LumaSense® Technologies Has Joined Advanced Energy®

Luxtron m920 Series Module

Fiber Optics Temperature Sensor

User Manual

November 2020 **Part No 514-0012-01 Revision D**

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PRIMARY CONTACT INFORMATION

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http://www.advancedenergy.com

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  800.446.9167

  or

  +1.970.221.0108

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  mailto:technical.support@aei.com

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+1.360.694.7871

mailto:thermalapplications@aei.com

Contents

1 General

1.1 Information about the user manual

Congratulations on choosing this high quality and highly efficient LumaSense instrument.

This manual provides important information about the instrument and can be used as a work of reference for installing, operating, and maintaining your instrument. It is important that you carefully read the information contained in this manual and follow all safety procedures before you install or operate the instrument.

To avoid handling errors, keep this manual in a location where it will be readily accessible.

1.1.1 Legend

Note: The note symbol indicates tips and useful information in this manual. All notes should be read to effectively operate the instrument.

Attention: This sign indicates special information which is necessary for a correct temperature measurement.

Warnings and Cautions: The general warnings and cautions symbol signifies the potential for bodily harm or damage to equipment.

1.2 Safety

This manual provides important information on safely installing and operating the m920 Series Module.

Several sections of this manual provide safety warnings to avert danger. These safety warnings are specified with a warning symbol. You must read and understand the contents of this manual before operating the instrument even if you have used similar instruments or have already been trained by the manufacturer.

It is also important to continually pay attention to all labels and markings on the instrument and to keep the labels and markings in a permanent readable condition.

Warning: The instrument is only to be used as described in this manual. It is recommended that you only use accessories provided by the manufacturer.

1.3 Unpacking the Instrument

Before shipment, each instrument is assembled, calibrated, and tested at the LumaSense Factory. When unpacking and inspecting your system components, you need to do the following:

1. Check all materials in the container against the enclosed packing list.

   LumaSense Technologies cannot be responsible for shortages against the packing list unless a claim is immediately filed with the carrier. Final claim and negotiations with the carrier must be completed by the customer.

2. Carefully unpack and inspect all components for visible damage. If you note any damage or suspect damage, immediately contact the carrier and LumaSense Technologies, Inc.

3. Save all packing materials, including the carrier's identification codes, until you have inspected all components and find that there is no obvious or hidden damage.

Note: LumaSense encourages you to register your product with us to receive updates, product information, and special service offers: http://info.lumasenseinc.com/registration.

1.4 Disposal / decommissioning

Inoperable instruments must be disposed of in compliance with local regulations for electro or electronic material.

1.5 RoHS Compliant

The m920 Series module is RoHS 2 compliant.

2 Introduction

The m920 Series Module consists of the m924 four-channel module and the m922 two-channel module. These modules are designed to replace the existing LumaSense Series m800 and m600 class Fiber Optic Temperature (FOT) sensors and provide a higher performance solution with improved manufacturability and modern architecture.

The m924 and m922 modules provide accurate, precise, and repeatable temperature measurements for control of processes involving EMI and high voltages. It is ideal for monitoring temperature in critical control applications, including high-voltage, microwave, plasma, strong magnetic fields, inductive heating, and RF environments.

Key improvements over the Series m800 and m600 class include:

- Completely independent channels
- Improved speed, up to 50 Hz on each channel
- Ability to excite Alpha phosphor and allow for backwards compatibility with all LumaSense/Luxtron Alpha phosphor probes
- Extended calibration capacity to provide improved accuracy over a wider temperature range
- Superior environmental shielding resulting in improved noise performance
- Improved user interface and added software features
- Fully RoHS 2 compliant, modern design

2.1 Theory of Operation

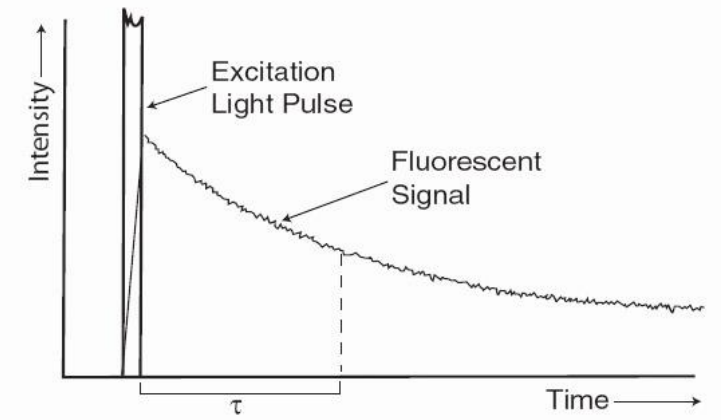
The m920 Series Module builds upon the previous generation of fiber optic thermometry modules first commercialized by LumaSense (formerly Luxtron in 1978). This technology utilizes the temperature dependent decay time of a phosphorescent material.

The complete LumaSense m920 Series Module consists of the Electronics module assembly plus probes. The probes are often custom developed for each application. Optional accessories include other FOT probes, fiber optic extension cables, vacuum feedthroughs, special bulkhead fittings, metal enclosure, etc.

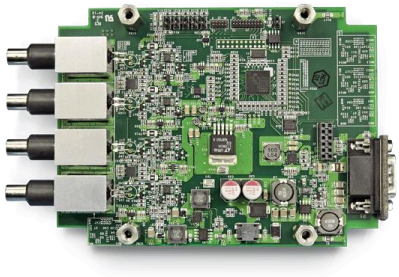
The m920 Series Module uses LumaSense Technologies' Fluoroptic® technology, based on a temperature sensitive phosphorescent sensor attached to the end of an optical fiber. Pulses of light are transmitted down the fiber optic probe causing the sensors to be excited and phosphoresce. The electronics of the m920 Series Module detect and calculate the decay time of this phosphorescence after each pulse. This decay time varies precisely with the temperature of the sensor, providing the basis for accurate temperature measurement.

The figure below shows a representation of the method used to extract the florescence decay time (τ) of the phosphor sensor.

A mathematical curve fit correlates individual data points with stored values of (τ). The measured value of (τ) is then conditioned with the values in appropriate calibration tables to determine temperature.



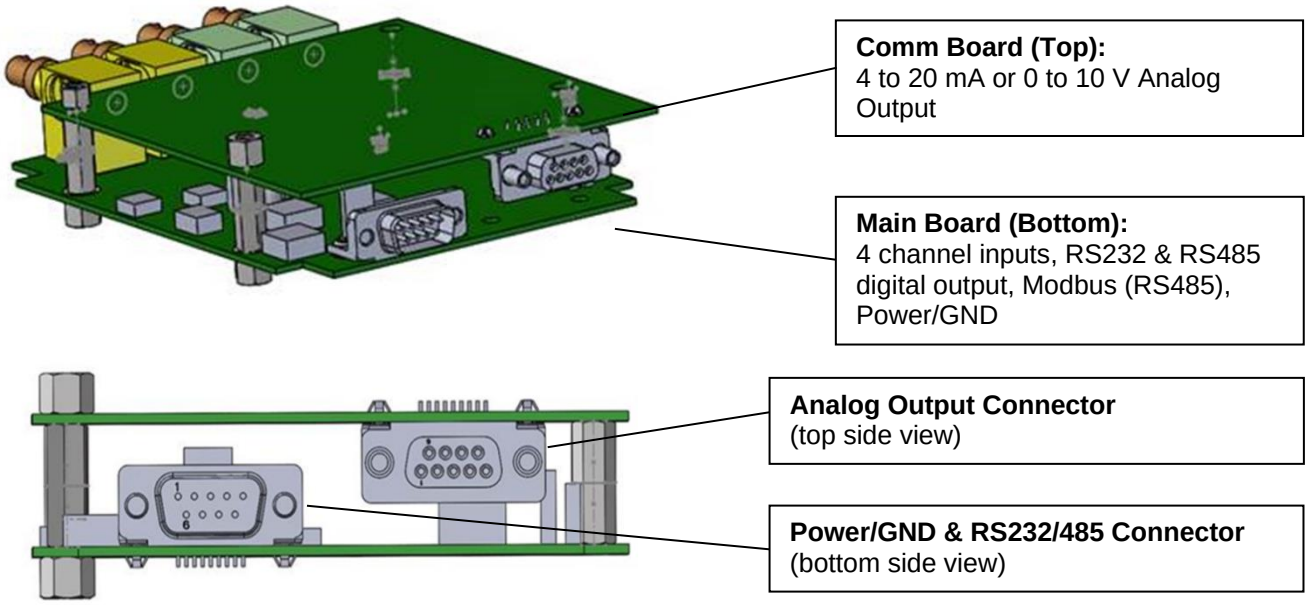
2.2 Technical Data

	m924 Series Module
	
Number of Channels	2, 4
Temperature Range	- 100 … 330 °C (probe dependent)
Matched Probe Accuracy	± 0.05 °C (probe dependent)
Mix & Match Probes Accuracy (Accudisc)	± 0.25 °C over limited temperature range (probe dependent)
Sampling Rate	50 Hz each channel
Analog Output	0 …10 V or 4 … 20 mA
Communication interface	RS232 / RS485
Protocol	ASCII, Modbus
Operating Temperature	- 40 … 85 °C
Input Power	5 … 24 V DC nominal @ 100 mA
Dimension	Main Board: 23.7 mm (H) x 100.6 mm (W) x 134.4 mm (L)
Enclosure Option	Yes

2.3 Physical Interface Overview

This design is intended to be a functional replacement for the m800 and m600 series of FOT systems. The system has been designed to be backwards compatible to the m800 and m600 series instruments and supports all series probes and series command sets. Additional features and commands allow for increased performance.

The electronics module is comprised of two boards. PCBs are stacked to form a system. See diagram below for a functional description:



The **Main Board** includes:

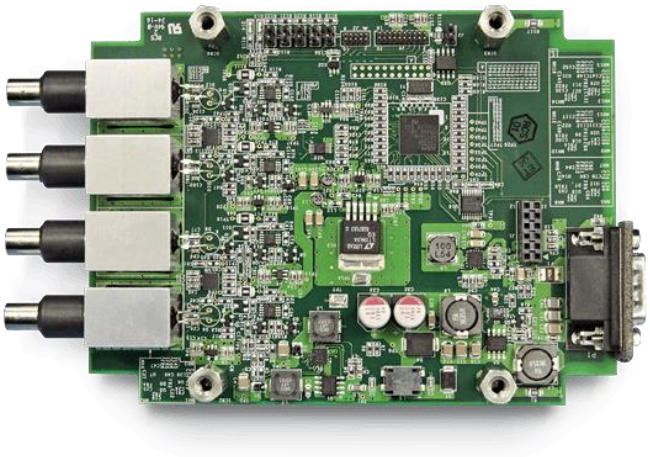
1. The CPU, power supply, RS232 and RS485 communications interface
2. An LED driver circuit containing the actual interface to the external fiber optics. The m920 Series Module can have 2 fiber optic channels (m922) or four fiber optic channels (m924).
3. Modbus is available from the Main Board (standard).

The **Comm Board** (optional) is a daughter board for Analog Output.

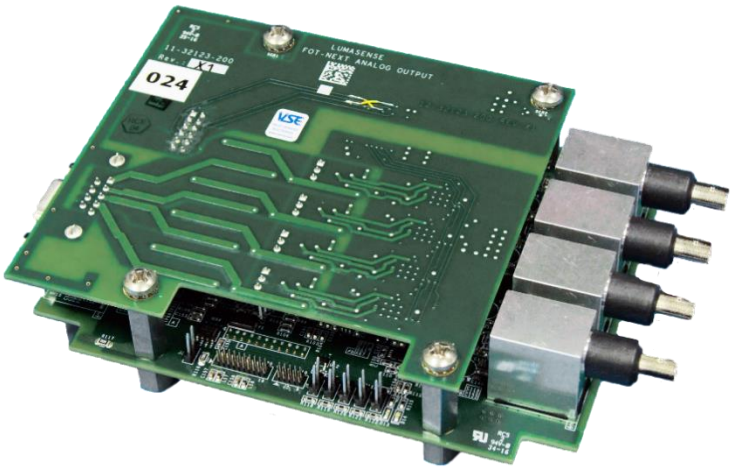
The Analog Output board provides an analog output interface, which supports:

- 4 … 20 mA output
- 0 … 10 V DC output

The analog output board is the same for both output types. This board provides electrical isolation, surge, static and lightening protection.



m924 Main Board



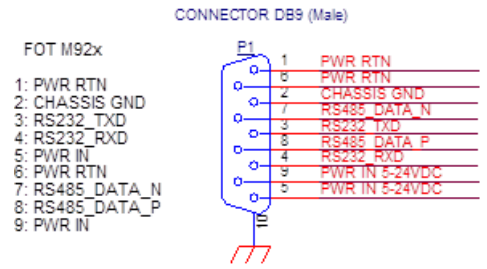
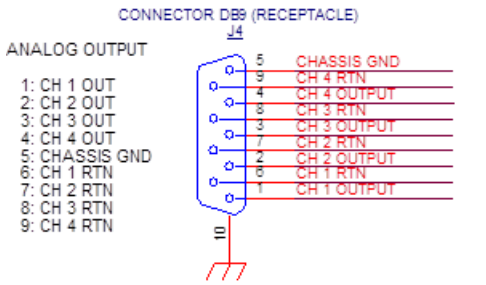
Analog Output Comm Board (on top of m924 Main Board)

An enclosure is available to house the m920 Series module. Shown below is the m924 module inside the metal enclosure.

m920 Series Module Enclosure (Front Side)

m920 Series Module Enclosure (Back side)

The diagram below shows the pin assignments for the two connectors located on the back of the m920 Series Module. The male DB-9 connector (Main) is used for the power and digital communication. The female DB-9 connector (Option) is used for the optional communication such as analog output.

Male DB-9 (MAIN)	Female DB-9 (Analog Output)
	

Note: Pin 10 represents the DB-9 shells which are tied to Pin 2 of the Main Board Chassis ground. This connection should be tied to the facilities earth ground.

2.4 Probe Connections

The m920 series accepts all LumaSense probes with ST style connectors. Attach each probe to the optical port by carefully rotating the probe alignment pin to match the receptacle slot. Insert until the probe bottoms and then twist to lock into place. Best practice is to connect the probes first and then power on the m920 series instrument. If probes are disconnected and/or reconnected during processing, temperature errors can occur. After changing the probes, always power cycle the instrument or reset the instrument with the Ctrl + X command.

2.5 Electrical Connections

Providing power supply and electrical cabling to support the m920 series installation is the responsibility of the customer. Refer to the following drawing and recommendations.

Digital:

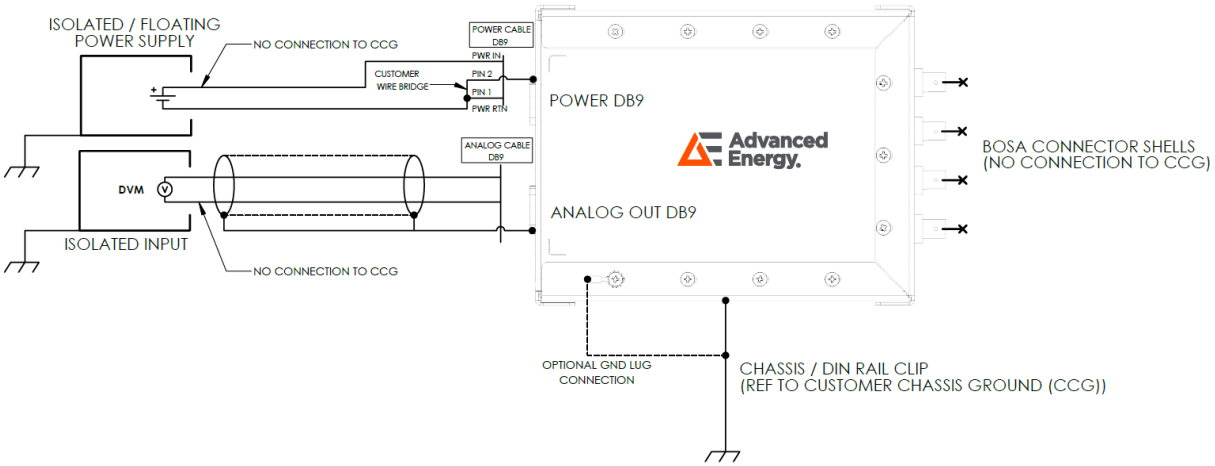
- Use the DIN rail (or the provided Grounding Stud) as the ONLY connection to customer chassis ground (ccg). This serves as the local ground reference for the FOT subsystem.
- Make only ONE connection between PWR RTN (negative pole of the power supply) and the local ground reference by providing a wire on the customer side of the Main DB-9 Connector (Connector for Power and RS232) between Pin1 and Pin2 of that connector.

  The power supplies positive and negative pole must be floating in respect to customer chassis ground.
- The ST Fiber optic connection port and ST probe connector should be electrically isolated.

  No metal connections should touch the Fiber Optic inputs.

Analog:

- The shell of the analog DB-9 connector cannot be connected to customer chassis ground elsewhere (such as at the other end of the analog cable).


ISOLATED / FLOATING
POWER SUPPLY
NO CONNECTION TO CCG
POWER CABLE
DB9
PWR IN
CUSTOMER
WIRE BRIDGE
PIN 2
PIN 1
PWR RTN
POWER DB9
Advanced
Energy.
BOSA CONNECTOR SHELLS
(NO CONNECTION TO CCG)
ANALOG CABLE
DB9
DVM
ANALOG OUT DB9
ISOLATED INPUT
NO CONNECTION TO CCG
OPTIONAL GND LUG
CONNECTION
CHASSIS / DIN RAIL CLIP
(REF TO CUSTOMER CHASSIS GROUND (CCG))

3 Probe Calibration

A preliminary calibration has already been made at the LumaSense facility for each m920 Series Module with a reference probe(s). When the proper table is selected for the probe installed then the default system accuracy is obtained (Generally ± 2 °C over the complete range) when any probe is used on any channel. This is called *"No Calibration"*.

Note: Improved "*Select Mix & Match*" accuracy can be obtained for special probe & table combinations with consultation with the LumaSense factory.

Further improvement in the system accuracy can be obtained by calibrating each probe with a specific channel. This is called *a "Matched Probe"*.

The m920 Series Module has an improved, multi-point calibration algorithm that can provide a significant improvement in calibration accuracy. The user can select a single point, two-point, or three-point calibration. Finally, a complete custom calibration can be made for a selected probe to allow ±0.05 °C over the complete probe range. These calibration options are described in the section below. The table below summarizes the expected system accuracy.

Calibration	Accuracy	Temperature range
No Calibration	± 2 °C	Over complete range of table selected
Select Mix & Match	± 0.25 °C … ± 0.5 °C	Probe dependent > 100 °C range (Example Accudiscs)
Single Point Matched	± 0.5 °C	Within ± 50 °C of cal point (Example Spring Probes)
3-Point Matched	± 0.25 °C	> 100 °C range (Example Spring Probes)
Custom	± 0.05 °C	Over complete range of table (contact LumaSense)

Note: A two hour warm up period is recommended for best accuracy performace.

3.1 Single Point Probe Calibration

1. Connect probes to channels you wish to calibrate.
2. Label probes with channel numbers.
3. Place probes in calibration bath at a known fixed temperature.

   Note: Each probe can be at a separate temperature if desired.

4. Allow probes to stabilize at the bath temperature(s), and see that output readings on the m920 modules are constant and not drifting.
5. Set the Calibration Temperature CT[n] (where n = 1 to 4) value to the reference temperature of the bath (command CT[n]=xx.xx where xx.xx is the temperature (C) Example: CT[1]=30.05 CT[2]=30.05, CT[3]=60.50, CT[4]=80.00

   Note: The command can also be issued as: CT=30.05,30.05,60.50,80.00

6. Select proper table (Command TU[n]=X).
7. Issue the Ctrl K command (to start the auto calibrate routine).

8. The m920 modules will then calculate the offsets needed for each probe, and automatically enter these into the UC[n] parameters.
   (UC[1]=$Ch1_{offset}$, UC[2]= $Ch2_{offset}$ …..)
   (At this point each channel should be reading within ± 0.1 °C of the known bath temperatures.)
9. After the calibration is complete, the calibration flag for each channel will automatically be enabled. (CC[n]=E) to return to the default calibration, you can disable this flag (CC[n]=D)
10. The calibration parameters can also be adjusted by directly editing the UC[n] parameters. This allows for precision adjustment when needed.
11. Once you are satisfied with the calibration, issue the **Save command (SV enter)** to store your settings.

> **Note:** Be sure to always enter the Save command SV, otherwise your calibration will be lost when the power is interrupted.

> **Note:** The calibration is matched to each channel so do not change probes to other channels without re-calibration. You can disconnect probes and reconnect, but swapping channels will result in unknown accuracy.

12. It is recommended to power cycle the m920 series instrument after any Save Command.

3.2 Two & Three Point Calibration

This procedure follows a similar flow as above. But we now add CL (**C**alibrate **L**ow) and CH (**C**alibrate **H**igh) parameters. Where CL < CT <CH

For example, let's assume that the complete range of calibration is 0 to 150 °C. Reasonable calibration temperature choices are: CL=10.00, CT=100.00C, CH=140.00C

1. First, we assume that the calibration has been performed at CT=100 as in the section above.

> **Note:** Be sure to always enter the Save command SV, otherwise your calibration will be lost when the power is interrupted.

2. Next, Set the temperature bath to 140 °C.
3. Let the bath and probes stabilize.
4. **Do not adjust the CT setting**; this must remain set at the original value. CT=100.
5. Set the CH (Calibrate High) temperature to the known bath temperature.
   (CH[n]=140.00)
6. Issue the Ctrl H command to begin the high calibration.
7. When complete the program will have adjusted the UH[n] slope parameters such that the readings agree with the reference bath readings.
   Example: **Toutput = Tmeasured + Offset + (Tmeasured + Offset - CT)*Slope**

> **Note:** The slope parameter can be either positive or negative. This parameter adds a correction to the raw temperature reading that is scaled to the distance from the CT setting.
> *These slopes can also be adjusted by editing the UH[n] parameters*

8. **Save the settings with the SV command and power cycle the instrument.**

9. Next repeat the above steps with the bath set at 10 °C and CL[n]=10
10. Issue the Ctrl L command to initiate the lower calibration command.
11. Once complete, the UL[n] parameters will now have been adjusted.
12. **Save the settings with the SV command and powercycle the instrument**

3.3 Custom Calibration to obtain ±0.05 °C over the complete probe range

To obtain this precision calibration a multi-point (>20 point) calibration is needed. This requires capturing an ordered pair of Tau vs Temperature data over the complete range of the probe. The data is then fit, and a custom lookup table is downloaded into the m924. Please consult with your LumaSense Applications Engineer for more detail.

4 Look up Table/Tau to Temperature conversion

There are multiple tables loaded within the m920 Series Module that convert from the measured decay time (tau) to temperature. Tables 1 through 5 have been determined experimentally at LumaSense for common phosphor probe types. Tables 6+ allow for future expansion.

Table	Description	Temperature range
1	General STF	- 100 … 330 °C
2	Spring probe	- 25 … 200 °C
3	Accudisc probes	- 35 … 170 °C
4	N/A	N/A
5	STB	- 100 … 330 °C
6+	Future Tables	Undefined

The user can select which table to use on each m920 Series module channel. This allows different probes types to be used with one m924 or m922 module. These tables can be modified and updated in the field. Please consult with LumaSense for detailed instructions.

These tables can be selected with the command 'TU=X,X,X,X'

See Section 8.3.22 for more information on the TU[n] command.

5 ASCII Communications

5.1 Hardware

The primary onboard communications is an RS232 serial interface. Presently it operates at a fixed 115.2 kbps, No Parity, 8 bits, 1 stop bit on the DB9 male 'MAIN' connector. The TXD and RXD lines are used to transmit the data to/from the m920 instrument.

5.2 Protocol

The protocol on the RS232 port is ASCII. The table below shows the ASCII character set. Full descriptions of the user commands are available in Section 8.3. The output of the m920 is continuously flowing at a constant data rate of the user's choice. No commands are needed once the device is configured and powered.

5.3 Output data format

The standard data output is of the following form where the format is always fixed. No times stamp is given. Each of the enabled channels is output in the following format of 14 characters per channel (four channel examples below):

1: 181.92 C	2: 200.00P2	3: 39.87 C	4: 0.00P7
1: -36.26 C	2: 0.00P7	3: 39.77 C	4: 0.00P7
ss1:s####.##sC	ss2:s####.##P#	ss3:s####.##sC	ss4:s####.##P#

- where 's' is a space character
- '####.##' is a F7.2 float number (temperature)
- The last two characters are
  - the Temperature unit (C, F or K)
  - Or an error code P# (P0- … P8)

5.4 ASCII Table

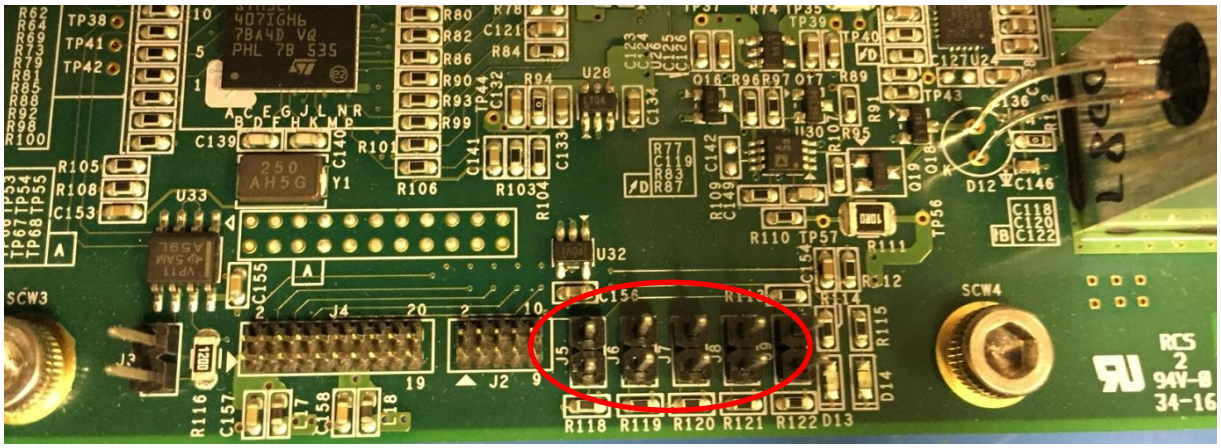
Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char	Dec	Hex	Oct	Char
0	0	0		32	20	40	[space]	64	40	100	@	96	60	140	`
1	1	1		33	21	41	!	65	41	101	A	97	61	141	a
2	2	2		34	22	42	"	66	42	102	B	98	62	142	b
3	3	3		35	23	43	#	67	43	103	C	99	63	143	c
4	4	4		36	24	44	$	68	44	104	D	100	64	144	d
5	5	5		37	25	45	%	69	45	105	E	101	65	145	e
6	6	6		38	26	46	&	70	46	106	F	102	66	146	f
7	7	7		39	27	47	'	71	47	107	G	103	67	147	g
8	8	10		40	28	50	(	72	48	110	H	104	68	150	h
9	9	11		41	29	51	)	73	49	111	I	105	69	151	i
10	A	12		42	2A	52	*	74	4A	112	J	106	6A	152	j
11	B	13		43	2B	53	+	75	4B	113	K	107	6B	153	k
12	C	14		44	2C	54	,	76	4C	114	L	108	6C	154	l
13	D	15		45	2D	55	-	77	4D	115	M	109	6D	155	m
14	E	16		46	2E	56	.	78	4E	116	N	110	6E	156	n
15	F	17		47	2F	57	/	79	4F	117	O	111	6F	157	o
16	10	20		48	30	60	0	80	50	120	P	112	70	160	p
17	11	21		49	31	61	1	81	51	121	Q	113	71	161	q
18	12	22		50	32	62	2	82	52	122	R	114	72	162	r
19	13	23		51	33	63	3	83	53	123	S	115	73	163	s
20	14	24		52	34	64	4	84	54	124	T	116	74	164	t
21	15	25		53	35	65	5	85	55	125	U	117	75	165	u
22	16	26		54	36	66	6	86	56	126	V	118	76	166	v
23	17	27		55	37	67	7	87	57	127	W	119	77	167	w
24	18	30		56	38	70	8	88	58	130	X	120	78	170	x
25	19	31		57	39	71	9	89	59	131	Y	121	79	171	y
26	1A	32		58	3A	72	:	90	5A	132	Z	122	7A	172	z
27	1B	33		59	3B	73	;	91	5B	133	[	123	7B	173	{
28	1C	34		60	3C	74	<	92	5C	134	\	124	7C	174	|
29	1D	35		61	3D	75	=	93	5D	135	]	125	7D	175	}
30	1E	36		62	3E	76	>	94	5E	136	^	126	7E	176	~
31	1F	37		63	3F	77	?	95	5F	137	_	127	7F	177	

6 Modbus Communications

This section assumes you have a working knowledge of Modbus protocol.

Note: Modbus does not use encrypted communications or authentication/passwords. When using this protocol, it is the user's responsibility to provide end-to-end secured communications to prevent system configuration from an unauthorized remote computer.

The m920 Series Module supports Modbus communication protocol over RS485. Modbus and RS485 are available on the m920 Main Board. Modbus is configured as slave with addresses 1 to 16 set by jumpers J5 – J8 on the m920 Series Main Board to support expansion up to 64 channels. The Modbus communication is query only. Any commands to configure the m920 Series should be sent by the RS232 port on the Main Board. Modbus on the m920 Series supports only RTU mode. The RS485 port with Modbus communication supports 8 bits, 1 stop bit, even/odd/no parity, and five different baud rates (9600, 19200, 38400, 57600, 115200 bps).



6.1 Jumper Settings for Board ID

The table below shows which jumpers to set for the desired board IDs. J indicates jumper is set and X indicates no jumper.

Board ID	J8	J7	J6	J5
1	J	J	J	J
2	J	J	J	X
3	J	J	X	J
4	J	J	X	X
5	J	X	J	J
6	J	X	J	X
7	J	X	X	J
8	J	X	X	X
9	X	J	J	J
10	X	J	J	X
11	X	J	X	J
12	X	J	X	X
13	X	X	J	J
14	X	X	J	X
15	X	X	X	J
16	X	X	X	X

6.2 Modbus Registers

Modbus is used only for reporting temperatures and status information like signal strength, LED drive level, error type, SN, and customer ID string. The registers are defined in the following sections.

6.2.1 Coil Registers

A single bit write to coil register at address 1 will reset the m920 Series Module.

Address	Description	Data Type
1	Reset FOT*	Single Bit Read/Writable

*returns 0 until initialization completes

6.2.2 Discrete Inputs Registers

Discrete input registers are single bit readable registers.

Channel enabled registers – Reads 1 if channel is enabled or 0 if channel is disabled.

Channel in Error registers – Reads 0 if there are no errors and 1 if there is a probe error.

1. **m924 (4 channel instrument):** The channel in error register will never be 1 if the corresponding channel enabled registers is 0 (disabled).
2. **m922 (2 channel instrument):** The channel enabled registers for channel 3 and 4 will always be 0 and channel error registers for channel 3 and 4 will always be 1.

Address	Description	Data Type
1	Channel 1 Enabled	Single Bit Readable (Status)
2	Channel 2 Enabled	Single Bit Readable (Status)
3	Channel 3 Enabled	Single Bit Readable (Status)
4	Channel 4 Enabled	Single Bit Readable (Status)
5	Channel 1 is in Error	Single Bit Readable (Status)
6	Channel 2 is in Error	Single Bit Readable (Status)
7	Channel 3 is in Error	Single Bit Readable (Status)
8	Channel 4 is in Error	Single Bit Readable (Status)

6.2.3 Input Registers

Board ID – Board ID of the m920 Series address is between 1 and 16, and is set by the jumpers J5 – J8 on the m920 Series Main Board. This is updated only once at power up since this is not something that can be changed at runtime.

Channel Temperatures – The temperature of the channel in the units set by the UN command. Since Modbus handles only 16 bit integers, the temperature should be displayed in Float CD AB format to convert the two 16 bit integers to float value for the correct temperature representation.

When the channel is disabled or in error, the temperature will be reported as 999 indicating that something is incorrect. The user can then look at the discrete registers or channel error type registers for more information. On the m922 channels 3 and 4 will always report as 999.

Signal Strength – Quality of the return signal in percentage. This should be around 100%. When the channel is disabled or in error the signal strength will be displayed as 65535 (the max

16 bit unit value). The user can then look at the discrete registers or channel error type registers for more information. On an m922 instrument, the channels 3 and 4 will always report as 65535.

LED Drive Level – Percentage of current put into the LED to get the desired signal strength back. When the channel is disabled or in error the signal strength will be displayed as 65535 (the max 16 bit unit value). The user can then look at the discrete registers or channel error type registers for more information. On an m922 instrument channels 3 and 4 will always report as 65535.

Error Type – When the channel is in error, these registers will have additional information about the probe error.

- **0:** When the program experiences an unknown error during the tau to temperature conversion.
- **1:** When the calculated tau is greater than the maximum value stored in the tau to temperature lookup table. Applicable only for LUT table based conversion.
- **2:** When the calculated tau is less than the minimum value stored in the tau to temperature lookup table. Applicable only for LUT table based conversion.
- **3:** LED drive level is close to the maximum power allowed for the channel.
- **4:** Lookup table entry error. When the tau values are incorrect in the tau to temp lookup table.
- **5:** When there is DIVIDED-by-ZERO error during the calculation of temperature. This only applies to equation based conversion.
- **6:** Incorrect temperature calculated. When there is OUT-OF-RANGE error during the calculation of temperature and the resulting calculated temperature is greater than a 32-bit floating point can represent or calculated temperature is less than -100.0 or greater than 1000.0. This only applies to equation based conversion.
- **7:** LED drive level is close to the minimum power that is needed to power the LED.
- **8:** Bias is in progress to correct from coming out of probe error. Don't unplug the probe or it will cause bad temperature readings.
- **999:** Channel not present. This is applicable only for m922 module and will be set only for channel 3 & 4. This error type is not a probe error but rather a channel not present error and is applicable only for Modbus.

Serial Number – Serial number of m920 Series instrument. This is also updated only once during power up like the board ID. This is not something that changes during runtime.

Customer ID – Displays the customer data string set using the DS command. DS command supports up to 31 chars + NULL termination. If the user enters a string longer than 31 chars, it would be truncated to 31 chars and char #32 will always be zero. This will be updated at runtime to immediately reflect the change in DS command. Refer to Section 8.3.10 for details on the DS command.

Address	Description	Data Type
1	Board ID (Jumper Settable)	16 Bit Readable (Measurements)
2 - 3	Channel 1 Temperature (Float CD AB)	16 Bit Readable (Measurements)
4 - 5	Channel 2 Temperature (Float CD AB)	16 Bit Readable (Measurements)
6 - 7	Channel 3 Temperature (Float CD AB)	16 Bit Readable (Measurements)
8 - 9	Channel 4 Temperature (Float CD AB)	16 Bit Readable (Measurements)

10	Channel 1 Signal Strength	16 Bit Readable (Measurements)
11	Channel 2 Signal Strength	16 Bit Readable (Measurements)
12	Channel 3 Signal Strength	16 Bit Readable (Measurements)
13	Channel 4 Signal Strength	16 Bit Readable (Measurements)
14	Channel 1 LED Drive Level	16 Bit Readable (Measurements)
15	Channel 2 LED Drive Level	16 Bit Readable (Measurements)
16	Channel 3 LED Drive Level	16 Bit Readable (Measurements)
17	Channel 4 LED Drive Level	16 Bit Readable (Measurements)
18	Channel 1 Error Type	16 Bit Readable (Measurements)
19	Channel 2 Error Type	16 Bit Readable (Measurements)
20	Channel 3 Error Type	16 Bit Readable (Measurements)
21	Channel 4 Error Type	16 Bit Readable (Measurements)
22	Reserved	16 Bit Readable (Measurements)
23	Serial Number Char #1	16 Bit Readable (Measurements)
24	Serial Number Char #2	16 Bit Readable (Measurements)
25	Serial Number Char #3	16 Bit Readable (Measurements)
26	Serial Number Char #4	16 Bit Readable (Measurements)
27	Serial Number Char #5	16 Bit Readable (Measurements)
28	Serial Number Char #6	16 Bit Readable (Measurements)
29	Serial Number Char #7	16 Bit Readable (Measurements)
30	Serial Number Char #8	16 Bit Readable (Measurements)
31	Serial Number Char #9	16 Bit Readable (Measurements)
32	Serial Number Char #10	16 Bit Readable (Measurements)
33	Serial Number Char #11	16 Bit Readable (Measurements)

34	Serial Number Char #12	16 Bit Readable (Measurements)
35	Serial Number Char #13	16 Bit Readable (Measurements)
36	Serial Number Char #14	16 Bit Readable (Measurements)
37	Serial Number Char #15	16 Bit Readable (Measurements)
38	Serial Number Char #16	16 Bit Readable (Measurements)
39	Customer ID Char #1	16 Bit Readable (Measurements)
40	Customer ID Char #2	16 Bit Readable (Measurements)
41	Customer ID Char #3	16 Bit Readable (Measurements)
42	Customer ID Char #4	16 Bit Readable (Measurements)
43	Customer ID Char #5	16 Bit Readable (Measurements)
44	Customer ID Char #6	16 Bit Readable (Measurements)
45	Customer ID Char #7	16 Bit Readable (Measurements)
46	Customer ID Char #8	16 Bit Readable (Measurements)
47	Customer ID Char #9	16 Bit Readable (Measurements)
48	Customer ID Char #10	16 Bit Readable (Measurements)
49	Customer ID Char #11	16 Bit Readable (Measurements)
50	Customer ID Char #12	16 Bit Readable (Measurements)
51	Customer ID Char #13	16 Bit Readable (Measurements)
52	Customer ID Char #14	16 Bit Readable (Measurements)
53	Customer ID Char #15	16 Bit Readable (Measurements)
54	Customer ID Char #16	16 Bit Readable (Measurements)
55	Customer ID Char #17	16 Bit Readable (Measurements)
56	Customer ID Char #18	16 Bit Readable (Measurements)
57	Customer ID Char #19	16 Bit Readable (Measurements)

58	Customer ID Char #20	16 Bit Readable (Measurements)
59	Customer ID Char #21	16 Bit Readable (Measurements)
60	Customer ID Char #22	16 Bit Readable (Measurements)
61	Customer ID Char #23	16 Bit Readable (Measurements)
62	Customer ID Char #24	16 Bit Readable (Measurements)
63	Customer ID Char #25	16 Bit Readable (Measurements)
64	Customer ID Char #26	16 Bit Readable (Measurements)
65	Customer ID Char #27	16 Bit Readable (Measurements)
66	Customer ID Char #28	16 Bit Readable (Measurements)
67	Customer ID Char #29	16 Bit Readable (Measurements)
68	Customer ID Char #30	16 Bit Readable (Measurements)
69	Customer ID Char #31	16 Bit Readable (Measurements)
70	Customer ID Char #32	16 Bit Readable (Measurements)

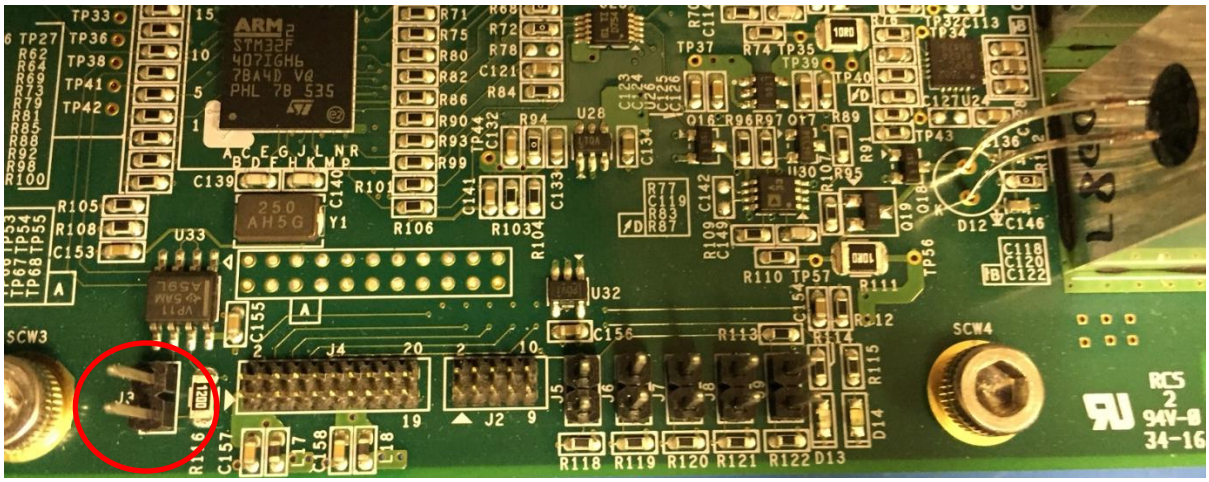
6.3 Parameters/Commands for Modbus Configuration

The following parameters can be configured for Modbus:

1. **Baud rate for RS485 port** – The baud rate for RS485 Modbus port is defaulted to 19.2Kbps. It also supports: 9600 bps, 38.4Kbps, 57.6 Kbps, 115.2 Kbps. It can be configured through the BR (Baud Rate) command. The baud rate can be changed at runtime and the re-initialization of the Modbus stack to the new baud rate will happen immediately.
2. **Parity setting for RS485 port** – The parity for RS485 is defaulted to None. The even and odd parity is supported as well. The parity can be configured through MP (Modbus Parity) command. The parity can be changed at runtime and the re-initialization of the Modbus stack to the new parity will happen immediately.
3. **Response Delay** – The response delay is defaulted to disable. Once the request from Modbus is received, delay the slave response by the number configured in the RD parameter. The valid values for RD command are 10 to 100ms. It can also be disabled to return the response as soon as possible.

Note: For any given baud rate, when the number of daisy chained FOT increases, the overall polling rate for a channel decreases since more polls are required to service all channels.

In multiboard Modbus communication configurations, the last m920 instrument (furthest from the Master) in the single path chain must have a termination resistor inserted by jumpering the J3 header.



7 Analog Output

The Analog Output Board is a unified hardware design that functions as:

- Voltage Output with a range of 0 to 10 V DC
- Current output with a range of 4 to 20 mA

The 0->10 V DC and 4->20mAdc boards have DAC to control their output that is configured during construction at LumaSense facilities.

The analog output range is completely user configurable. Currently all channels must have the same configuration. There are three parameters that control the functionality:

1. AE=ENABLE/DISABLE
   (Turns analog output on/off)
2. AO=0
   (Offset: Example 0C = 0 Volts or 4 mA)
3. AS=50
   (Scale: Example 50mV/C or 50uA/C).

Using a range of -30 °C to 200 °C would result in the following resolution:

12 Bit DAC	
# Steps	4096
Min Temperature	- 30 °C
Max Temperature	200 °C
Range	230 °C
Resolution (Range/steps)	0.056 °C / step

7.1 Setup

With the ID command, the present User Portion of the setup can be seen in the following fields:

- AE=ENABLE
  AE (Analog Enable) is showing that the output is enabled.
- AO= -30 °C
  AO (Analog Offset) is set so that - 30 °C will cause the output to go to minimum Scale (0V, 4mA).
- AS=83.33
  In Voltage Output Mode, this represents how many mV there will be to add to the output for every °C above AO (- 30 °C). In Current Output Mode, this represents how many uA there will be to add to the output for every °C above AO (- 30 °C).

The generalized equation for determining output voltage is:
(Tpresent – AO) * (AS/1000) = Vout

So at 25 °C, the output voltage would be (25 – (-30)) * .08333 = 4.58315 V DC

The generalized equation that represents full scale (10 V DC) is:
(Vmax/(AS/1000)) * AO = Tmax

The temperature that represents full scale (10 V DC) would be: Tmax = (10/.08333) – 30 = ~90 °C

8 Command Line Interface (CLI)

The command and control for the m920 series is through RS232 serial interface which operates at 115.2 Kbps baud rate, no parity, 8 bit, and 1 stop bit (115200,N,8,1).

All System Commands are started by entering the "ESCAPE" 0x1B character, followed by the ASCII Command, and terminate with a "Carriage Return"(0x0D) and "Line Feed" (0x0A).

8.1 User Interface Commands

The user interface commands of the m920 are based upon its predecessors, the m800 and m600. While not identical in every detail, it is substantially the same command set with a few necessary modifications to accommodate the new hardware platform.

User interface commands fall into two general categories:

1. Parameter Commands: Two-letter command codes with required or optional arguments.
2. Action Commands: One-letter character command codes consisting of the Control key plus one letter key.

For a summary of the Parameter Commands, see Section 8.2.3.
For a summary of the Action Commands, see Section 8.2.4.

8.2 Parameter Commands

The Parameter Commands are used to adjust user-selectable parameters and to query the instrument to report a current parameter setting.

The Parameter Command code consist of the Escape character (1Bh) followed by two ASCII characters defining the command with optional arguments for retrieving information or setting system parameters. Commands are not case sensitive.

Whitespace (spaces/tabs) is allowed but is ignored except where it is necessary for separation of arguments.

All commands must be terminated by a carriage-return character **CR** (0Dh) optionally followed by a linefeed character **LF** (0Ah).

These parameter commands are used in either of two ways: information requests or parameter modification.

8.2.1 Information Request Format

Example Query: **<Esc>ID ? <CRLF>**

Information Request

Character	Hexadecimal
Escape	0x1BH
I	0x49H
D	0x44H
Space (Optional)	0x20H
?	0x3FH
Carriage Return	0x0DH
Linefeed	0x0AH

Informational output data packets consist of echoing the command code in upper case characters followed by an equal sign (=) followed by the requested information. The **Escape** character is not echoed.

Whitespace is consistently applied with exactly one (1) space character between each pair of arguments. Informational output data is always terminated by a carriage-return/ linefeed pair (**CR LF**).

Example Response: **AA = INFO**

Information Request

Character	Hexadecimal
A	0x41H
A	0x41H
Space (Optional)	0x20H
=	0x3DH
Space (Optional)	0x20H
I	0x49H
N	0x4EH
F	0x46H
O	0x4FH
Carriage Return	0x0DH
Linefeed	0x0AH

If the command is unrecognized or the command syntax is incorrect the system responds with the request as typed with the addition of a question mark '**?**' followed by a **CRLF** pair.

The system responds to the information request as described, although certain exceptions exist e.g. multi-line responses. Refer to the descriptions of the individual commands for additional details.

8.2.2 Parameter Modification Format

This command code consists of the Escape character followed by a two-letter command followed by an equal sign ('**=**') and the new parameter value(s), and ending with a carriage return/line feed.

These commands provide the mechanism for modification of setup parameters or for initiation of an event or sequence of events.

Example Command: **<Esc>AA = E <CRLF>**

Parameter Modification

Character	Hexadecimal
Escape	0x1BH
A	0x41H
A	0x41H
Space (Optional)	0x20H
=	0x3DH
Space (Optional)	0x20H
E	0x45H
Carriage Return	0x0DH
Linefeed	0x0AH

If the command is successfully received, parsed, and executed, the new parameter will immediately take effect and a success message will be displayed.

If the command is unrecognized or the command syntax or parameter value is incorrect the system echoes the command with the addition of a question mark '?' followed by a **CRLF** pair.

8.2.3 Summary Listing of Parameter Commands

Command Code	Command	Description
AE	**A**nalog output **E**nable	Enable/Disable Analog Outputs
AO	**A**nalog **O**utput	Set Analog-Output Temperature Offset Factor
AS	**A**nalog **S**caling factor	Set Analog-Output Temperature Scaling Factor
BR	**B**aud **R**ate	Set the RS485 output rate
CC	**C**alibration **C**orrection	Enable/Disable Application of Calibration Factors
CH	**C**alibrate **H**igh Temp	Set high temperature calibration point for auto-calibration
CL	**C**alibrate **L**ow Temp	Set low temperature calibration point for auto-calibration
CT	**C**alibration **T**emperature	Set Central Calibration Temperature for Auto-Calibration Function
DF	**D**ata **F**ormat	Set Serial Data Output Format
DS	**D**ata **S**tring	Capture User Data Sequence
ID	**I**nformation **D**isplay	Report Device ID and Current Parameter Settings
ME	**M**ask **E**rror	Set number of errors before analog alarm allowed
MP	**M**odbus **P**arity	Parity Setting of the RS485 Modbus Port
MU	**M**easurement **U**pdate	Set Interval Between Temperature Measurement Reports
PE	**P**robe **E**rror	Set Voltage (current) to drive on error condition
PS	**P**robe **S**elect	Specify Active-Input List
RD	**R**esponse **D**elay	Delay in Slave Response to Modbus Master request
SL	**S**ignal **L**evel	Report LED Light Source Intensity Level
SM	**S**ample **M**easurement	Set Number of Samples to be Retained Per Measurement
SN	**S**erial **N**umber	Report Device's Serial Number
ST	**ST**art up mode	Select Startup Mode
SV	**S**a**V**e parameters	Save Current User Parameters and Calibration Factors
TU	**T**able **U**sed	Select calibration table to use
UC	**U**ser **C**alibration	Sets Central offset calibration
UH	**U**ser Calibration – **H**igh	Sets High slope calibration
UL	**U**ser Calibration - **L**ow	Sets Low slope calibration
UP	**UP**time	Reads Time since the instrument was powered.
UN	output **UN**its	Specify Output Units of Measure

8.2.4 Summary Listing of Action Commands

Command Code	Command	Description
CTRL + A	Abort (0x01)	Abort calibration sequence in progress
CTRL + H	Calibrate High (0x08)	Begin auto-calibration, High Temperature
CTRL + K	Calibrate (0x0B)	Begin auto-calibration sequence
CTRL + L	Calibrate Low (0x0C)	Begin auto-calibration, Low Temperature
CTRL + R	Run (0x12)	Exit standby mode/Run
CTRL + T	Standby (0x14)	Enter Standby mode
CTRL + X	Reset (0x18)	Firmware Reset

8.3 Command Line Interface (CLI) Commands

For simplicity, the following command descriptions omit the stating the necessity to prefix the command with the Escape Character, and the suffix of CR/LF.

8.3.1 AE (Analog Enable)

This command enables or disables the analog output board measurement.

Command	Argument(s)	Read/Write	Name
AE	ENABLE | DISABLE	R/W	Analog Enable

8.3.2 AO (Analog Offset)

Set Analog-Output Temperature Offset Factor.

Command	Argument(s)	Read/Write	Name
AO	Add User Defined Temperature XX.XX	R/W	Analog Offset

8.3.3 AS (Analog Scaling Factor)

Set analog output temperature scaling factor.

Command	Argument(s)	Read/Write	Name
AS	Add User defined scale factor	R/W	Analog Scaling Factor

8.3.4 BR (Baud Rate)

This command is used to configure the baud rate setting for Modbus-RS485 port.

Command	Argument(s)	Read/Write	Name
BR	9600 | 19200 | 38400 | 57600 | 115200	R/W	Baud Rate

8.3.5 CC[n] (Calibration Correction)

Where n is the channel number 1->4. When enabled, the offsets and slopes calculated during calibration process will be applied to the calculated temperature.

Command	Argument(s)	Read/Write	Name
CC[n]	ENABLE | DISABLE	R/W	Calibration Correction

8.3.6 CH[n] (Calibration High Temperature)

Where n is the channel number 1->4.

This command sets the high temperature at which calibration will be done for 3-point calibration. This value should be higher than the center temperature for calibration (CT) and below the maximum temperature the currently selected tau to temperature table can support.

Command	Argument(s)	Read/Write	Name
CH[n]	CT+1 to Max Temp -1	R/W	Calibration High Temp

8.3.7 CL[n] (Calibration Low Temperature)

Where n is the channel number 1->4. This command set the low temperature at which calibration will be done for 3-point calibration.

This value should be lower than the center temperature for calibration (CT) and above the minimum temperature the currently selected tau to temperature table can support.

Command	Argument(s)	Read/Write	Name
CL[n]	Min temp -1 to CT -1	R/W	Calibration Low Temp

8.3.8 CT[n] (Calibration Temperature)

Where n is the channel number 1->4. This command sets the center temperature at which calibration will be done for 3-point calibration. The value should be between the CL and CH.

Command	Argument(s)	Read/Write	Name
CT[n]	CL+1 to CH -1	R/W	Calibration Center Temp

8.3.9 DF (Data Format)

Set Serial Data Output Format.

When set to ABBR, if a channel is disabled, it won't be shown on the serial output.

When set to FULL, even if the channel is disabled, the label for channel will be displayed and there would be space followed by that resulting in the output data string exact same length.

Command	Argument(s)	Read/Write	Name
DF	ABBR/FULL	R/W	Data Format

8.3.10 DS (Data String)

Capture User Data Sequence. The user can enter a string of up to 31 chars and 32nd char will automatically be a null termination.

Command	Argument(s)	Read/Write	Name
DS	31 chars	R/W	Data String

8.3.11 ID (Information Display)

Reports key configuration information such as:

- Serial Number, Part Number, firmware version, Board configuration, board ID, etc.
- Analog output parameters like scaling and offset factors and if it is enabled are listed.
- Temperatures at which calibration is done and if it is enabled are also listed.
- Number of channels enabled, temperature reporting rate, output units of the temperatures, probe error, data string, etc.

Command	Argument(s)	Read/Write	Name
ID	N/A	R	Information Display

8.3.12 ME (Mask Error)

This command sets the number of continuous probe errors to mask before actually reporting an error. Some customers don't want one spurious probe error to be reported as error. So this functionality will report the last valid temperature till it goes over ME number of continuous probe error and then an error will be reported.

Note: This feature is applicable only for analog output. On the RS232 output and Modbus, the probe error will be reported immediately.

Command	Argument(s)	Read/Write	Name
ME	1 - 50	R/W	Mask Error

8.3.13 MP (Modbus Parity)

This command is used to configure the parity setting for Modbus-RS485 port.

Command	Argument(s)	Read/Write	Name
MP	NONE | EVEN | ODD	R/W	Modbus Parity

8.3.14 MU (Measurement Update)

This command sets the rate at which the temperature is output.

Command	Argument(s)	Read/Write	Name
MU	0.02 – 3600 secs	R/W	Measurement Update

8.3.15 PE (Probe Error)

This command is used to define the output setting of the Analog Output board when a probe error occurs. It is the percentage of the output range the analog board should be driven.

Example: In voltage mode (0 to 10 V), 100% will report 10 V, and 50% will report 5 V. In current mode (4 to 20 mA), 100% will report 20 mA, 50% will report 12 mA and 0% will report 4 mA.

Note: In the m800 and m600 series, on PE error the analog output was driven to 10 V. With the NextGen instruments the user can select which voltage or current to drive the output to when an error condition is presented. Default is PE=100. Disabled channels will have the analog set to maximum value regardless of the setting. On power up, all channels momentarily are driven high.

Command	Argument(s)	Read/Write	Name
PE	0.00 to 100.00	R/W	Probe Error

8.3.16 PS (Probe Select)

This command sets the list channel to be enabled. This is a bitmapped parameter so the command should list all the channels to enable. To enable channels 1 and 3, PS = 1,3.

Command	Argument(s)	Read/Write	Name
PS	List of channels to enable	R/W	Probe Select

8.3.17 RD (Response Delay)

This command configures the time in milliseconds the Modbus slave (i.e m92x) should wait before responding to Modbus master request. The delay can also be disabled so the slave can respond as soon as the response is ready. The slave generally takes around 3 ms to frame the response and start the transfer. If the Modbus Master needs more time to start receiving the response from slave, this command can be used to make the slave wait for few milliseconds before sending out the response.

Command	Argument(s)	Read/Write	Name
RD	DISABLE (or) 10 - 100	R/W	Response Delay

8.3.18 SL (Signal Level)

SL commands reports 4 parameters for each channel.

1. **Signal Quality with respect to desired level (~100%).**
   Quality of the return signal strength in percentage. It should be around 90%.
2. **Percentage of maximum allowed current the LED can be driven.**
   Percentage of current put into the LED to obtain the desired signal strength back. The lower the percent, the better. When it gets closer to 90% the channel will go in probe error P3.
3. **Percentage of LED ON time.**
   In the current configuration, this value is always 100%.
4. **Gain (H or L)**
   Gain of the feedback circuit in the AGC module. L indicates low noise mode and H indicates high noise mode.

Note: Changing gain states may affect the system accuracy. Consult your LumaSense Applications Engineers.

Command	Argument(s)	Read/Write	Name
SL	N/A	R	Signal Level

8.3.19 SM[n] (Samples per Measurement)

Where n is the channel number 1->4.

Sample Averaging at 50 Hz rate. The <samples> count can vary from 1 to 200.

With SM=1 the output will have no averaging, and each output will show the result of an individual measurement (i.e. once/50 Hz). With SM=50, the previous 50 reading (at 50 Hz) will be averaged. This is a simple boxcar average.

Example: If MU (measurement unit, see below is set to 1s)

If SM=10, then each 1s output will show the averaged result of the preceding 10 samples (when running internally at 50 Hz

If SM=100, then each 1s output will show the averaged result of the preceding 100 samples (or

2 seconds)

Command	Argument(s)	Read/Write	Name
SM[n]	1 - 200	R/W	Samples per Measurement

8.3.20 ST (Select Start Mode)

This command selects the output control mode the FOT starts up in. The operation mode can later be changed by Action commands.

ENABLE – Standard Operating Mode – Temperature reporting starts automatically at power up.

DISABLE – Standby Mode – The user has to manually start reporting temperature at power up.

Command	Argument(s)	Read/Write	Name
ST	ENABLE | DISABLE	R/W	Select Start Mode

8.3.21 SV (Save Parameters)

This command saves the parameters to the data flash so it is not lost during reset.

Wait for 2 seconds after the SV command is issued before sending any other commands. This is to ensure that the parameters are saved properly in the data flash.

Note: After issuing the SV command, a power reset is recommended.

Command	Argument(s)	Read/Write	Name
SV		W	Save parameters

8.3.22 TU[n] (Calibration Table)

Where n is the channel number 1->4. Use a Tau to Temp table for each channel. Tables can run from 1 to 20 depending on whether they have been preloaded on to the FOT instrument.

Command	Argument(s)	Read/Write	Name
TU[n]	1 - 20	R/W	Calibration Table

8.3.23 UC[n] (User Cal)

Where n is the channel number 1->4.

Offsets are in degrees K (or C).

These values can be set manually or automatically via Ctrl +K during 3 point calibration process. The offsets are how far off the calculated temperature is from the CT temperature when calibrating the center temperature.

Command	Argument(s)	Read/Write	Name
UC[n]	Offsets	R/W	User Cal

8.3.24 UH[n] (User Cal High)

Where n is the channel number 1->4.

These values can be set manually or automatically via Ctrl +H during 3-point calibration process. The upper slopes are calculated when calibrating CH temperature and the slope is calculated with respect to the CT temperature.

Equation to manually calculate upper slope:
UH[n] = (CH[n] – (UC[n] + Measured Temp))/ (CH[n] – CT[n])

Command	Argument(s)	Read/Write	Name
UH[n]	Upper slopes	R/W	User Cal High

8.3.25 UL[n] (User Cal Low)

Where n is the channel number 1->4.

These values can be set manually or automatically via Ctrl L during 3-point calibration process. The lower slopes are calculated when calibrating CL temperature and the slope is calculated with respect to the CT temperature.

Equation to manually calculate lower slope:
UL[n] = (CL[n] – (UC[n] + Measured Temp))/ (CL[n] – CT[n])

Command	Argument(s)	Read/Write	Name
UL[n]	Lower slopes	R/W	User Cal Low

8.3.26 UP (Up Time)

Reports how long it has been since the last reset of the FOT board. Time is reported as days, hours, minutes and seconds.

Command	Argument(s)	Read/Write	Name
UP		R	Up Time

8.3.27 UN (Output Units)

This command sets the units at which the temperature should be output. (Celsius/Fahrenheit/ Kelvin).

Command	Argument(s)	Read/Write	Name
UN	C/F/K	R/W	Output Units

8.4 Action Commands

Action commands are used for calibration and switching between two different modes of operation.

Standard Mode – Reports the temperature at the rate defined in MU command.

Standby Mode – Sampling and reporting are turned off and waits for the user to issue additional commands.

8.4.1 CTRL+A (0x01) (Abort calibration)

Abort calibration sequence in progress. This will force the output control to go to standby mode. To start reporting again, Ctrl + R should be used.

Command	Argument(s)	Read/Write	Name
CTRL+A	N/A	W	Abort calibration

8.4.2 CTRL+H (0x08) (Calibrate High Temp)

Begin auto-calibration sequence for high temperature CH. After calibration, it would calculate the slope from the calculated temperature and the CT and save the values to upper slopes part of UH[n] command.

Note: High temperature calibration should be done only after center point calibration is done as it uses the offset calculated by Ctrl + K to calculate the slopes.

Command	Argument(s)	Read/Write	Name
CTRL+H	N/A	W	Calibrate High Temperature

8.4.3 CTRL+K (0x0B) (Calibrate Center Temp)

Begin auto-calibration sequence for center temperature CT. After calibration, it would calculate the offset of the calculated temperature from the CT and save the values to offsets part of UC[n] command. It also enables the CC[n] command.

Note: This should be the first step in 3-point auto calibration process. Low and high temperature calibration should be done only after this is done as they use the offset calculated in this process to calculate the slopes.

Command	Argument(s)	Read/Write	Name
CTRL+K	N/A	W	Calibrate

8.4.4 CTRL+L (0x0C) (Calibrate Low Temp)

Begin auto-calibration sequence for low temperature CL. After calibration, it would calculate the slope from the calculated temperature and the CT and save the values to lower slopes part of UL[n] command.

Note: Low temperature calibration should be done only after center point calibration is done as it uses the offset calculated by Ctrl +K to calculate the slopes.

Command	Argument(s)	Read/Write	Name
CTRL+L	N/A	W	Calibrate Low Temperature

8.4.5 CTRL+R (0x12) (Run)

This command switches the m92x from Standby mode to Standard mode and starts to report temperature.

Command	Argument(s)	Read/Write	Name
CTRL+R	N/A	W	Run

8.4.6 CTRL+T (0x14) (Standby)

This command switches the m92x from Standard mode to Standby mode.

Command	Argument(s)	Read/Write	Name
CTRL+T	N/A	W	Standby

8.4.7 CTRL+X (0x18) (Reset)

Reset the FOT instrument.

Command	Argument(s)	Read/Write	Name
CTRL+X	N/A	W	Reset

9 Troubleshooting

9.1 Probe Error Messages

The followings are the description of the ERROR Codes. This is an update from PE which means Probe Error.

- **P0**: When the program experiences an unknown error during the tau to temperature conversion.
- **P1:** When the calculated tau is greater than the maximum value stored in the lookup table. Applicable only for lookup table based conversion.
- **P2:** When the calculated tau is less than the minimum value stored in the lookup table. Applicable only for lookup table.
- **P3:** LED drive level is closer to the maximum power allowed for the channel.
- **P4:** Lookup table entry error. When the tau values are incorrect in the tau to temp lookup table.
- **P5:** When there is DIVIDED-by-ZERO error during the calculation of temperature. This only applies to equation based conversion.
- **P6:** Incorrect temperature calculated. When there is OUT-OF-RANGE error during the calculation of temperature and the resulting calculated temperature is greater than a 32-bit floating point can represent or calculated temperature is less than -100.0 or greater than 1000.0. This only applies to equation based conversion.
- **P7:** LED drive level is close to the minimum power that is needed to power the LED.
- **P8:** Bias is in progress to correct from coming out of probe error. Don't unplug the probe or it will cause bad temperature readings.

9.2 Power On Tests Failure

At power on, the m92x does a self test that checks the voltage and temperature test points and the status of the data flash that stores the parameters. If there is an error in data flash check, the firmware will try to correct the error. If the error doesn't recover, then the message: "Power On Tests: FLASH ERROR" is displayed.

If any of the voltages reads outside the 10% margin of the expected value, then the message: "Power On Tests: VOLTAGE OUT OF RANGE" will be displayed.

FR? Command can be used to get the details of the failure if any message other than "Power On Tests: PASSED" is displayed. Contact your LumaSense representative for help with debugging.

Attention: The m924 has an internal biasing algorithm that performs precision adjustments when the system is first powered. Under some error conditions, it is recommended that:

a) Probes should be connected to the instrument prior to power being applied.
b) On power up, wait 1 minute for the bias to be complete, and the temperature becomes stable before collecting data
c) Do not disconnect probes during the first 1 min when the power is applied.
d) If a probe(s) are disconnected during temperature measurements and then reconnected, wait for 1 min before collecting data
e) If the P8 (bias flag) is observed in the data stream, do not disconnect probes, wait for p8 flag to clear.

9.3 Hardware Checkpoints

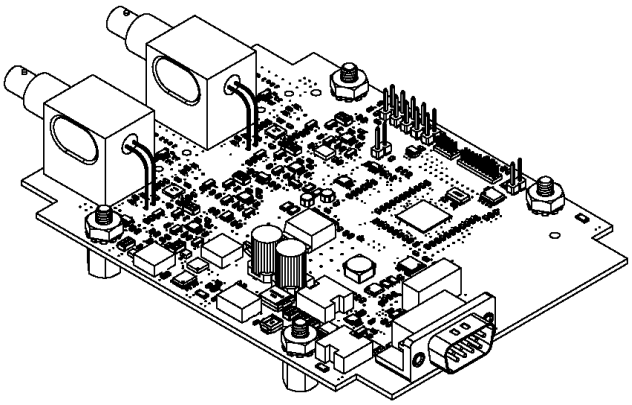
Problem	Probable Cause	Corrective Action
Optical Port LED(s) are not flashing	Power loss	Examine DB-9 connection and Mains supply. • Flashing Green LED on board is indication power is present and boot is successful. Booting process takes ~ 5-10 second • Flashing Red LED on board is indication of poor (low voltage) power input.
	Channels disabled	See PS command, section 8.3.16. At least one channel must be enabled for temperature output to occur.
Inaccurate temperature measurement	Incorrect table selected	See TU command, section 8.3.22.
	Incorrect probe used	See TU command, section 8.3.22.
	The m924 board needs to warm up	For high accuracy performance (better than ± 0.25 °C), the m924 instrument requires 1-2 hours to warm to ambient temperatures.
	Calibration may have been disabled or changed	See CC command, section 8.3.5.
	User changes may not have been saved correctly	See SV command, section 8.3.21.
	Probe biasing procedure may temporarily influence temperature	Wait 1 minute for biasing to complete. During Bias, a 'B' is placed next to the temperature reading on the digital output.
	High noise is leading to temperature variations	See SM command, section 8.3.19.
	Poor probe signal	Examin the signal level for probe signal quality. See SL command section, 8.3.18.
	Probe ferrule not fully seated in ST connector	Insert the probe ferrule fully and lock it.
	Bad user settings are being used	Issue a ID command (see section 8.3.11) and record the current configuration. Then reset to the factory default (Command RF=Reset). This will override any settings the user may have set.
	Temperature measurement is working correctly, but is not as the user expects	Probes are tested to ensure accuracy, but this may vary slightly (probe dependent).

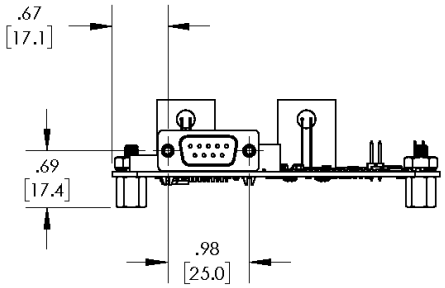
Higher than expected noise (variations)	Average buffer is too small	See SM command, section 8.3.19.
	Readout speed is too high	See MU command, section 8.3.14.
	Excess noise on the input lines	Try using an isolated power supply.
	Excess EMI interference on main m920 board	Try using the optional metal enclosure, shown in section 2.3
No digital data output	Power not applied	Examine DB-9 connection and Mains supply. • Flashing Green LED on board is indication power is present and boot is successful. Booting process takes ~ 5-10 second • Flashing Red LED on board is indication of poor (low voltage) power input.
	Communication port parameters set incorrectly	Refer to ASCII Communications, Chapter 4. Digital output is ASCII over RS232 port on main board. Default port parameter is 115.2 kbps, No Parity, 8 bits, 1 stop bit on the DB9 male 'MAIN' board. On power-up, the m924 should first output a header welcome message and then go directly into data readout within 10 seconds. If the header is present but no temperature data, this implies that the communication is properly established.
	RX/TX communication lines are broken or incorrect	Check the DB-9 pinout. Replace cable.
	Probe channels are not enabled	See PS command, section 8.3.16. At least one channel must be enabled for temperature output to occur.
	Computer is not receiving the data from the m924	Verify the computer serial port is working with another device. Verify any USP RS232 converters are working correctly.
Commands issued to the m924 are not being received	Incorrect port parameters have been set	Verify that the port parameters have been set correctly. Refer to ASCII Communications, Chapter 4.
	RX (receive line) is broken or damaged	Check the DB-9 pinout. Replace cable.
	Not pressing the ESC key for commands	Most commands to the m924 require the ESC key to be pressed and released before issuing the two-letter command. For example: Esc PS=1 Enter

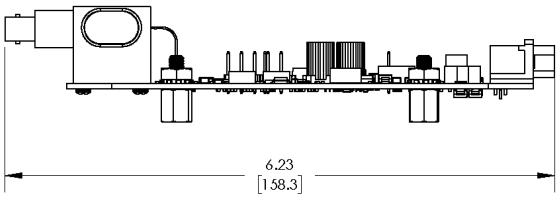
	Some USB converters do not properly handle the ESC key	Try another converter.

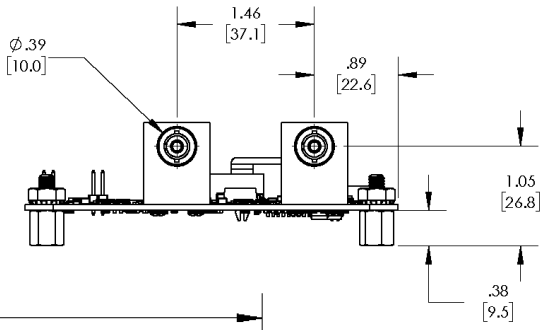
10 Dimensional Drawings

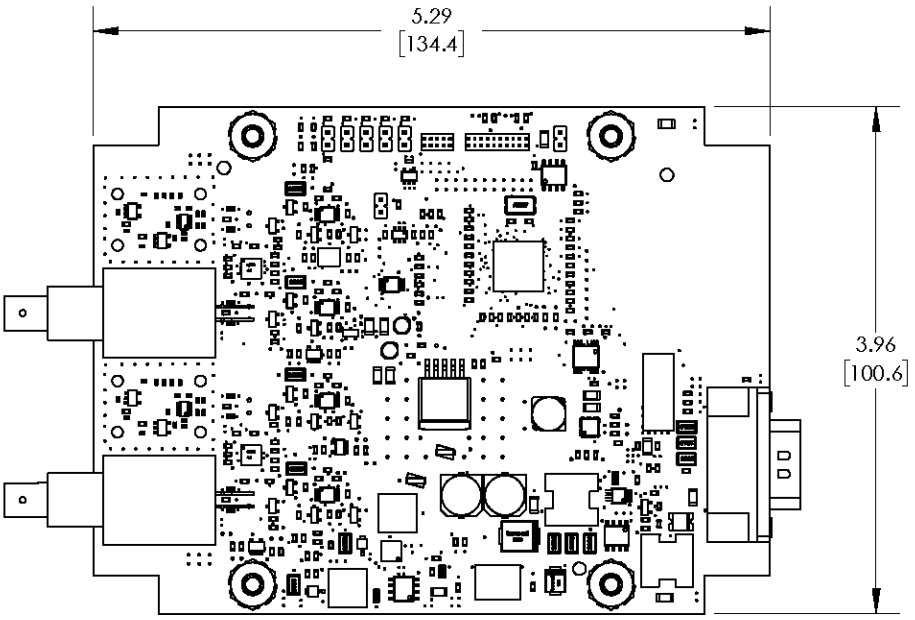
10.1 Main Board (2 channels)



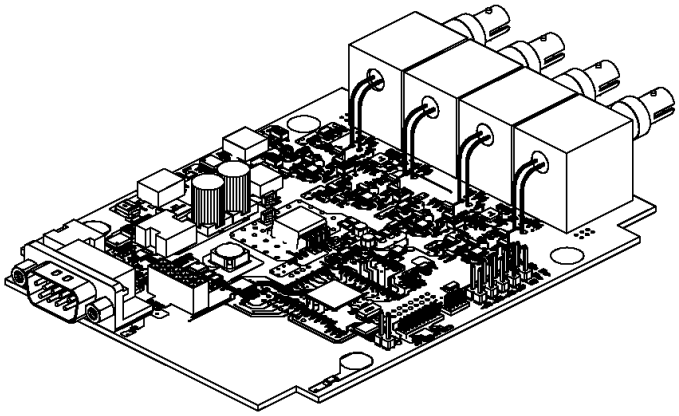


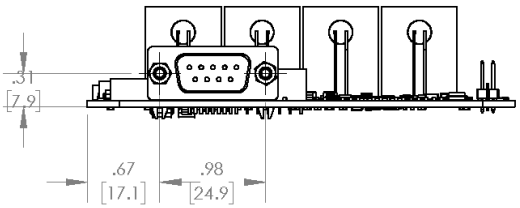


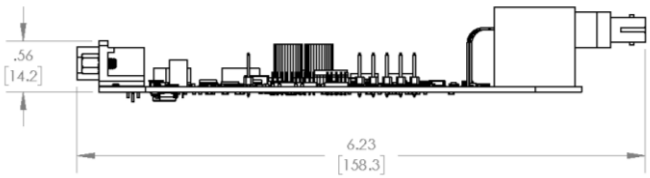


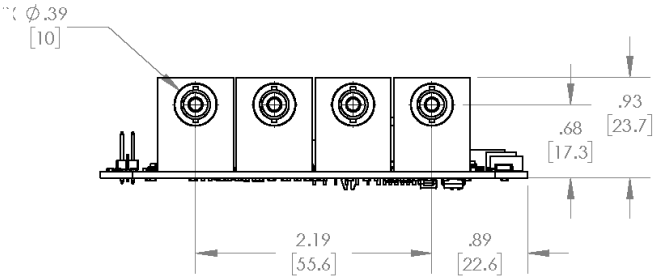


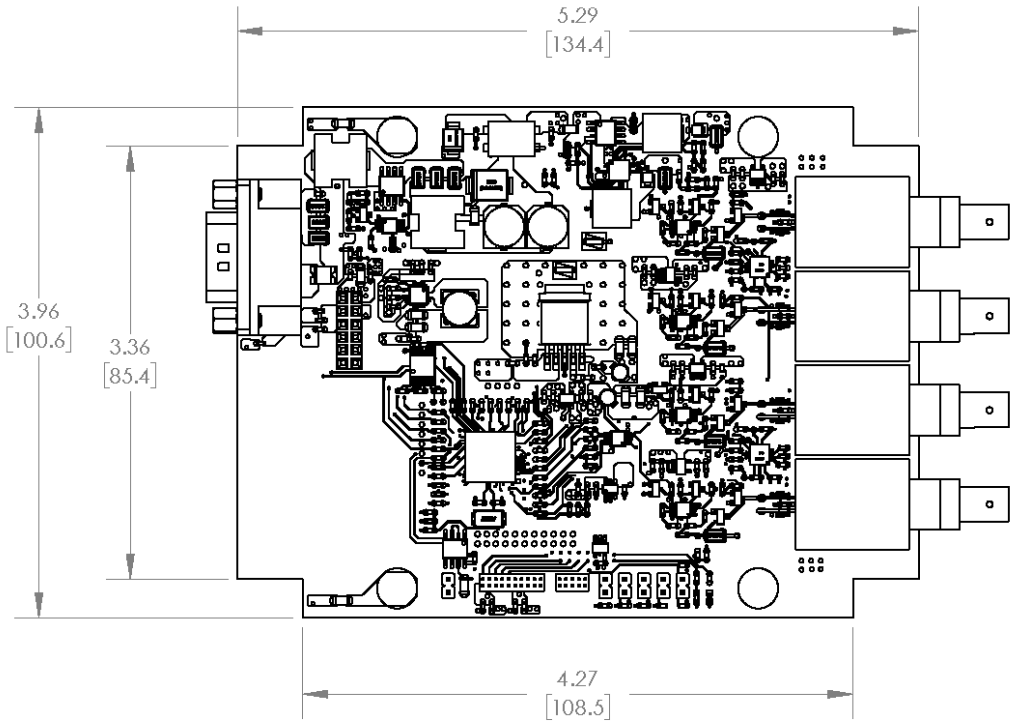
10.2 Main Board (4 channels)



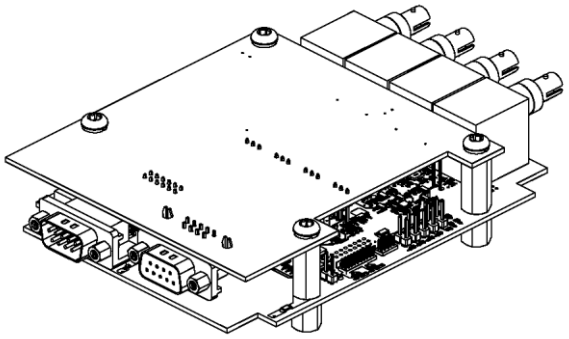


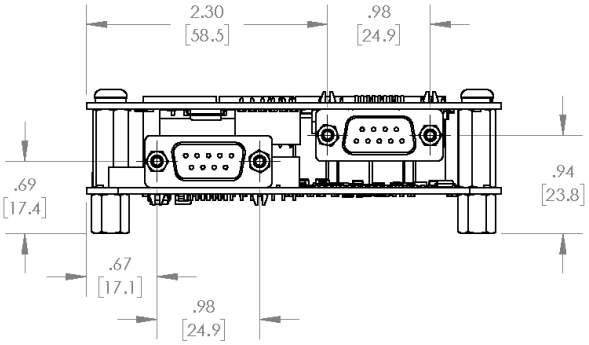


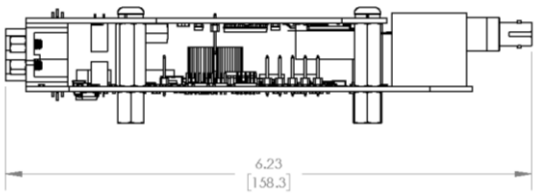


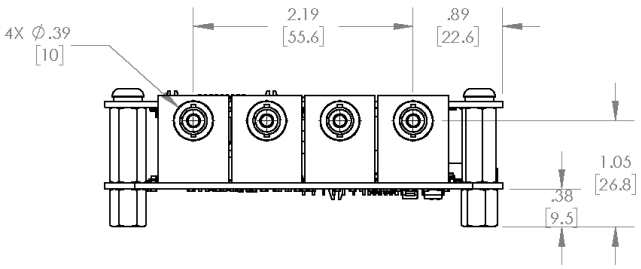


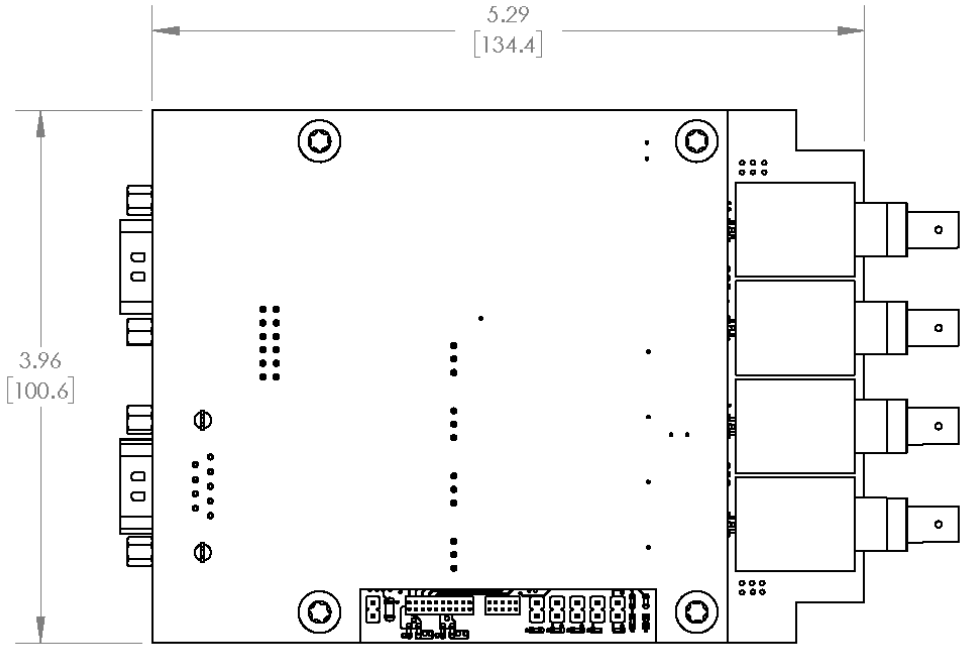
10.3 Main Board and Analog Output Comm Board



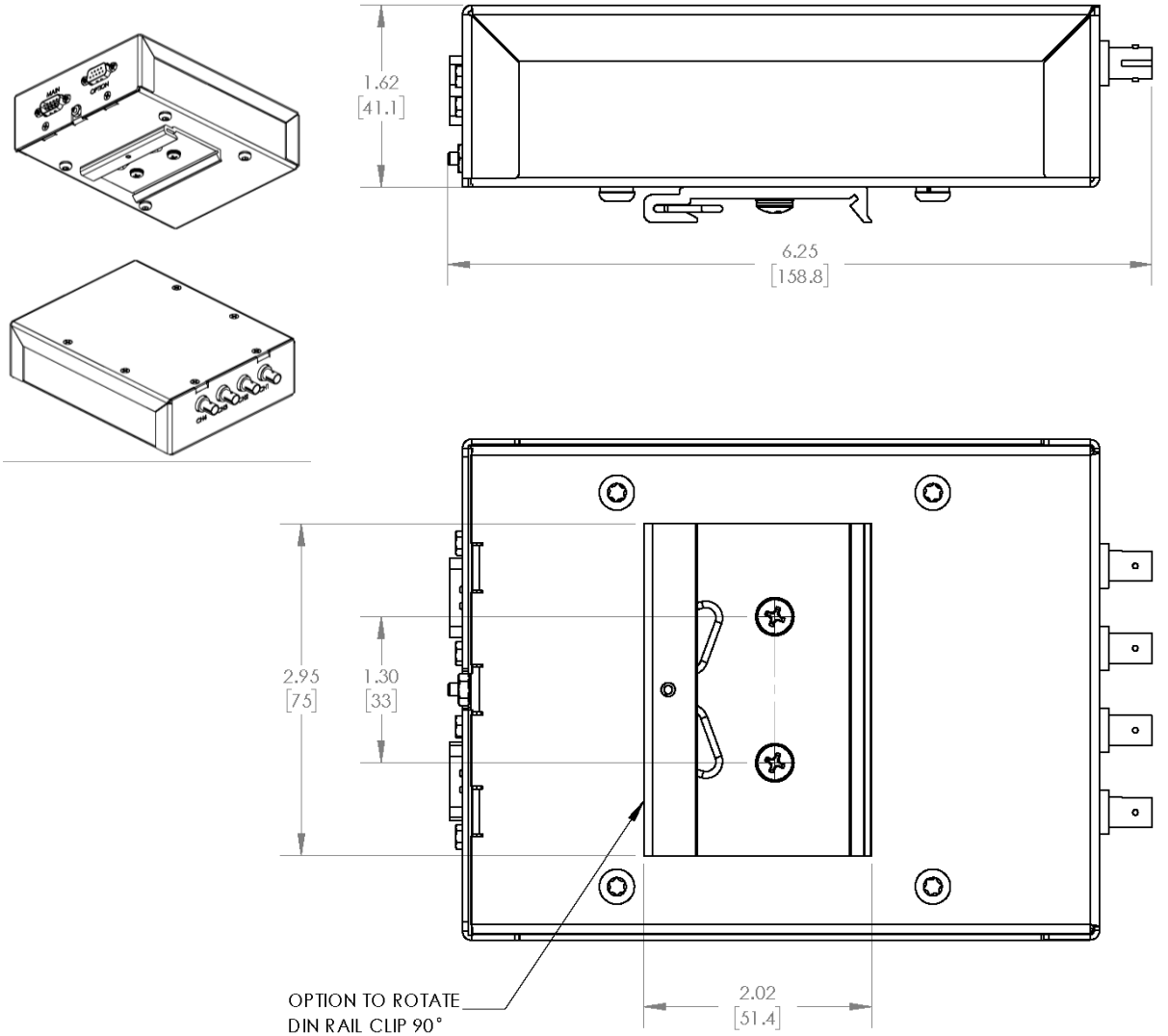


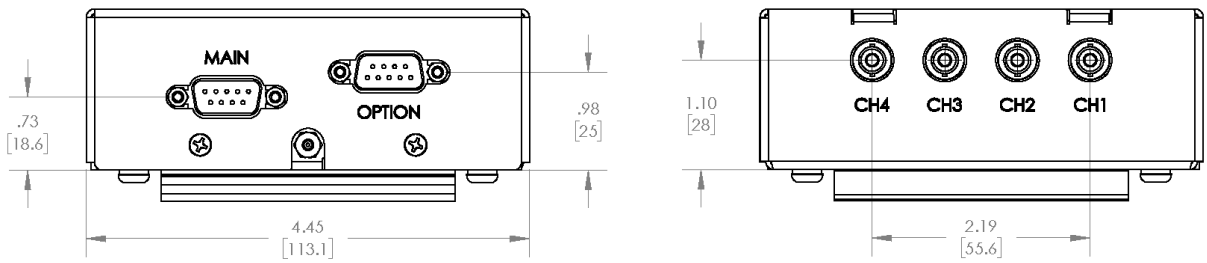






10.4 m920 Series Enclosure





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