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1 DEFINITIONS

The following definitions apply to WARNINGS, CAUTIONS, ACTIONS and NOTES used throughout this manual.

WARNING:

The warning symbol is used to indicate instructions that, if they are not followed, can result in minor, serious or even fatal injuries to personnel.

The caution symbol is used to indicate instructions that, if they are not followed, can result in damage to the equipment (hardware and/or software), or a system failure occurring.

ACTION: How data from the device should be used during normal operation.

NOTE: Operating conditions or statements pertaining to the recommended action.

The following terminology and acronyms are used throughout this manual:

- Input registers are read only 16-bit registers. Valid address range starts at 30001.
- Holding registers are read / write 16-bit registers. Valid address range starts at 40001.
- **MSB** Most Significant Bits.
- LSB Least Significant Bits.
- **EEPROM** Electrically Erasable Programmable Read-Only Memory.
- **32-bit Integers** Unsigned 32-bit integers are split over two 16-bit registers where the MSB and LSB are identified.
- Floating point numbers are digitally represented using the IEEE–754 format. Single precision floating point numbers are used throughout and they require 32-bits of data. Since a Modbus register holds 16-bits, it takes two registers to represent a floating point number. The IEEE 754 standard specifies a binary32 as having:
 - Sign bit: 1 bit
 - Exponent width: 8 bits
 - Significand precision: 24 bits (23 explicitly stored)



For example, 20.7 in IEEE 754 format is: 0 10000011 01001011001100110011001

2 MODBUS SETUP

NOTE: Background reading is strongly recommended if there is no prior knowledge of Modbus. A good place to start is <u>www.modbus.org</u>, where the specification and resources can be obtained in the technical resources page.

The RS232 TTL Modbus interface is configured as follows:

- Modbus mode: RTU
- Address: One
- **Baudrate:** 9600
- Parity: None
- Stopbits: Two

3 MODBUS REGISTERS

NOTE: Default values are shown in **bold**.

NOTE: Values shown in grey are reserved, not applicable or indicate that they should not be changed.

3.1 Serial Registers

Name	Register Address	Description	Actions / Notes
Serial Status	0x762B (30251)	0 = Error Error committing serial changes to memory 1 = Not Ready Serial changes are currently not permitted 2 = Ready Serial changes are permitted 3 = Busy Serial changes in process 4 = Complete Serial changes committed to memory, system will restart in 1s with the new communication settings	ACTION: Monitor in system NOTE: Used in Table 3-2 below.

Table 3-2 – Serial - Holding Registers

Name	Register Address	Description / Valid Values	Actions / Notes
Serial Address ^a	0x9D3B (40251)	1-247	ACTION: Set/Monitor in system
Reserved	0x9D3C (40252)	Reserved	
Reserved	0x9D3D (40253)	Reserved	
Serial Control	0x9D3E (40254)	0 = Idle 1 = Save and reset	

^a LuminOx Trace evaluation kit; sensor serial address set to 1.

Table 3-4 – Temperature - Holding Registers

Name	Register Address	Description / Valid Values	Actions / Notes
Temperature Control	0x9E35 (40501)	Reserved	ACTION: Monitor in system NOTE: The temperature measurement cannot be switched off.
Clear Temperature Warning	0x9E36 (40502)	0 = Idle 1 = Clear warning (Reserved)	ACTION: None NOTE: Any warning present in <i>Temperature Warning</i> (30502) will auto clear if the condition that caused the warning is removed.
Clear Temperature Error	0x9E37 (40503)	0 = Idle 1 = Clear Error	ACTION: None NOTE: If an error present in <i>Temperature Error</i> (30503) has forced <i>Temperature</i> <i>Status</i> to <i>OFF</i> (30508 = 1) the error may be cleared using this register. If the error persists, contact <u>technical@sstsensing.com</u> for guidance.

3.3 Pressure Registers

Name	Register Address	Description	Actions / Notes
Pressure ID	0x781F (30751)	0102	ACTION: For reference NOTE: Unique identifier
Pressure Warning	0x7820 (30752)	16-bit bitmask Each bit represents an individual warning state 0 = No fault Pressure within normal operating range 14 = Greater Pressure above valid operating limit 15 = Less Pressure below valid operating limit	ACTION: Monitor in system NOTES: Warnings are not retained on power loss.
Pressure Error	0x7821 (30753)	16-bit bitmask Each bit represents an individual error state	ACTION: Monitor in system NOTES: Errors are not retained on power loss.
Pressure Uncalibrated Value	0x7822 (30754) 0x7823 (30755)	Floating point IEEE 754 (MSB 16-bits) Unit = mbar Floating point IEEE 754 (LSB 16-bits) Unit = mbar	ACTION: Monitor in system
Pressure Calibrated Value	0x7824 (30756) 0x7825	Floating point IEEE 754 (MSB 16-bits) Unit = mbar Valid Range = 260 to 1260 Floating point IEEE 754 (LSB 16-bits)	ACTION: Monitor in system
	(30757)	Unit = mbar Valid Range = 260 to 1260	
Pressure Status	0x7826 (30758)	0 = Loading System initialising, no pressure measurements 1 = OFF No pressure measurements 2 = Standby No pressure measurements 3 = Reserved 4 = ON Valid pressure measurements 5 = Reserved 6 = Calibration Invalid pressure measurements, calibration in process	ACTION: Monitor in system

Table 3-5 – Pressure - Input Registers

Table 3-6 – Pressure - Holding Registers

Name	Register Address	Description / Valid Values	Actions / Notes
Pressure Control	0x9F2F (40751)	Reserved	ACTION: Monitor in system NOTE: The pressure measurement cannot be switched off.
Clear Pressure Warning	0x9F30 (40752)	0 = Idle 1 = Clear warning (Reserved)	ACTION: None NOTE: Any warning present in <i>Pressure Warning</i> (30752) will auto clear if the condition that caused the warning is removed.
Clear Pressure Error	0x9F31 (40753)	0 = Idle 1 = Clear Error	ACTION: None NOTE: If an error present in Pressure Error (30753) has forced Pressure Status to OFF (30758 = 1) the error may be cleared using this register. If the error persists, contact technical@sstsensing.com for guidance.

3.4 ppO₂ Registers

Name	Register Address	Description	Actions / Notes
ppO₂ ID	0x7919 (31001)	0103	ACTION: For reference NOTE: Unique identifier
ppO₂ Warning	0x791A (31002)	16-bit bitmask Each bit represents an individual warning state 0 = No fault ppO ₂ within normal operating range 14 = Greater ppO ₂ above valid operating limit 15 = Less ppO ₂ below valid operating limit	ACTION: Monitor in system NOTES: Warnings are not retained on power loss.
ppO₂ Error	0x791B (31003)	16-bit bitmask Each bit represents an individual error state 0 = DAC error 1 = X2 error 14 = Peripheral error 15 = Network error	ACTION: Monitor in system NOTES: Errors are not retained on power loss.
ppO₂ Uncalibrated Value	0x791C (31004)	Floating point IEEE 754 (MSB 16-bits) Unit = mbar	ACTION: Monitor in system NOTES: This value can be greater than or less than the sensor range and is used to determine measurement
	0x791D (31005)	Floating point IEEE 754 (LSB 16-bits) Unit = mbar	stability during the calibration process. Refer to instructions on page 3-16.
ppO₂ Calibrated Value	0x791E (31006)	Floating point IEEE 754 (MSB 16-bits) Unit = mbar Valid Range = 0 to 1.2	ACTION: Monitor in system NOTE: Refer to instructions on page 3-16.
	0x791F (31007)	Floating point IEEE 754 (LSB 16-bits) Unit = mbar Valid Range = 0 to 1.2	
ppO₂ Status	0x7920 (31008)	0 = Loading System initialising, no ppO ₂ measurements 1 = OFF No ppO ₂ measurements 2 = Standby No ppO ₂ measurements 3 = Reserved 4 = ON Valid ppO ₂ measurements 5 = Reserved 6 = Calibration Invalid O ₂ measurements, calibration in process	ACTION: Monitor in system NOTE: Refer to instructions on page 3-16.

Table 3-7 – ppO₂ - Input Registers

Name	Register Address	Description	Actions / Notes
ppO2 Offset Status (Calibration)	0x7921 (31009)	0 = Error Error during the calibration process 1 = Not Ready Calibration is currently disabled 2 = Ready Calibration enabled 3 = Busy Calibration in progress 4 = Complete Calibration complete	ACTION: Monitor in system NOTE: Refer to instructions on page 3-16.
ppO2 Gain Status (Calibration)	0x7922 (31010)	0 = Error Error during the calibration process 1 = Not Ready Calibration is currently disabled 2 = Ready Calibration enabled 3 = Busy Calibration in progress 4 = Complete Calibration complete	ACTION: Monitor in system NOTE: Refer to instructions on page 3-16.
ppO ₂ MAF Status (Configur- ation)	0x7923 (31011)	0 = Error Error during the configuration process 1 = Not Ready Configuration is currently disabled 2 = Ready Configuration enabled 3 = Busy Configuration in progress 4 = Complete Configuration complete	ACTION: Monitor in system NOTE: Refer to instructions on page 3-16.
ppO2 DAC (Diagnostic)	0x7924 (31012) 0x7925 (21012)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits)	ACTION: Monitor in system
	(31013)	Unit = (0.8mv) steps Valid range = 0 to 65535	

Name	Register Address	Description	Actions / Notes
ppO2 DAC Status (Diagnostic)	0x7926 (31014)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system
ppO2 ADC Background (Diagnostic)	0x7927 (31015) 0x7928 (31016)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535	ACTION: Monitor in system
ppO2 ADC Background Status (Diagnostic)	0x7929 (31017)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system
ppO2 ADC Peak (Diagnostic)	0x792A (31018) 0x792B (31019)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535	ACTION: Monitor in system
O2 ADC Peak Status (Diagnostic)	0x792C (31020)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system

Name	Register Address	Description / Valid Values	Actions / Notes
ppO ₂ Control	0xA029 (41001)	Reserved	ACTION: Monitor in system
Clear ppO ₂ Warning	0xA02A (41002)	0 = Idle 1 = Clear warning (Reserved)	ACTION: None NOTE: Any warning present in ppO_2 Warning (31002) will auto clear if the condition that caused the warning is removed.
Clear ppO ₂ Error	0xA02B (41003)	0 = Idle 1 = Clear error	ACTION: Set in system NOTE: If an error present in ppO_2 Error (31003) has forced ppO_2 Status to OFF (31008 = 1) the error may be cleared using this register. If the error persists, contact <u>technical@sstsensing.com</u> for guidance.
ppO2 Offset (Calibration)	0xA02C (41004) 0xA02D (41005)	Floating point IEEE 754 (MSB 16-bits) Unit = mbar Valid Range = 0 to 0.1 Floating point IEEE 754 (LSB 16-bits) Unit = mbar Valid Range = 0 to 0.1	ACTION: Set/Monitor in system NOTES: Any changes are saved in EEPROM and retained on power loss. Default = 0.01 . Refer to instructions on page 3-16.
ppO ₂ Offset Control (Calibration)	0xA02E (41006)	0 = Idle 1 = Apply Calibration 2 = Reset Status	ACTION: Set in system NOTE: Refer to instructions on page 3-16.
ppO₂ Gain (Calibration)	0xA02F (41007) 0xA030 (41008)	Floating point IEEE 754 (MSB 16-bits) Unit = mbar Valid Range = 0.1 to 1.2 Floating point IEEE 754 (LSB 16-bits) Unit = mbar Valid Range = 0.1 to 1.2	ACTION: Set/Monitor in system NOTES: Any changes are saved in EEPROM and retained on power loss. Default = 1.0 . Refer to instructions on page 3-16.
ppO₂ Gain Control (Calibration)	0xA031 (41009)	0 = Idle 1 = Apply Calibration 2 = Reset Status	ACTION: Set in system NOTE: Refer to instructions on page 3-16.

Table 3-8 – ppO₂ Sensor - Holding Registers

Name	Register Address	Description / Valid Values	Actions / Notes
ppO2 MAF (Configur- ation)	0xA032 (41010)	Floating point IEEE 754 (MSB 16-bits) Valid Range = 100 to 10000	ACTION: Set/Monitor in system NOTES: Any changes are saved in EEPROM and retained on power loss. Default = 5000 . Refer to instructions on page 3-16.
	0xA033 (41011)	Floating point IEEE 754 (LSB 16-bits) Valid Range = 100 to 10000	
Control (Configur ation)	0xA034 (41012)	0 = Idle 1 = Apply Calibration 2 = Reset Status	ACTION: Set in system NOTE: Refer to instructions on page 3-16.

3.5 O₂ Registers

Name	Register Address	Description	Actions / Notes
O2 ID	0x7A13 (31251)	0104	ACTION: For reference NOTE: Unique identifier
O ₂ Warning	0x7A14 (31252)	16-bit bitmask Each bit represents an individual warning state O = No fault O ₂ within normal operating range 14 = Greater O ₂ above valid operating limit 15 = Less O ₂ below valid operating limit	ACTION: Monitor in system NOTES: Warnings are not retained on power loss.
O ₂ Error	0x7A15 (31253)	16-bit bitmask Each bit represents an individual error state 0 = DAC error 1 = X2 error 14 = Peripheral error 15 = Network error	ACTION: Monitor in system NOTES: Errors are not retained on power loss.
O ₂ Uncalibrated Value	0x7A16 (31254)	Floating point IEEE 754 (MSB 16-bits) Unit = ppm	ACTION: Monitor in system NOTES: This value can be greater than or less than the ppm sensor range and is used to determine measurement stability
	0x7A17 (31255)	Floating point IEEE 754 (LSB 16-bits) Unit = ppm	during the calibration process. Used in Section 3.6 on page
			3-16.
O ₂ Calibrated Value	0x7A18 (31256)	Floating point IEEE 754 (MSB 16-bits) Unit = ppm Valid Range = 0 to 1200	ACTION: Monitor in system NOTE: Used in Section 3.6 on page 3-16.
	0x7A19 (31257)	Floating point IEEE 754 (LSB 16-bits) Unit = ppm Valid Range = 0 to 1200	
O2 Status	0x7A1A (31258)	0 = Loading System initialising, no O ₂ measurements 1 = OFF No O ₂ measurements 2 = Standby No O ₂ measurements 3 = Reserved 4 = ON Valid O ₂ measurements 5 = Reserved 6 = Calibration Invalid O ₂ measurements, calibration in process	ACTION: Monitor in system NOTE: Used in Section 3.6 on page 3-16.

Name	Register Address	Description	Actions / Notes
O2 Offset Status (Calibration)	0x7A1B (31259)	0 = Error Error during the offset calibration process 1 = Not Ready Offset calibration is currently disabled 2 = Ready Offset calibration enabled 3 = Busy Offset calibration in progress 4 = Complete Offset calibration complete	ACTION: Monitor in system NOTES: Used in Section 3.6.1 on page 3-16.
O2 Gain Status (Calibration)	0x7A1C (31260)	0 = Error Error during the gain calibration process 1 = Not Ready Gain calibration is currently disabled 2 = Ready Gain calibration enabled 3 = Busy Gain calibration in progress 4 = Complete Gain calibration complete	ACTION: Monitor in system NOTES: Used in Section 3.6.2 on page 3-16.
O2 MAF Status (Configuratio n)	0x7A1D (31261)	0 = Error Error during the configuration process 1 = Not Ready Gain calibration is currently disabled 2 = Ready Gain calibration enabled 3 = Busy Gain calibration in progress 4 = Complete Gain calibration complete	
O2 DAC (Diagnostic)	0x7A1E (31262) 0x7A1F (31263)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535	ACTION: Monitor in system
O2 DAC Status (Diagnostic)	0x7A20 (31264)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system
O2 ADC Background (Diagnostic)	0x7A21 (31265) 0x7A22 (31266)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535	ACTION: Monitor in system

Name	Register Address	Description	Actions / Notes
O2 ADC Background (Diagnostic)	0x7A23 (31267)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system
O2 ADC Peak (Diagnostic)	0x7A24 (31268) 0x7A25 (31269)	32-bit integer (MSB 16-bits) Unit = (0.8mv) steps Valid range = 0 to 65535 32-bit integer (LSB 16-bits)	ACTION: Monitor in system
	(,	Unit = (0.8mv) steps Valid range = 0 to 65535	
O2 ADC Peak (Diagnostic)	0x7A26 (31270)	0 = Error Error during the diagnostic index change process 1 = Not Ready Diagnostic values are currently disabled 2 = Ready Diagnostic values enabled	ACTION: Monitor in system

Table 3-10 -	O ₂	Sensor -	Holding	Registers
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Name	Register Address	Description / Valid Values	Actions / Notes
O ₂ Control	0xA123 (41251)	Reserved	ACTION: Monitor in system NOTE: The O ₂ measurement cannot be switched off.
Clear O2 Warning	0xA124 (41252)	0 = Idle 1 = Clear warning (Reserved)	ACTION: None NOTE: Any warning present in O_2 Warning (31252) will auto clear if the condition that caused the warning is removed.
Clear O ₂ Error	0xA125 (41253)	0 = Idle 1 = Clear Error	ACTION: Set in system NOTE: If an error present in O_2 Error (31253) has forced O_2 Status to OFF (31258 = 1) the error may be cleared using this register and an attempt made to reset the status by setting the O_2 Control to Reset Status (41256 = 2 or 41259 = 2). If the error persists, contact technical@sstsensing.com for guidance.
O2 Offset (Calibration)	0xA126 (41254) 0xA127 (41255)	Floating point IEEE 754 (MSB 16-bits) Unit = ppm Valid Range = 0 to 100 Floating point IEEE 754 (LSB 16-bits) Unit = ppm Valid Range = 0 to 100	ACTION: Set/Monitor in system NOTES: Any changes are saved in EEPROM and retained on power loss. Default = 10 . Used in Section 3.6.1 on page 3-16.
O ₂ Offset	0xA128 (41256)	0 = Idle 1 = Apply Calibration	ACTION: Set in system
(Calibration)	(41230)	2 = Reset Status	on page 3-16.
O ₂ Gain (Calibration)	0xA129 (41257) 0xA12A	Floating point IEEE 754 (MSB 16-bits) Unit = ppm Valid Range = 100 to 1200 Floating point IEEE 754 (LSB 16-bits)	ACTION: Set/Monitor in system NOTES: Any changes are saved in EEPROM and retained on power loss.
	(41258)	Unit = ppm Valid Range = 100 to 1200	Default = 1000 . Used in Section 3.6.2 on page 3-16.
O2 Gain Control (Calibration)	0xA12B (41259)	0 = Idle 1 = Apply Calibration 2 = Reset Status	ACTION: Set in system NOTE: Used in Section 3.6.2 on page 3-16.

Name	Register Address	Description / Valid Values	Actions / Notes
O ₂ MAF (Configuration)	O2 MAF 0xA12C (Configuration) (41260)	32-bit integer (MSB 16-bits) Valid range = 100 to 10000	ACTION: Monitor in system
	0xA12D (41261)	32-bit integer (LSB 16-bits) Valid range = 100 to 10000	
Control (Configuration)	0xA12E (41262)	0 = Idle 1 = Apply Configuration 2 = Reset Status	ACTION: Set in system NOTE: Used in Section 3.6.2 on page 3-16.

3.6 Calibrating the Sensor

3.6.1 Offset Calibration

- 1. Confirm O_2 Offset Status (Calibration) = Ready (31259 = 2).
- 2. Apply a "zero" (Offset) gas of a known ppm value over the sensor.

NOTE: The "zero" gas MUST have an Oxygen concentration less than 100ppm; it is recommended that the "zero" gas is less than 25ppm.

NOTE: Recommended flow rate is one litre per minute.

3. Monitor *O*₂ *Uncalibrated Value* (31254 and 31255) and wait at least 30 minutes until the value stabilises.

NOTE: Wait time based on purging from air.

- 4. Input the "zero" gas value (ppm) into O₂ Offset (Calibration) (41254 and 41255).
- 5. Set *O*₂ *Offset Control (Calibration)* to *Apply Calibration* (41256 = 1).
- 6. During the calibration routine O_2 Offset Status (Calibration) will change to Busy (31259 = 3) and O_2 Status will change to Calibration (31258 = 6). O_2 measurements are not valid during this phase.
- 7. When the calibration routine is complete O_2 Offset Status (Calibration) will change to Complete (31259 = 4) and O_2 Status will return to ON (31258 = 4).
- 8. Set O_2 Offset Control (Calibration) to Reset Status (41256 = 2) to return O_2 Offset Status (Calibration) to Ready (31259 = 2).
- 9. Confirm the O₂ Calibrated Value (31256 and 31257) is within ±2 ppm of the calibration gas applied. If not, repeat Steps 3 to 9 and allow the O₂ Uncalibrated Value (31254 and 31255) to stabilise for a longer period. If multiple calibration attempts do not result in an accurate calibration, contact technical@sstsensing.com for guidance.

3.6.2 Gain Calibration

The Offset is the main calibration point, however, if a "span" (Gain) calibration is required:

- 1. Confirm O_2 Gain Status (Calibration) = Ready (31260 = 2).
- 2. Apply a "span" (Gain) gas of a known ppm value over the sensor.

NOTE: The "span" gas MUST have an Oxygen concentration greater than 100ppm; it is recommended that the "span" gas is the maximum of the working range or, if available, 1000ppm should be used.

NOTE: Recommended flow rate is one litre per minute.

3. Monitor *O*₂ *Uncalibrated Value* (31254 and 31255) and wait at least 10 minutes until the value stabilises.

NOTE: Wait time based on purging from air.

- 4. Input the "span" gas value (ppm) into O₂ Gain (Calibration) (41257 and 41258).
- 5. Set O_2 Gain Control (Calibration) to Apply Calibration (41259 = 1).
- 6. During the calibration routine O_2 Gain Status (Calibration) will change to Busy (31260 = 3) and O_2 Status will change to Calibration (31258 = 6). O_2 measurements are not valid during this phase.
- 7. When the calibration routine is complete O_2 Gain Status (Calibration) will change to Complete (31260 = 4) and O_2 Status will return to ON (31258 = 4).

- 8. Set O_2 Gain Control (Calibration) to Reset Status (41259 = 2) to return O_2 Gain Status (Calibration) to Ready (31260 = 2).
- Confirm the O₂ Calibrated Value (31256 and 31257) is within ±2 ppm of the calibration gas applied. If not, repeat Steps 3 to 8 and allow the O₂ Uncalibrated Value (31254 and 31255) to stabilise for a longer period. If multiple calibration attempts do not result in an accurate calibration, contact <u>technical@sstsensing.com</u> for guidance.

REFERENCE DOCUMENTS

Reference documents are listed below. The SST documentation list is not exhaustive, always refer to the <u>SST website</u> for the latest information.

Part Number	Title
DS-0154	Oxygen Sensing – LuminOx Trace Series Datasheet
UG-015	Oxygen Sensing – LuminOx Trace Series User's Guide

As customer applications are outside of SST Sensing Limited's control, the information provided is given without legal responsibility. Customers should test under their own conditions to ensure that the equipment is suitable for their intended application.

For technical assistance or advice, please contact <u>technical@sstsensing.com</u>.

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