Hardware Manual for
Stock Level Monitoring System

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1. Introduction

The purpose of this document is to give guidelines for installation, use and integration of the Terabee Stock Level Monitoring System. The user manual includes instructions about the hardware part of the system (Stock Level Supervisor and Stock level TOF Sensors), including mechanical integration and connectivity. For software and interface connectivity guidelines please refer to the software manual.

1.1. About Terabee Stock Level Monitoring System

Enable real-time level measurements for solid, powder and liquid materials with the Terabee Stock Level Monitoring System. Developed to monitor open containers, storage tanks, and open stockpiles with raw materials - Terabee's versatile system offers single-point as well as multi-sensor level monitoring capabilities - all in one solution!
Benefit from non-intrusive and safe inventory management as our LED-based Time-of-Flight system does not come in direct contact with stored materials. The IP65-rated enclosure ensures installations and operations in outdoor conditions, whilst the available RS485 and Ethernet interfaces allow for reliable data connection in a variety of applications.

Figure 1. Terabee Stock Level TOF Sensor (left) and Stock Level Supervisor (right)

The system features on-the-edge computing - turning distance data from sensors into volume and level estimations of the remaining material stock. Benefit from a free web-based configuration software to set up the system and the volume / level computation capabilities.

For more information about the system please visit the official product page of the Terabee website or contact terabee-sales@terabee.com.

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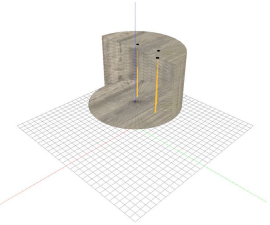
1.2. System Components

Table 1 - Stock Level Monitoring: system components and use

Components	Visuals	Purpose
Stock Level Supervisor		- Central computing unit for volumes, level estimations - Access point for all Stock Level TOF Sensors connected via RS485 connection using a single bus, - Provides data output via Ethernet (Modbus TCP/IP), - Provides power management to connected sensors and requires 24V DC supply for operation. - Hosts on-board computation of volume and level data
Stock Level TOF Sensor		- TOF distance sensor (up 60m), operated only through Stock Level Supervisor, - Connection to Supervisor via RS485 (power and data), - On-board LED signalization for sensor status
Web-configurator (software application)		- Available via direct connectivity to the Supervisor - Used for system setup and volume / level computation configuration - Optimized for use with PC

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1.3. Technical Specifications

Table 2 - Technical specifications of the Stock Level Supervisor

Stock Level Supervisor		
No. of Sensors Connected	Up to 8 sensors ready (extension to 32 sensors possible)	
Data Output	Distance 1 (sensor to material surface) in millimeters Distance 2 (material surface to container bottom) in millimeters Computed level in percentage (%) Computed volume in liters (l)	
Accuracy (1)	Distance: Volume / Level:	±4 cm in the first 14 m; ±1.5% beyond 14 m depending on application conditions
Update Rate	1 measurement every minute	
Interface, Data communication	Ethernet - 100mbps	
Interface, System configuration	Ethernet - 100mbps WiFi - 2.4 GHz / 5GHz IEEE 802.11.b/g/n/ac	
Communication Protocol	Sensors: Data:	Modbus RTU Modbus TCP/IP
Type of Connection	Power: Sensors: Data:	M12 t-coded male connector, 4-pin M12 a-coded female connector, 5-pin M12 d-coded female connector, 4-pin
Supply Voltage	24V DC +/-10%	
Current Consumption (8 Sensors @ +45°C)	Minimum: Average: Maximum:	350 mA 410 mA 700 mA
Visual Notification	3 x LEDs (multicolor)	
Dimensions (LxWxH)	112 x 47 x 123 mm	
Weight	480 g	
Housing Material	Polyurethane, Aluminium	
Housing Protection	IP65	
Ambient Temperature Operation	-10°C to +45°C	
System Configuration	Yes, via web-based application	
Mounting	DIN EN50022 Rail 2x M5 Through-hole 2x M5 Screws	

(1) Accuracy of volume and level calculations will strongly depend on the overall container dimensions, number of sensors used, container size and architecture, available space for sensor positioning, material type and distribution.

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Table 3 - Technical specifications of the Stock Level TOF Sensor

Stock Level TOF Sensor	
Detection Principle	Optical Time-of-Flight (infrared)
Range (1)	0.5 m up to 60 m
Output Resolution	5 mm
Accuracy, Distance (1)	±4 cm in the first 14 m, and ±1.5% beyond 14 m
Repeatability (1) (2)	5mm
Field of View	Approx. 2°
Projected Reception Area	10.5 cm x 10.5 cm @ 3 m distance
Light Source Wavelength	940nm
Supply Voltage	24V DC (powered via DSS)
Initialization Time	< 1 s
Serial Interface	RS485 (half-duplex, 19.2 kbps)
Communication Protocol, to Supervisor	Modbus RTU
Type of Connection	M12 A-coded male connector, 5-pin
Visual Notification	4 x LEDs (multicolor)
Dimensions	94 x 56 x 31 mm
Weight	99g
Housing Material	ABS and Aluminium
Housing Protection	IP65
Ambient Temperature Operation	-20°C to +45°C
Mounting	4 x M4 Screws

(1) Specifications are derived from tests in controlled conditions (target with 80% diffuse reflectivity, indoor fluorescent lighting, ambient temperature around 25°C). Note that bright sunlight, target surface reflectivity and other variables can affect sensor performance, including maximum range
(2) Evaluated as one standard deviation over multiple measurements

1.4. Symbols explanation

The following symbols are used within the document:

This symbol indicates specific recommendations in order to run the sensor in the intended way

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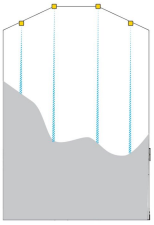
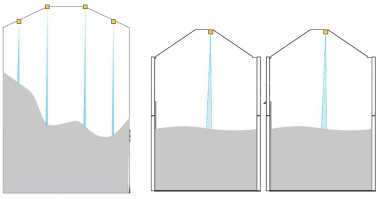
1.5. Applications guide

Use case	Single sensor applications, 1 container	Multi sensor applications, 1 container	Multi-sensor, multi-container applications
			
Applications and Products			
Recommended Materials	• Liquids; • Solids with known material distribution	• Solids with unknown material distribution	• Liquids; • Solids with known material distribution; • Solids with unknown material distribution
Recommended Products	Stock Level Monitoring System x 1 	Stock Level Monitoring System x 4 	Stock Level Monitoring System x 4 + Additional Systems or Sensors 
Data output (Stock Level Supervisor)			
Distance Data 1 (mm) *sensor to material surface*	Yes	Yes	Yes
Distance Data 2 (mm) *material surface to container bottom*	Yes	Yes	Yes
Material Level (%)	Yes	Yes	
Material Volume (l)	Yes	Yes	

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2. Mechanical integration

2.1. Mechanical design

2.1.1. Stock Level Supervisor

Housing material : Polyurethane, Aluminium
Housing color : Grey RAL7004
Protection level : IP65-rated

External dimensions :

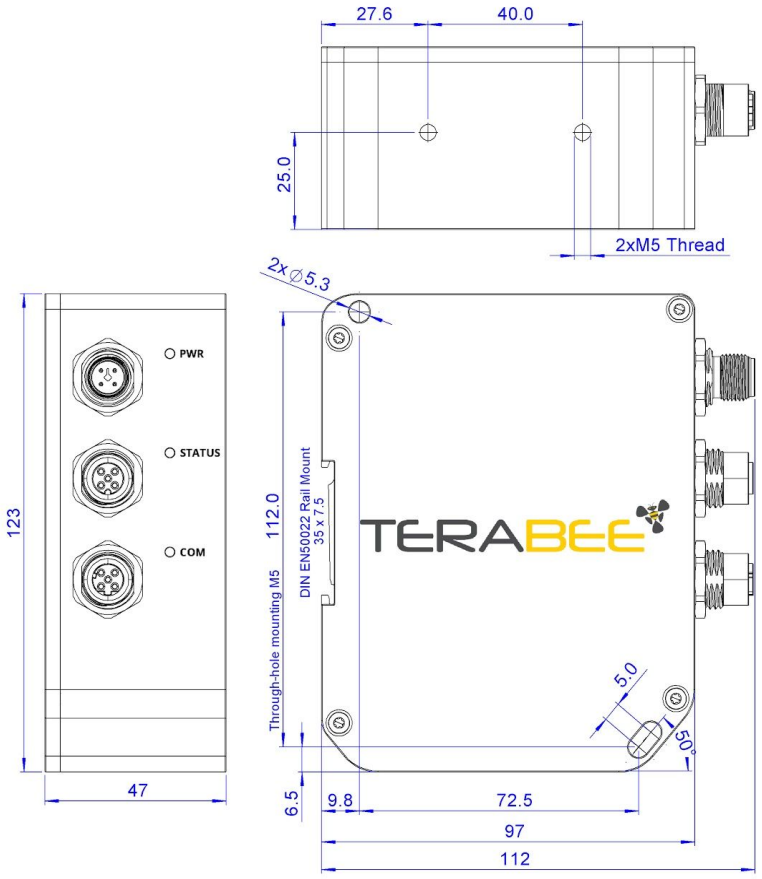

Figure 2. External dimensions and mounting options of Terabee Stock Level Supervisor

2.1.2. Stock Level TOF Sensor

Housing material : ABS, Aluminium
Housing color : Black
Protection level : IP65-rated

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External dimensions :

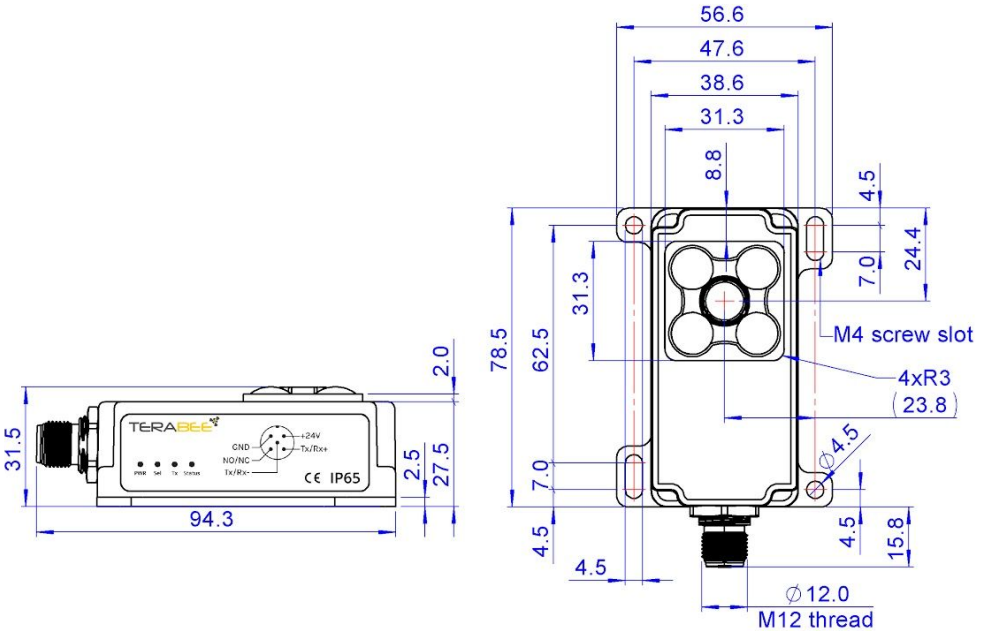

Figure 3. External dimensions of Stock Level TOF sensor

2.2. System Installation

The following section briefly describes steps for system hardware installation in applications with volume and level measurements.

2.2.1. Selection of mounting location/s

As a fist step, Terabee recommends the user to evaluate and decide on the best physical installation possibilities for the Stock Level TOF Sensors. This will depend on a variety of application factors (see section 2.2.3).

Please use technical drawings of the containers, or access most suitable installation points by inspecting the container in real-life. For each sensor installation, it is important to determine X and Y positions (measured from the center of the container). This information will then need to be input as a parameter in the system configuration software to allow accurate level and volume computation. In case only raw distance data (in millimeters) is required, determining sensors X and Y positions is not necessary.

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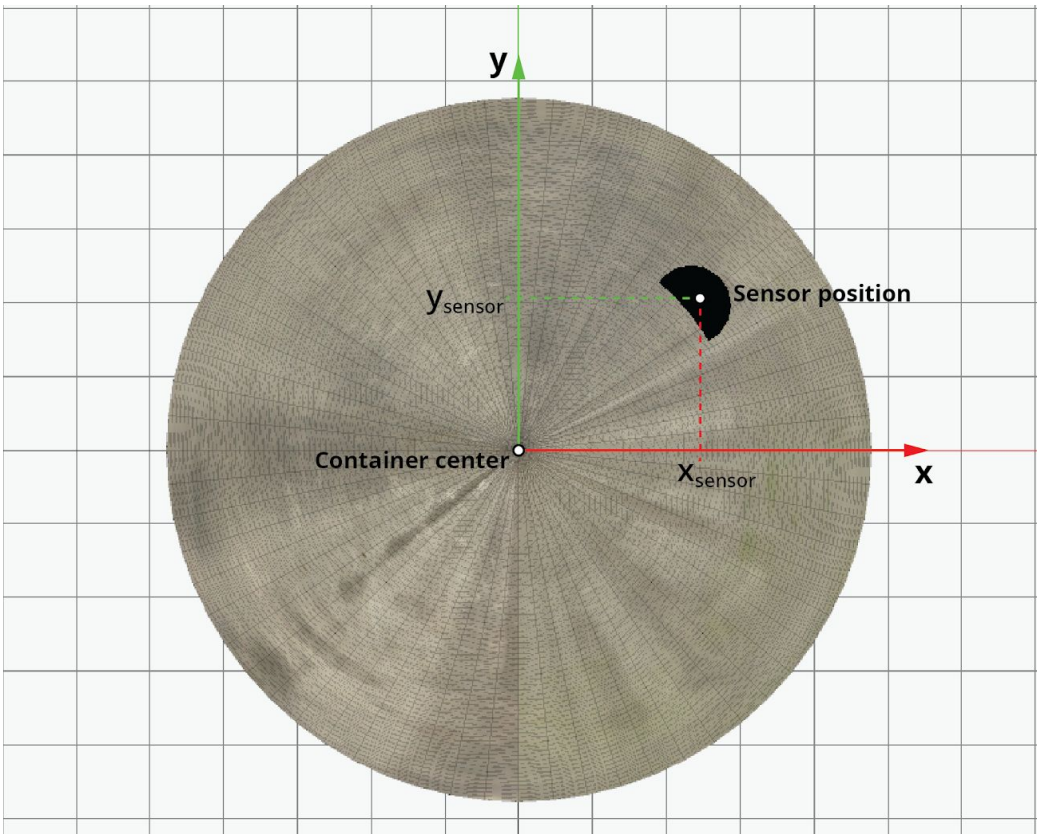

Figure 4. Top view of the container in the configuration tool. X and Y position of the sensor measured from the container center

2.2.2. Software setup

Before any physical installation of the system, please use the web-application to configure the system, and ensure optimal performance. If you are using the estimated volume and level data as an output, this step is critical - as the software requires to input application-related parameters including container shape and dimensions, material type to be monitored, etc. For more detailed instructions about software setup please refer to the software manual.

Please note that the Terabee web-configuration software is only used as a means to set up the system, including volume and level computation logic. The software is not intended to provide any recommendations on most suitable mounting possibilities, necessary number or configuration of sensors, or other information related to the application setup. This information is to be evaluated and confirmed by the user before configuring the Stock Level Supervisor.

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2.2.3. Sensor mounting and positioning

Selecting an appropriate location for the sensor installation is a critical part of the whole system commissioning as it ensures high accuracy and reliability of the data output. For optimal performance and accurate measurements, please ensure the sensor is installed vertically - 90 degrees to the ground level.

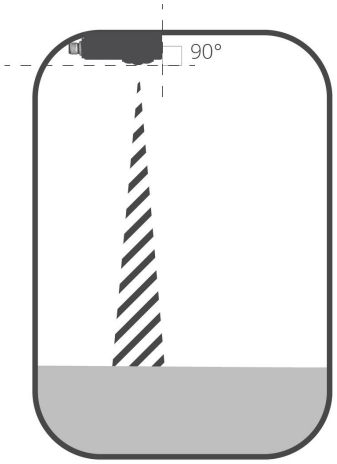

Figure 5. Optimal sensor positioning for level measurements

Diagonally positioned sensors or other types of inaccurate installations may lead to less accurate measurements and lower system performance (e.g measuring the side of the walls, internal equipment or flowing material during the filling process).

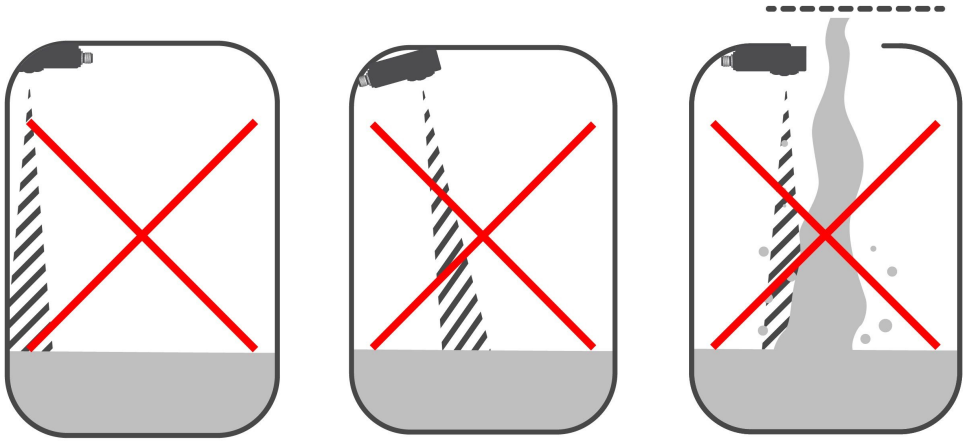

Figure 6. Example of inaccurate sensor positioning for level measurements

Exact sensor installation location will depend on several factors, including: available/allowed space for hardware mounting, inlet and outlet positions, accessibility, container overall dimensions and architecture, material type to be monitored and more. Given the variety of containers available, installation points will strongly vary from one container to another.

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Please regard the following factors and recommendations when choosing an installation point for each sensor:

- *Consider the overall container dimensions*
- *Do not install the sensor near the container side (wall) or any other equipment / obstructions inside the tank, that might block the sensors Field of View*
- *Consider material inlet and outlet points in the container. Do not mount the sensor inside or close to the filling point as the material intake process can can damage the sensor*
- *The sensor must be attached with a clear line of sight from the sensor lens to the material top surface layers*
- *Mounting close to sources of heat or strong electromagnetic fields can decrease performance*
- *Internal structure and equipment can potentially abstract the light beam of the sensor resulting into false data*
- *Within the first meter from the sensor avoid objects with high surface reflectivity in a cone of approximately ± 45° around the central optical axis of the sensor*
- *Do not mount anything directly in front or next to the sensor, that might interfere with the light emitting and receiving light beams*
- *Do not mount the sensor close to anything with lots of movement and vibration (electrical motors, etc)*
- *Please note that material measured closer than 50cm range will be reported as an error, as it breaches the minimum range of the sensor. Once the material level decreases and passes the 50cm distance mark from the sensor lens, the system will continue outputting corresponding distance values*
- *It is recommended to avoid having other sources of continuous wave or modulated IR light close to the sensor*

The Stock Level TOF Sensor features 4 slots for mounting the sensor using standard M4 screws. The following mounting methods can be used to support a variety of level monitoring applications:

A. Integrated M4 screws slots in the sensor mechanical design with 4 attachment points for horizontal installations. This supports mounting to ceilings, half-open containers or other flat infrastructures with a 90 degree angle to the ground level.

Figure 7. Sensor mounted on a ceiling.

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B. Using the 2mm ledge on the front side of the sensor (square shape around lenses) for installations in closed containers with a flat top surface. To support this, please drill 4 x M4 screw holes into the selected location on the top of the container together with a 32x32 mm cutout for the sensor lens. Pass low-profile M4 screws from the inside through the holes and tighten with silicone washers and nuts directly to the container. Use a Ø 37 mm x 1.5 mm o-ring to apply around the 2 mm ledge on the front of the sensor to seal the 32x 32 mm cutout. Insert the sensor into the cutout with the screws passing through the integrated M4 screw slots on the sensors backplate. Compress the o-ring and fix the sensor in place using M4 washers and nuts.

Figure 8. Sensor mounted inside a ceiling.

Without access to the inside of the container, the lens cutout can be extended up to 32x62 mm to allow easier insertion of the screws through this opening. Proceed as previously described to fix the screws with silicone washers and nuts to the container. In order to seal the container, use a 1.5 mm thick rubber sheet to cut a rectangular gasket with 32x62 mm inner shape and 36x66 mm outer shape. Apply the gasket between sensor and container and compress by tightening the sensor in place using M4 washers and nuts. A detailed view of the mounting including the silicone washers and rubber gasket (in yellow) is shown below.

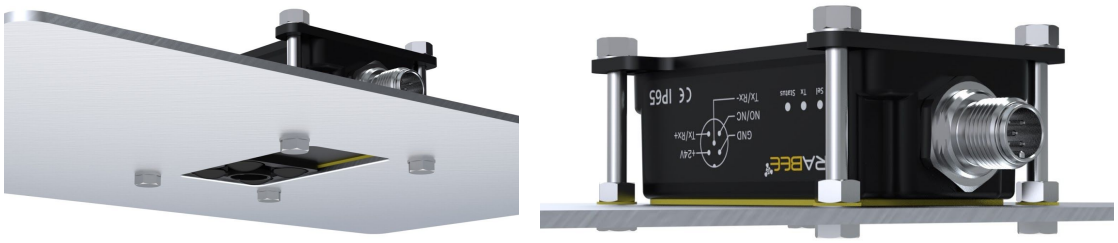

Figure 9. Sensor mounted inside a ceiling with a gasket.

C. Installations on vertical surfaces using the 90 degree mounting bracket to allow downwards positioning of the sensor towards material surface. When mounting in open or half-open containers, please make sure that the sensor's beam does not hit the wall surface, which may lead to inaccurate measurements. To avoid this, use an extension pole.

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Figure 10. Sensor mounted using the 90 degree mounting bracket.

D. For installations on angled surfaces with clear access to the mounting location - use the Adjustable Mounting Bracket to position the sensor in custom angles for accurate detection of the material surface.

Figure 11. Sensor mounted using the adjustable mounting bracket.

***IMPORTANT**: For installations inside containers with angled top structures, the Stock Level TOF Sensor does not yet provide an easy physical attachment method, and additional integration or supporting bracket development must be done. Please contact your sales representative or terabee-sales@terabee.com to find the best possible installation method, if the offered attachments do not fit your requirements. Upon demand, Terabee Engineers can also work with clients to build new brackets and support specific application needs.*

2.2.4. Installation of Stock Level Supervisor

The central computing unit (Supervisor) should be installed with easy access to the technical personnel (e.g ground level) and preferably in close proximity to the Programmable Logic Control for power supply and data communication (e.g inside the

Control box). The Supervisor can also be mounted on the top infrastructure of the containers, however please avoid direct exposure to strong sunlight and extremely high temperatures.

Table 4 summarizes mounting possibilities with the Stock Level Supervisor.

Table 4. Mounting methods : Stock Level Supervisor

	Mounting 1	**Mounting 2**	**Mounting 3**
Visualization			
Mounting description*	Mounting directly on a 35 mm x 7.5 mm DIN EN50022 Rail	Side-mounting using the M5 through-holes provided in the housing	Bottom-mounting using M5 screws and the M5 threads

Please regard the following factors and recommendations when choosing an installation point for the Stock Level Supervisor:

- *Mount the Supervisor unit at an easy to access location (e.g ground level)*
- *Consider the maximum cable length limitations for RS485 interface when choosing a mounting location for the Supervisor unit*
- *Do not mount the Supervisor unit to anything with lots of movement and vibration (electrical motors, etc)*
- *Do not install the computing unit in direct sunlight as this can lead to an increase in housing temperature and reduce computing performance.*

2.2.5. Wiring the Sensors to the Stock Level Supervisor via RS485

A single Stock Level Supervisor can support up to 8 sensor connections. For more than 8 sensor applications with a single Supervisor unit, please contact terabee-sales@terabee.com or your Terabee sales representative.

The Supervisor unit features an RS485 connector (M12, 5-pin) to allow raw distance data collection from connected Stock Level TOF Sensors - in a single bus configuration using Modbus protocol. It is recommended to use an appropriate cable rated for RS485 interface use with the following characteristics and recommendations:

- For the RS485 communication - a twisted pair with an impedance of 120 Ohm and a minimum section of 0,25 mm2 (24 AWG)
- Note: provide a termination resistor at the end of the line
- The power supply wire section will depend on the cable length and the number of connected sensors. A minimum of 0,32 mm2 (22 AWG) is recommended.
- Avoid using bus (cable) length above 80m, as this may affect / reduce performance

For multi-sensor connectivity using the RS485 bus, it is advised to use T-connections between the sensors. For the connector location and description of the connector pinout, please refer to section 2.4 and 2.5.

2.2.6. Wiring the Stock Level Supervisor to a PLC via Ethernet

The connection between the Supervisor unit and a PLC has to be done with a shielded Ethernet cable (e.g. Cat5 and beyond). For the connector location and description of the connector pinout, please refer to section 2.4 and 2.5.

2.2.7. Power supply to the Stock Level Supervisor

The Stock Level Supervisor needs to be supplied with 24V DC over the M12, T-coded, 4-pin male Power connector located on the device. The power supply wire section depends on the cable length and the number of connected sensors. A minimum of 0,518 mm^2 (20 AWG) is recommended.

For the connector location and description of the connector pinout, please refer to section 2.4 and 2.5.

2.3. System Maintenance

Please note the following application factors and recommendations for system maintenance:

- Performance of Stock Level TOF Sensors may be affected by large amounts of dust - present in the measuring environment. Depending on the application, periodical sensor cleaning might be necessary to remove collected dust and dirt build-up on the sensor lense. The frequency of maintenance will strongly depend on application environment and conditions, and mostly - type of material to be monitored. Please contact terabee-sales@terabee.com or your sales representative to discuss custom developments for physical sensor protection
- For removing dust and dirt from sensor lenses, Terabee recommends using a soft cloth with mild soap. Remove residues of soap using a wet, lint-free cloth.

- Ensure proper fitting and sealing of cable entry openings
- Visually inspect power and communication cables used for system connectivity, and ensure these are not damaged

2.4. Connectors and Onboard indicators

2.4.1. Stock Level Supervisor

The Supervisor unit offers onboard multi-color LEDs that provide a visual confirmation of sensor power, error and communication status. Figure 12 and the corresponding Table 5 describe the connector locations and onboard indicators. Table 6 summarizes the signalization sequence of the LEDs.

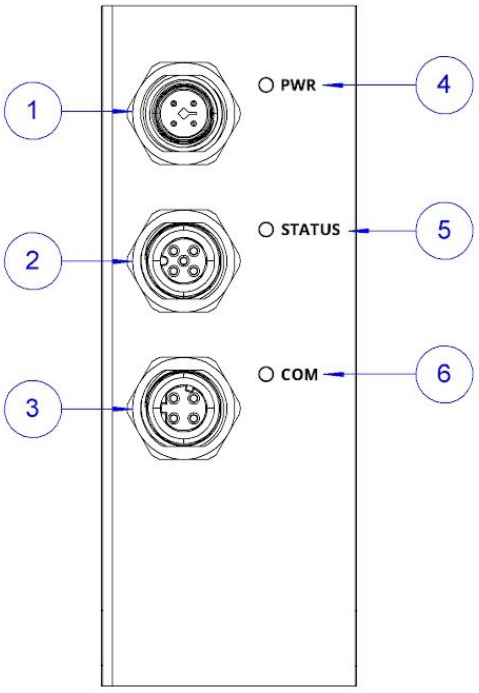

Figure 12. Stock Level Supervisor connectors and LED indicators

Table 5 - Stock Level Supervisor connectors and onboard indicators

No.	Category	Designator	Description
1	Connection	M12 Power	Power supply, T-coded male, 4 pin
2	Connection	M12 Sensor	Sensor input, A-coded female, 5 pin
3	Connection	M12 Communication	Communication output, D-coded female, 4 pin
4	LED indicator	PWR	Power indicator
5	LED indicator	STATUS	Error indicator
5	LED indicator	COM	Communication status

Table 6 - Stock Level Supervisor LED signalization logic

LED indicator	LED Color	Signalization logic
PWR	Green	LED continuously ON whenever connected to a power supply
STATUS	Green/Red/Yellow	Continuous GREEN indicates normal operation of the device Blinking GREEN (3 times), application configuration saved to the device (used for volume and level calculations). Blinking GREEN (10 times) indicates a new IP address set to the device. Short YELLOW indicates there was a warning during a step of the operation (e.g if one or multiple sensors failed to measure a distance in a multiple sensor setup, but at least one sensor communicated a distance value) Short RED indicates an error message during system operation Continuous RED indicates a failure of the Supervisor software; or a missing configuration file
COM	Green	LED blinking indicates data communication

2.4.2. Stock Level TOF Sensor

The distance sensor features onboard multi-color LEDs that provide a visual confirmation of sensor power, device selection, data transmission and error notification. Figure 12 and the corresponding Table 7 describe the connector location and onboard indicators. Table 8 summarizes the signalization sequence of the LEDs.

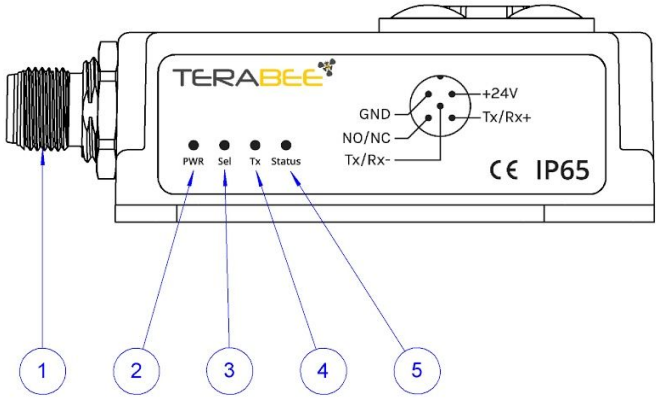

Figure 13. Stock Level TOF Sensor connector and LED indicators

Table 7 - Stock Level TOF Sensor connector and onboard indicators

No.	Category	Designator	Description
1	Connection	M12 connector	A-coded male, 5 pin
2	LED indicator	PWR	Power indicator
3	LED indicator	Sel	Notification on device selection by master
4	LED indicator	Tx	RS485 data transmission
5	LED indicator	Status	Error notification

Table 8 - Stock Level TOF Sensor LED signalization logic

LED indicator	LED Color	Signalization logic
PWR	Green	LED continuously ON whenever connected to a power supply
Sel	Blue	LED blinking indicates that the sensor (slave device) has been selected by a master. This means the sensor received data on the bus and confirmed it is addressed to it
Tx	Orange	LED blinking indicates that sensor (slave) is sending data on the bus
Status	Green/Red	Green LED indicates normal operation. Red LED indicates an error. Read the Error case by accessing the distance register. Refer to section 2.7 for the Error case description.

2.5. Connector pinouts

The Stock Level Supervisor uses three M12 connectors as indicated in Figure 12. The power is supplied through a M12, T-coded male connector as shown and described in Figure 14 and Table 9.

Figure 14. Stock Level Supervisor power connector pinout layout

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Table 9 - Stock Level Supervisor power connector pinout description

Pin	Designator	Description
1	+24V	Computing unit 24V DC power supply input
2	GND	Ground (power supply and data)
3	GND	Ground (power supply and data)
4	+24V	Sensor 24V DC power supply input

For ethernet communication with the Stock Level Supervisor, a M12 D-coded female connector is available on the device with the following pinout:

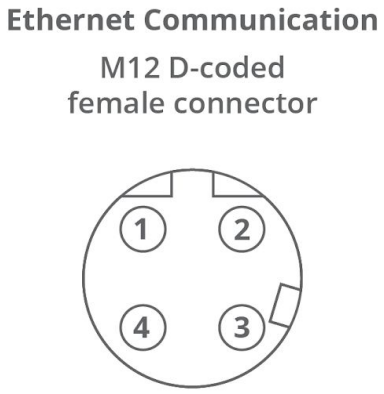

Figure 15. Stock Level Supervisor communication connector pinout layout

Table 10 - Stock Level Supervisor communication connector pinout description

Pin	Designator	Description
1	+Tx	Transmit data+
2	+Rx	Receive data+
3	-Tx	Transmit data-
4	-Rx	Receive data-

The Stock Level TOF Sensor is connected to the Stock Level Supervisor through an M12 A-coded connection with the female connector on the Supervisor and the male connector on the sensor. Both pinouts are shown and described below:

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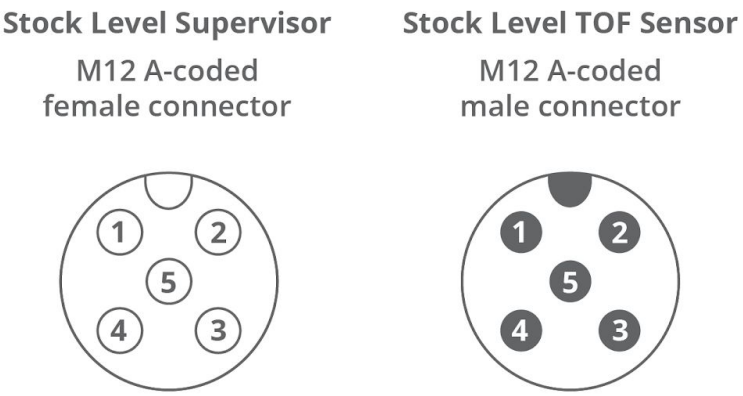

Figure 16. Pinout for the mating female and male M12, 5-pin connector on the Stock Level Supervisor (left) and Stock Level TOF Sensor (right)

Table 11 - Stock Level Supervisor and Stock Level TOF Sensor connector pinout description

Pin	Designator	Description
1	+24V	24V DC power supply
2	GND	Ground (power supply and data)
3	-	*Reserved for future use*
4	Tx/Rx+	RS485 differential line. High for logic 1 and low for logic 0
5	Tx/Rx-	RS485 differential line. Low for logic 1 and high for logic 0

2.6. DC Electrical characteristics

Table 12 - DC Electrical characteristics

	Parameter	Minimum	Standard	Maximum
Power supply	Voltage input DC	24 V	24 V	24 V
	Current consumption	350 mA	410 mA	700 mA

2.7. Error cases

The following table 13 summarizes error cases and the corresponding codes. The Supervisor unit stores the error codes inside the Input Register with address 00. Once a new error is stored in this register, the New Error Flag is raised (Discrete Input 01 is set to true). Table 14 shows the meaning of possible error codes for this register.

For a detailed explanation on how to detect an error during operation, please refer to the software manual of the *Stock Level Supervisor Operation.*

Table 13 - Error Register Codes

Error case	Output value	LED signalization
No Error	0x0000	This is the value of the register by default at the start up of the device. It indicates no error.
Sensor Failure	0xFF01	If one or more sensors fail, the Error Register will store this error code. In addition, the Sensor Failure Indicators will show which sensor has failed and the Distance Register corresponding to the ID of the sensor which has failed will show the reason of the error (table 14).
Impossible to compute results	0xFF02	If all the sensors fail, the Error Register will store this error code. In consequence, the Stock Level Supervisor will not be able to compute a volume or a level. Then, both Volume registers and the Level register will be set to 0xFFFF.

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Table 14 - Specific Sensor Failure codes.

Error case	Output value	LED signalization
Target too close	0x0000	The target is closer than the minimum range of the sensor.
Target too far	0xFFFF	The target is farther than the maximum range of the sensor.
Invalid reading	0x0001	Ambient light is too high. Target surface is too reflective.
Communication failure	0x0002	There was an error with the communication between the Stock Level Supervisor and the sensor. This could be due to a disconnected sensor, a damaged cable or a bad hookup.
Sensor not configured	0x00FF	If there is no configured sensor with the corresponding ID, the register is set to this value.

3. Optical characteristics

3.1. Projected reception area - Stock Level TOF Sensor

The Stock Level TOF Sensor is an optical distance measurement sensor that uses infrared Time-of-Flight principle. The sensor features an approximately 2 degree Field of View beam, which corresponds to a detection area of 35 x 35 cm (spot diameter in reception) at 10 m range, and scales linearly with distance. Figure 17 illustrates the spotlight geometry of the sensor at different reference distances.

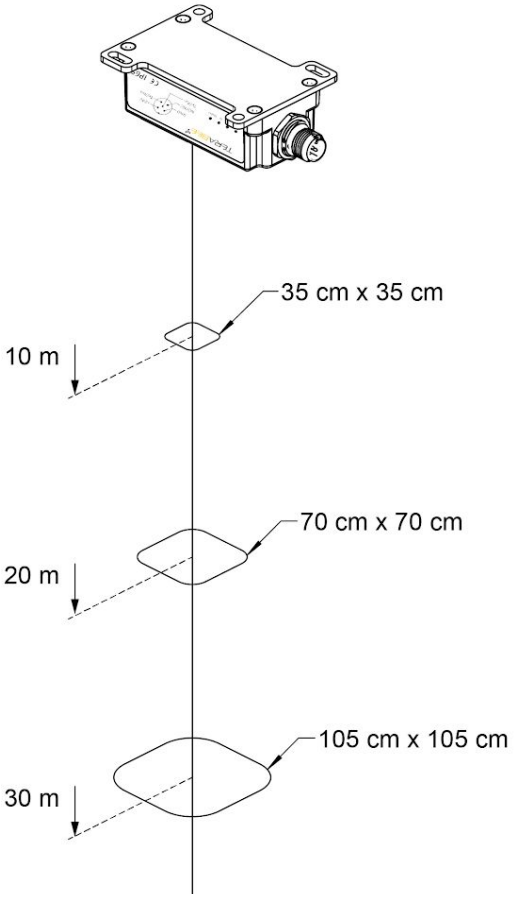

Figure 17. Stock Level TOF Sensor spot light geometry (reception) at 10 m, 20 m and 30 m reference distance

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3.2. Field of View characteristics

Due to the open Field of View nature of the LED optics, the Stock Level TOF Sensor measures an average distance within the projected area . At larger distances and in cases when the material surface has formed under a steeper angle (e.g due to coning or arching effects) - the sensor will average and output a “middle point” from the projected area.

Figure 18 shows an example of this phenomenon.

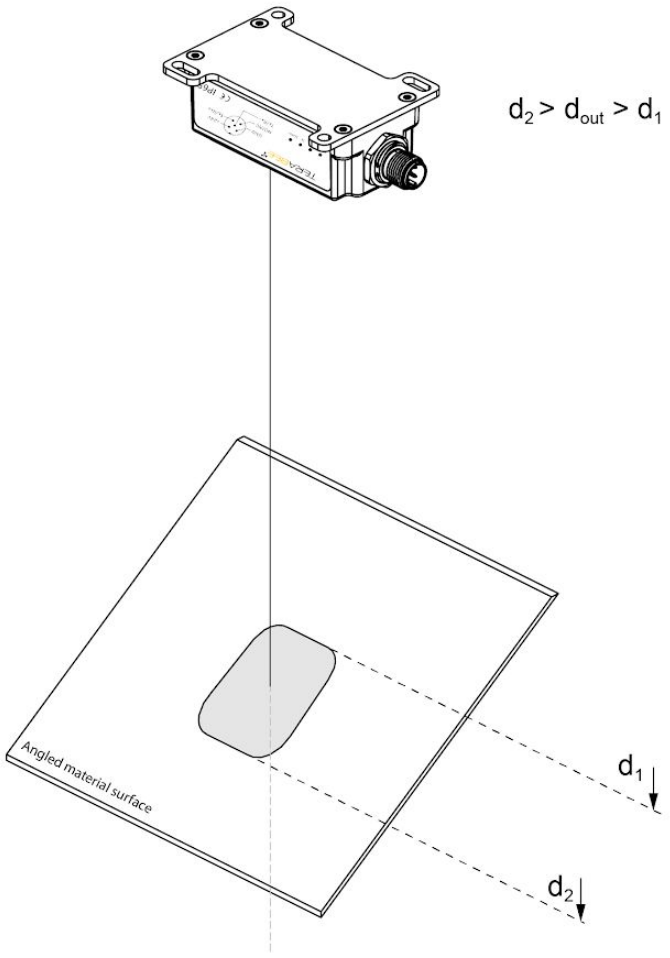

Figure 18. Example of distance averaging effect (d_{out}) due to the sensor Field of View expanding over two different real distances (d_1 and d_2) for an angled material surface.

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