed by the sample rate code. Allowed sample rate code values and resultant sample rates are:

Sample Rate Code	Sample Rate
1	1000 samples/second (1000 microsec/sample)
2	100 samples/second (10000 microsec/sample)
3	10 samples/second (100000 microsec/sample)
4	1 sample/second (1000000 microsec/sample)

Set Maximum Range 1-6 bytes ASCII Code: F [<Max Range>]
(0 <= Max Range <= 99999)
Default: 650 inches Input switch code: 5

Specifies the maximum range the sensor will be expected to measure, in inches, or to the presently measured distance if no numeric parameter is entered or the pushbutton is used. Setting this value to a short distance allows maximum resolution to be obtained for higher sample rates. See the section on resolution in the Serial and Analog Output Performance chapter. It is suggested that for sample rates above 1000 samples per second, this value be set as low as the maximum expected range allows.

Note: The maximum range cannot be set to a value greater than its present value with the pushbutton. The sensor will not properly measure distances beyond the maximum range setting, so attempting to set the maximum range to a greater value will give unpredictable results. The serial port may be used to set a long maximum range, and then the pushbutton used to set a closer value.

Set Zero Point (Calibrated) 1-6 bytes Default: 0 inches	ASCII Code: Z[<Zero Point>] (0 <= Zero Point <= 99999) Input switch code: 1

Applies to serial and current loop outputs. Sets the zero point for the serial and analog current outputs to the value specified. If English output mode is enabled, the distance should be entered in 1/100ths of an inch. If metric output is enabled, the distance should be entered in millimeters. If no numeric parameter is entered or the pushbutton is used to enter this command the zero point will be set to the presently measured range. The sensor should be operating and pointed at a stationary target to use the latter technique. Note: The zero point may be set for either the calibrated output or the low level sensor output, but setting one will reset the other to zero. The sensor can be made to reverse the direction of increasing distance values for the serial and current loop outputs by setting the zero point and then using the U (Set Span) command with a closer location specified (See the Set Span command).

Set Zero Point (Uncalibrated) 1-8 bytes Default: Zero counts	ASCII Code: Y[<Zero Point>] (0 <= Zero Point <= 9999999) Input switch code: 16

Applies to serial and current loop outputs. Sets the zero point for the serial and analog current outputs to the value specified in the present uncalibrated operating resolution of the sensor, or to the presently measured range if no numeric parameter is entered or the pushbutton is used to enter this command. The physical location of this point will depend on the sample rate and maximum range settings, and is in the same units as are in effect when the command is issued. The sensor should be operating and pointed at a stationary target to use the latter technique. Note: The zero point may be set for either the calibrated output or the low level sensor output, but setting one will reset the other to zero.

Set Span	1-8 bytes	ASCII Code: U[<Span>] (0 <= Span <= 9999999)
Default: 650 inches (undefined in uncalibrated mode)		Input switch code: 2

Set the point at which the current loop output is set to its maximum value. If the span is set to a distance which is less than a previously set zero point, the sensor output values will increase as the target point moves closer from the zero point to the span point. Other than causing this reversal of direction in the serial data, this command does not affect the serial output. If English output mode is enabled, the distance should be entered in 1/100ths of an inch. If metric output is enabled, the distance should be entered in millimeters. If no numeric parameter is entered or the pushbutton is used to enter this command, the distance at which the full scale level is output will be set to the presently measured range. If a parameter is entered, it is interpreted as the absolute distance from the sensor, not the distance from the zero point.

The sensor should be operating and pointed at a stationary target to set the span to the presently measured range. Note that if the zero point is subsequently changed with Set Zero Point, the full scale range position will change by the same amount, so that the span is preserved. Generally, the span should be set after the zero point.

Set Analog Output Mode	2 bytes	ASCII Code: X[<Type>] (Type:1=Calibrated,2=Uncalibrated, 3=off)
Default: Calibrated, if current loop installed.		Input switch code: 4

Selects whether the current loop output will be based on the calibrated distance or on the direct, uncalibrated sensor output, or turned off. Note that any changes to the zero point and the analog span are dependent on the output type enabled. Therefore, this command should be used to select the desired output type prior to setting the zero and span locations.

If the current loop output is enabled, a current between the zero current level and 20 milliamps will be transmitted out the current loop line. The zero reading current may be set anywhere from 0 to 20 milliamps with the Set Zero Current Command, and the Zero Point and Span commands may be used to set the distances at which minimum and maximum current occur. This command has no effect if the Current Loop option is not installed other than to reduce the maximum sample rate, and should be left set to Off.

Laser Power On	1 byte	ASCII Code: H Input switch code: 6
Factory Default: Laser on.		

Turns the laser on. For both the 4000-LIR and 4000-LV, this command turns the laser on within 50 microseconds of reception.

Laser Power Off	1 byte	ASCII Code: L Input switch code: 7

Factory Default: Laser on.

Turns the laser off. For both the 4000-LIR and 4000-LV, this command turns the laser off within 50 microseconds of reception.

Enable Serial Data Output	2 bytes	ASCII Code: A <Mode> Input switch code: 11 <Mode>

Default: English calibrated output enabled, Low level internal sensor data (uncalibrated) output disabled, flow control disabled.

Enables serial output transmission. Either or both of calibrated distance and internal sensor information may be transmitted at every sample time. Calibrated distance may be ouput in either inches or millimeters. If only calibrated output is enabled, the serial data stream consists only of actual distance measurements, in either ASCII or binary format. If only internal sensor information is enabled, the output stream contains only the uncalibrated range in internal sensor units, along with the signal strength, ambient light level, and sensor temperature. If both types of output are enabled, the calibrated distance is followed by the sensor information.

Calibrated distance measurements are corrected for signal strength and temperature with the AccuRange 4000 internal calibration algorithm. Calibrated output is the form typically used, unless the amplitude and other information is also required.

See the Output Data Formats section for a detailed description of the possible output formats, in ASCII or Binary. For high sample rates, disable any unused output mode. Disable both serial modes to halt serial output and improve the update rate of the current loop output.

RS-232 flow control is also enabled with this command. See the section on Flow Control.

Mode Value	Output Enabled
"1" or 1	Serial Calibrated Output in Inches
"2" or 2	Serial Uncalibrated
"3" or 3	Flow Control
"4" or 4	Serial Calibrated Output in Millimeters

If any serial output is enabled, and flow control is disabled or the DTR input is asserted, sample data is transmitted over the serial line at the selected sample rate and baud rate, in ASCII or binary as specified with the Set ASCII and Set Binary commands. If flow control is enabled, the state of the DTR input on the serial connector is monitored and output is suspended if the signal is false.

Disable Serial Data Output 2 bytes — ASCII Code: T <Mode>
Input switch code: 12 <Mode>

Factory Default: English calibrated output enabled, Low level internal sensor data output disabled, flow control disabled.

Disables the serial output data mode specified by the parameter. See the Enable Serial Data Output command. For high sample rates, disable all unused output modes. Flow control may also be disabled with this command.

Set Baud Rate 2 bytes — ASCII Code: B <Baud Code>
Default: 9600 Baud (Baud Code 6) — Input switch code: 10 <Baud Code>

Sets the baud rate to the specified value, as given by the following table. Note that if the baud rate combined with the number of bytes sent per sample (as determined by the output format: ASCII or Binary, Calibrated or Uncalibrated) exceeds the selected sample time, data will be transmitted continuously.

Baud Code (button or ASCII)	Baud Rate
1 or “1”	300
2 or “2”	600
3 or “3”	1200
4 or “4”	2400
5 or “5”	4800
6 or “6”	9600
7 or “7”	19200
8 or “8”	38400

Set Analog Zero Current 6 bytes ASCII Code: J [<Currentlevel>]
Input Switch Code: 3<Option Code>
(Option Code = 1, 2)

Factory Default: 4 milliamps

Sets the current that the analog output will deliver when the measured distance is less than or equal to the zero point as set by the Set Zero Point command. If the current drops below this level, the interface has experienced a hardware failure. The level may be set from 0 to full scale (20 mA).

When invoked by serial line, this command sets the zero current to the level specified, in microamps, or to the present current output level if no numeric parameter is entered. A value of 4000 will set it to 4 milliamps.

When invoked by push-button, there are 2 zero current setting options. They are:

Button Option Code 1: Set Zero Current to Zero milliamps. If the range is less than or equal to the zero point as set by the Zero command, the current loop output will be zero. To see the current go to zero upon using this command, use the Zero Point command first, and then point the sensor at a closer target and use this command. Setting the zero current to a level below its present value with the button must be done in 2 steps. The first is this step. The second is to use Set Zero Current to Present Reading.

Button Option Code 2: Set Zero Current to Present Reading. The zero current value is set to the present current level being output. To use this command, first use the Set Zero Current to Zero command, above. Then point the sensor at a target at a range which causes the desired zero current to be output and use this command.

Read Configuration Data From EEPROM 1 byte ASCII Code: R
Input Switch Code: 18

Reads the configuration from the EEPROM and makes it the current configuration. It may be used to restore the power-up configuration if a temporary change has been made with any of the configuration commands, and those changes have not been written to the EEPROM. This command is executed automatically upon power on.

Write Configuration Data To EEPROM 1 byte ASCII Code: W1234
Input Switch Code: 9

Sets the power up state of all configuration options to their present values. The configuration is immediately preserved and automatically becomes the new power up default. The argument “1234” is required to prevent accidental writes during power up. Factory defaults may be restored at any time with the Reset Configuration to Factory Defaults command.

Reset Configuration to Factory Defaults	1 byte	ASCII Code: I Input Switch Code: 15

Restores the operating configuration to the original factory defaults. May be used if the present state is unknown or inconvenient. This reconfiguration is NOT saved to EEPROM: The Write command must then be used to make this initialization permanent. The configuration may also be set to the factory settings by holding the push-button down on power up. The LED will stay off until the button is released, and the factory configuration will be loaded.

Set Serial Output to ASCII (Serial Entry Only)	1 byte	ASCII Code: D

Factory Default: ASCII

Sets the serial output format to ASCII, allowing it to be read on a terminal. See the Output Data Formats section for a detailed description of the serial data stream in ASCII format.

Set Serial Output to Binary (Serial Entry Only)	1 byte	ASCII Code: N

Factory Default: ASCII

Sets the serial output format to binary. See the Output Data Formats section for a detailed description of the serial data stream in binary format.

Set Temperature Hold Level	1-3 bytes	ASCII Code: C[<Temp. To Hold>] (Temp. To Hold: 32-99 in ^{o}F) Input Switch Code: 13

Factory Default: 95^{o}F

If power is applied to the temperature control power supply lines, the temperature will be maintained at this temperature or higher in the AccuRange 4000. On power up, the time to reach the target temperature is approximately 30 seconds/^{o}F temperature difference. Only heating capability exists, so the temperature may rise above this level if the ambient temperature is high. If this command is given with the push-button or without parameters, the present temperature is used as the temperature to hold.

Take Single Sample (Serial Entry Only)	2 bytes	ASCII Code: E[<Cal/Uncal.] (1=Calibrated, 2=Uncalibrated, 3=Both)

Turns on the laser, waits approximately 100 microseconds for the laser output to stabilize, takes a sample, turns the laser off, and sends the sample results over the serial port. If the parameter value is 1, calibrated distance is sent. If the parameter value is 2, uncalibrated range and other sensor data is sent. If the value is 3, both are sent. Note that the laser is turned off after this command, even if it was previously on.

Set Minimum Valid Amplitude 1-4 bytes ASCII Code: P[Amplitude] Input Switch Code: 17 Factory Default: 0 (Distance output calculated for all amplitudes) Sets the amplitude (signal strength) below which the calibrated distance output from the serial port and current loop will be zero. This may be used to detect and prevent what would be inaccurate readings resulting from low signal strength. If no parameter is entered or the switch is used to issue this command, the presently measured amplitude is used as the threshold value. Values from 0 to 999 may be entered. The amplitude of a range measurement is part of the sensor data which may be sent over the serial port using the Enable Serial Data Output command (Command "A2").

Set Maximum Valid Amplitude 1-4 bytes ASCII Code: M[Amplitude] Input Switch Code: 18 Factory Default: 1023 (Distance output calculated for all amplitudes) Sets the amplitude (signal strength) ABOVE which the calibrated distance output from the serial port and current loop will be zero. This may be used to detect and prevent what would be inaccurate readings resulting from sensor overload. If no parameter is entered or the switch is used to issue this command, the presently measured amplitude is used as the threshold value. Values from 0 to 999 may be entered. The amplitude of a range measurement is part of the sensor data which may be sent over the serial port using the Enable Serial Data Output command (Command "A2").

Show Version Number 4 bytes ASCII Code: V1234 (Serial Entry Only) The characters V1234 entered in sequence will cause the firmware revision number of the sensor to be output. If data is being output when this command is used, the version number will appear between samples. The argument "1234" is required to prevent accidental output during data transmission.

14. Data Sheet: Summary of Specifications

Download the most recent data sheet at www.acuityresearch.com/ar4000

15. AccuRange Line Scanner

15.1 General Description

The AccuRange Line Scanner consists of a motor with encoder and a mirror mounted on the motor. The mirror is machined from aluminum and coated with protected silver for high reflectance for both the 4000-LV and 4000-LIR. The mirror is encased in a cylindrical sleeve which together with the mirror forms a balanced system for minimum vibration when rotating.

The mirror deflects the outgoing beam from the sensor 90 degrees, and sweeps it through 360 degrees as the mirror rotates. Returning light is deflected off the mirror back into the sensor. The mirror surface is sized to match the collection aperture of the sensor.

Sensor and scanner are mounted on a flat plate that holds the mirror in the proper location relative to the sensor. The plate causes a blind spot of about 60 degrees of arc.

The line scanner is intended to be primarily used as a constant-speed scanner, although it is possible to control the position of the mirror through software to create a point-to-point scanner.

15.2 Scanner Performance Specifications

Mirror Reflectance: 96%. Total losses are 8% for the outgoing and return light together. This results in a slight reduction in sensitivity, which is not usually noticeable.

Maximum Motor Speed: 2600 R.P.M. Custom configurations with larger motors for higher speed are possible. This speed should not be exceeded. even though it is possible to do so with high motor power supply voltages and/or motor power settings.

Encoder: 2000 quadrature counts per revolution. 0/5 Volt levels, 2 channels plus index pulse.

Speed and Power Consumption: Motor speed at different voltages is shown below. This is the typical speed with power applied directly to the motor. If the scanner is controlled through the High Speed Interface, the motor speed will depend on the power level for which the motor is programmed.

Applied Voltage	Scanner Speed	Scanner Current
5.0	1050 rpm	45 mA
10.0	2100 rpm	90 mA
12.0	2600 rpm	110 mA

Typical Scanner Speed and Power

15.3 Scanner Installation and Use

If the scanner was ordered and delivered with an AccuRange 4000, the sensor will be mounted together with the scanner. If they were ordered separately, the sensor should be mounted so that the beam aligns with the motor axis, both in position and angle. If the scanner is ordered with the High Speed Interface, the motor encoder comes connected to the appropriate pins from the interface connector. For connection to other encoder readers, the encoder pinout is shown below.

Pin	Connector Wire Color	Function
1	Black (left side of encoder, viewed from top)	Ground
2	Blue	Index Pulse
3	White	Channel A
4	Red	Vcc (+5 Volts)
5	Brown	Channel B

Encoder Pinout

The index pulse is a brief pulse lasting 1/1000 of a revolution, occurring once per revolution. Channels A and B are standard quadrature signals, 50% duty cycle square waves, 90 degrees out of phase.

Do not attempt to remove the encoder from the motor. Encoder alignment is critical and will be lost. If necessary, the mirror can be removed from the motor shaft by loosening the two set screws holding the mirror sleeve to the shaft, but increased vibration at high motor speeds may result after reinstallation.

The mirror should be kept clean and free of excessive dust, fingerprints, etc. It may be cleaned with a soft cloth and alcohol or water.

15.4 Line Scanner Data Sheet

Download the most recent datasheet at www.acuityresearch.com/line-scanner