

Level Plus[®]

Magnetostrictive Liquid Level Transmitters
with Temposonics[®] Technology

Modbus Interface Manual
LP Series

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1. Contact information

United States

General

Tel: +1-919-677-0100
Fax: +1-919-677-2343
E-mail: info.us@mtssensors.com
<http://www.mtssensors.com>

Mailing and shipping address

MTS Systems Corporation
Sensors Division
3001 Sheldon Drive
Cary, North Carolina, 27513, USA

Customer service

Tel: +1-800-633-7609
Fax: +1-800-498-4442
E-mail: info.us@mtssensors.com

Technical support and applications

24 Hour Emergency Technical Support
Tel: +1-800-633-7609
e-mail: levelplus@mts.com

Germany

General

Tel.: +49-2351-9587-0
Fax: +49-2351-56491
e-mail: info.de@mtssensors.com
<http://www.mtssensors.com>

Mailing and shipping address

MTS Sensor Technologie, GmbH & Co. KG
Auf dem Schüffel 9
D - 58513 Lüdenscheid, Germany

Technical support and applications

Tel.: +49-2351-9587-0
e-mail: info.de@mtssensors.com
<http://www.mtssensors.com>

Japan

General

Tel.: +81-42-775-3838
Fax: +81-42-775-5516
e-mail: info.jp@mtssensors.com
<http://www.mtssensors.com>

Mailing and shipping address

MTS Sensors Technology Corporation
737 Aihara-cho, Machida-shi
Tokyo 194-0211, Japan

Technical support and applications

Tel.: +81-42-775-3838
Fax: +81-42-775-5512

2. Terms and definitions

6A Heavy Oils

'Generalized Crude Oils', Correction of Volume to 60 °F against API Gravity.

6B Light Oils

'Generalized Products', Correction of Volume to 60 °F against API Gravity.

6C Chemical

'Volume Correction Factors (VCF)' for individual and special applications, volume correction to 60 °F against thermal expansion coefficients.

6C Mod

An adjustable temperature reference for defining VCF.

A

API Gravity

The measure of how heavy or light a petroleum liquid is compared to water. Allowable values are 0 to 100 degrees *API* for (6A) and 0 to 85 degrees *API* for (6B).

D

DDA

'Direct Digital Access' – The proprietary digital protocol developed by MTS for use in intrinsically safe areas.

Density

Mass divided by the volume of an object at a specific temperature. The density value should be entered as lb / cu. ft..

E

Explosion proof

Type of protection based on enclosure in which the parts which can ignite an explosive gas atmosphere are placed within, and which can withstand the pressure developed during an internal explosion of an explosive mixture, and which prevents the transmission of the explosion to the explosive gas atmosphere surrounding the enclosure.

F

Flameproof

Type of protection based on enclosure in which the parts which can ignite an explosive gas atmosphere are placed within and which can withstand the pressure developed during an internal explosion of an explosive mixture, and which prevents the transmission of the explosion to the explosive gas atmosphere surrounding the enclosure.

FOUNDATION™ fieldbus

An all digital, serial, two-way communications system that serves as the base-level network in a plant or factory automation environment. Developed and administered by the fieldbus FOUNDATION™.

G

GOVI

'Gross Observed Volume of the Interface' – The total volume of the tank occupied by the interface liquid. The *GOVI* is only given when measuring two liquids and is calculated by subtracting the volume of the product from the total volume of liquid in the tank (*GOVT* – *GOVP*).

GOVP

'Gross Observed Volume of the Product' – The total volume of the tank occupied by the product liquid. When measuring only one liquid, it is also the total volume of liquid in the tank (*GOVT*). When measuring two liquids it is the total volume of liquid in the tank minus the volume of the interface liquid (*GOVT* – *GOVI*).

GOVT

'Total Gross Observed Volume' – The total volume of liquid in the tank. When measuring only one liquid it is equal to the volume of the product (*GOVP*). When measuring two liquids it is equal to the volume of the product and interface liquids (*GOVP* + *GOVI*).

GOVU

'Gross Observed Volume Ullage' – the difference in volume between the working capacity of a tank and the total volume in the tank (Working Capacity – *GOVT*).

H

HART®

A *Bidirectional communication protocol* that provides data access between intelligent field instruments and host systems.

I

Interface

Noun; The measurement of the level of one liquid when that liquid is below another liquid.

Interface

Adj.; The Software *Graphical User Interface* (GUI) that allows the user to access software protocols (*HART*, *DDA*, *MODBUS*).

Intrinsic safety

'Intrinsically safe' - Type of protection based on the restriction of electrical energy within apparatus of interconnecting wiring exposed to potentially explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects.

M

Mass

The property of a body that causes it to have weight in a gravitational field, calculated by density at the reference temperature multiplied by the volume correction factor ($Density * VCF$).

MODBUS

A *serial communications protocol* published by Modicon in 1979 for use with its programmable logic controllers (PLCs). It has become a de facto standard communications protocol in industry, and is now the most commonly available means of connecting industrial electronic devices.

N

NEMA Type 4X

A product *Enclosure* intended for indoor or outdoor use primarily to provide a degree of protection against corrosion, windblown dust and rain, splashing water, and hose-directed water; and to be undamaged by the formation of ice on the enclosure. They are not intended to provide protection against conditions such as internal condensation or internal icing.

NPT

U.S. standard defining tapered pipe threads used to join pipes and fittings.

NSVP

'Net Standard Volume of the Product' – The temperature corrected volume for the product liquid in the tank, requires the transmitter to be ordered with temperature measurement capabilities. The *NSVP* is calculated by multiplying the volume of the product liquid by a volume correction factor based on temperature ($GOVP * VCF$).

R

Reference Temperature

The *temperature* at which the density measurement is given, the allowable values are 32 °F to 150 °F (0 °C to 66 °C).

S

Specific Gravity

The *density ratio* of a liquid to the density of water at the same conditions.

Sphere Radius

The *internal radius* of the sphere that contains the liquid, the value is used to calculate the volume along with the *Sphere Offset*.

Sphere Offset

An *offset value* that accounts for additional volume in a sphere from non-uniform sphere geometry, the value is used to calculate the volume along with the *Sphere Radius*.

Strap Table

A *table of measurement* correlating the height of a vessel to the volume that is contained at that height. The transmitter can contain up to 100 points.

T

TEC

'Thermal Expansion Coefficient' - a value correlating the change in temperature for an object with the change in its volume. Allowable values are 270.0 to 930.0. TEC units are in 10 E-6/Deg F.

Temperature Correction Method

One of five *product correction methods* used to correct the product volume in the tank due to changes in temperature from 60 °F including (6A, 6B, 6C, 6C Mod, and Custom Table).

V

Volume Calculation Mode

One of two methods use to calculate volume measurements from level measurements, including *Sphere* and *Strap Table*.

VCF

'Volume Correction Factor' – A table of measurements correlating temperature points with correction factors for the liquids expansion/contraction. The transmitter can contain up to 50 points.

W

Working Capacity

The *maximum volume of liquid* that the user desires for their vessel to hold, typically 80% of the vessels maximum volume before overflow.

3. Introduction

3.1 Purpose and use of this manual

Before starting the operation of the equipment read this documentation thoroughly and follow the safety information.

The content of this technical documentation and of its various annexes is intended to provide information on mounting, installation and commissioning by qualified service personnel according to IEC 60079-14 and/or MTS trained service technicians and local regulations.

3.2 Used symbols and warnings

Warnings are intended for your personal safety and for avoidance of damage to the described product or connected devices. In this documentation, safety information and warnings to avoid dangers that might affect the life and health of personnel or cause material damage are highlighted by the preceding pictogram, which is defined below.

Symbol	Meaning
NOTICE	This symbol is used to point to situations that may lead to material damage and/or personal injury.

4. Safety instructions

4.1 Intended use

The purpose of this document is to provide detailed information on the protocol interface. All safety related information is in the product specific operation manual. Consult the operation manual before connecting to the level transmitter.

5. Quick start-up guide

5.1 Before you begin

Note:

You must use a RS-485 converter with “Send Data Control” and the M-Series Set-up Software to ensure proper operation.

Example:
RS-485 to USB, MTS 380114

5.2 Quick start-up procedure

1. Connect +24 Vdc to terminals.
2. Connect data lines to terminals.
3. Connect the PC (or other device) to data lines.
(If you are using a PC, use a RS-485 to USB converter. See Note above for more information.)
4. Turn on power to the transmitter.
5. Start the LP Dashboard. Select Com Port and Address. Factory default address is ‘247’ for Modbus.

6. Change the address to one that is suitable for the installation network.
7. Verify proper operation of product, interface floats, and/or temperature.
8. Turn off power to the transmitter.
9. Remove data lines.
10. Install the transmitter into the vessel (see Operation Manual).
11. Reconnect power and data lines.
12. Calibrate current tank level using setup software (optional).
13. Verify communications with the host system.

Default communication parameters

Modbus: 4800 BAUD 8, N, 1 8 Data bits, No Parity, 1 Stop bit

6. Display Menu

All LP-Series liquid level transmitters are shipped with a Stylus (MTS Part # 404108) to be used for manipulating the display. For single and dual cavity housings, the Stylus is designed to allow for programming of the unit without removing the housing. When using the Stylus make sure to align the Stylus with the shape outline around the buttons in the same orientation. Failure to correctly align the Stylus can cause the display to not function properly.

Note:

Do not use any device other than the MTS Stylus to operate the display on the LP Series.

Note:

Improper use of the Stylus can cause the display to not function properly.

6.1 Operation Modes

The LP Series level transmitter runs in one of the following modes of operation. You can use these modes to calibrate and set up various operating parameters.

6.1.1 Run Mode

Run mode is the primary mode of operation. This mode will perform measurements, display data, and respond to Modbus commands.

6.1.2 Program Mode

Program mode is the primary mode for commissioning and troubleshooting the level transmitter. The full menu and available functions are shown in section 6.3 Menu Structure. To enter program mode use the Stylus and press the Enter Key as shown in section 6.2 Display Diagram. Program Mode is protected by a password to keep unwarranted changes from occurring. The factory default password is 27513. When in program mode, remote communications are not functional. An automatic timeout feature is provided so that the transmitter does not remain inadvertently in program mode. The timeout is set for 1 minute before prompted for additional time. Total timeout is 2 minutes.

Note:

Whenever program mode is exited from the display the unit will reset itself to insure all changes have been accepted. The reset will take approximately 5 seconds before the level transmitter is able to respond to commands.

Note:

In program mode, the transmitter will not respond to incoming Modbus commands. A busy error will be sent to the controller to notify the unit is in program mode. This function will prevent a user at a remote terminal from programming the unit while a user is accessing program mode from the display.

6.2 Display Diagram

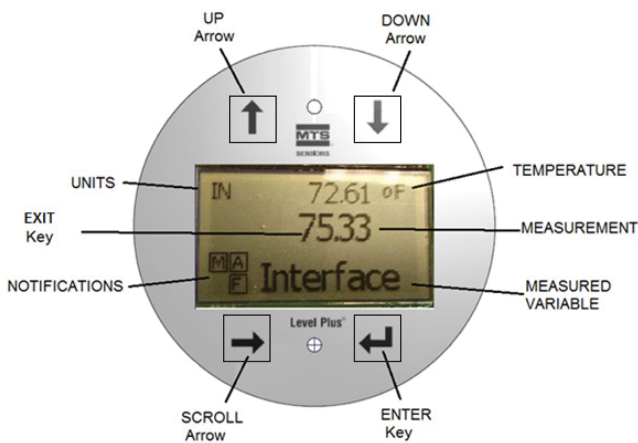


Fig. 1: Modbus Display

- UP Arrow** – Used to move cursor on screen up and to increment number.
- DOWN Arrow** – Used to move cursor on screen down and to decrease number.
- SCROLL Arrow** – Used to move cursor on screen to the right, cursor will cycle back.
- ENTER Key** – Used to Enter Program Mode, select Highlighted Item, and Confirm Selection.
- EXIT Key** – Hidden key in the middle of the display that is used to exit menu at any time.
- MEASURED VARIABLE** – The process variable that is selected to display. The display will automatically scroll between selected variables.
- MEASUREMENT** – The numerical value for the MEASURED VARIABLE shown on the display.
- UNITS** – Unit of measurement for the MEASURED VARIABLE shown on the display.
- TEMPERATURE** – Average temperature for the product in the tank. Only shown if the level transmitter was purchased with temperature.
- NOTIFICATIONS** – Four squares with letters. Top left square will always be present indicating a D for DDA mode or a M for Modbus mode. Top right square, A, will only show when there is an alarm. Toggle the UP Arrow key to view alarms. Bottom right square, F, will only show when there is a fault. Toggle the DOWN Arrow key to view error codes. Bottom left square, P, will only show when the unit is being programmed remotely.

6.3 Menu Structure

- Data From Device
 - Display
 - Units
 - ▶ Length Units
 - ▶ Temp Units
 - ▶ Volume Units
 - Address
 - Signal Strength
 - ▶ Prod Trig Lvl
 - ▶ Int Trig Lvl
 - ▶ Roof Trig Lvl
- Calibrate
 - Product Level
 - ▶ Current Level
 - ▶ Offset
 - Interface Level
 - ▶ Current Level
 - ▶ Offset
 - Roof Level
 - ▶ Current Level
 - ▶ Offset
- Factory
 - Settings
 - ▶ Gradient
 - ▶ Serial Number
 - ▶ HW Revision
 - ▶ SW Revision
 - ▶ SARA Blanking
 - ▶ Magnet Blanking
 - ▶ Gain
 - ▶ Min Trig Level
 - Temp Setup
 - Float Config
 - Auto Threshold
 - Baud Rate
 - Volume
 - Reset to Factory

7. Alarms

The Modbus output is equipped with several alarms that will be shown on the display. Use the stylus to tap the Up arrow to view alarms. The Modbus output is set to fail high, greater than the order length, if there is an issue and the level value output cannot be trusted.

8. Error Codes (Faults)

Fault Code	Description	Corrective Action
101	Missing Magnet	<ul style="list-style-type: none"> • Verify Float Configuration is correct for the number of floats installed. • Verify Float(s) are not in inactive zone. • Verify Auto Threshold is enabled. • Cycle power to sensor. If proper operation is not restored, Contact Factory.
102	Internal Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
103	Internal Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
104	Internal Fault 3	Cycle power to sensor. If proper operation is not restored, Contact Factory.
105	Lobe Fault 1	<ul style="list-style-type: none"> • Verify Auto Threshold is enabled • Cycle power to sensor. • If proper operation is not restored, Contact Factory.
106	Lobe Fault 2	<ul style="list-style-type: none"> • Verify Auto Threshold is enabled. • Cycle power to sensor. • If proper operation is not restored, Contact Factory.
107	Delta Fault	Contact Factory to discuss application.
108	Internal Fault 4	Cycle power to sensor. If proper operation is not restored, Contact Factory.
109	Peak Fault	<ul style="list-style-type: none"> • Verify Auto Threshold is enabled. • Cycle power to sensor. • If proper operation is not restored, Contact Factory.
110	Hardware Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
111	Power Fault	<ul style="list-style-type: none"> • Cycle power to sensor. • Verify Power Supply rating. • Verify wiring. • If proper operation is not restored, Contact Factory.
112	Hardware Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
113	Hardware Fault 3	Cycle power to sensor. If proper operation is not restored, Contact Factory.
114	Hardware Fault 4	Cycle power to sensor. If proper operation is not restored, Contact Factory.
115	Timing Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
116	Timing Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
117	Timing Fault 3	Cycle power to sensor. If proper operation is not restored, Contact Factory.
118	DAC Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
119	DAC Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
120	DAC Fault 3	Cycle power to sensor. If proper operation is not restored, Contact Factory.

Fault Code	Description	Corrective Action
121	DAC Fault 4	Cycle power to sensor. If proper operation is not restored, Contact Factory.
122	SPI Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
123	SPI Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
124	Setpoint Fault	The analog setpoints are too close. Minimum distance is 150 mm (6 in.) for analog and 290 mm (11.5 in.) for SIL. Adjust programmed setpoints as needed. (Analog only) If proper operation is not restored, Contact Factory.
125	Loop 1 Out of Range	Verify that magnets are positioned within expected measuring range. Adjust programmed setpoints as needed. (Analog only) If proper operation is not restored, Contact Factory.
126	Loop 2 Out of Range	Verify that magnets are positioned within expected measuring range. Adjust programmed setpoints as needed. (Analog only) If proper operation is not restored, Contact Factory.
127	EEPROM Fault 1	Cycle power to sensor. If proper operation is not restored, Contact Factory.
128	EEPROM Fault 2	Cycle power to sensor. If proper operation is not restored, Contact Factory.
129	Flash Failure	Cycle power to sensor. If proper operation is not restored, Contact Factory.
130	Internal Error	Cycle power to sensor. If proper operation is not restored, Contact Factory.

9. Modbus Interface

Note:

Termination and biasing of RS-485 data lines are as follows:

Biasing

Each LP-Series transmitter uses a Fail-Safe, Slew-Rate-Limited RS-485/RS-422 Transceivers. No additional biasing, resistors should be present on the connecting devices (PLC, DCS, PC, Converter).

Termination

Each LP-Series transmitter uses a Fail-Safe, Slew-Rate-Limited RS-485/RS-422 Transceivers. No additional termination resistors are necessary in connecting devices (PLC, DCS, PC, Converter).

9.1 LP Dashboard

The Modbus implementation for the digital transmitter conforms to the 'Modicon Modbus Protocol Reference Guide, PIMBUS-300 Rev. G' available from Modicon, Inc. The information provided below assumes familiarity with the Modbus protocol as outlined in this reference guide. All information provided applies to Modbus RTU protocol only.

9.1.1 Installing LP Dashboard

Adjustments to the calibration and setup parameters of the Modbus interface can be performed using the LP-Series Dashboard. The dashboard can be run from any Windows 7 or newer OS using a RS485 to USB converter (MTS part # 380114).

Perform the following steps to install the LP Dashboard and establish communication:

1. Install setup software from the USB stick that came with the level transmitter or go to www.mtssensors.com to download the latest version.
2. Connect level transmitter to RS485 to USB converter, connect 24 Vdc power to the level transmitter, and connect the RS485 to USB converter to the PC. Example setup shown below.

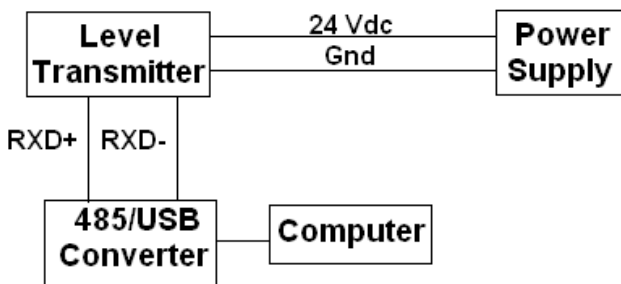


Fig. 2: Example setup

3. Open LP Dashboard and select Modbus protocol from drop down menu.
4. Select COM Port. Software will show active COM ports. Make sure converter is connected before starting LP Dashboard or COM port will not show.
5. The default address for the level transmitters from the factory is 247. Select address 247. If you do not know the address you can use the Search function at the bottom of the address range or the display menu.

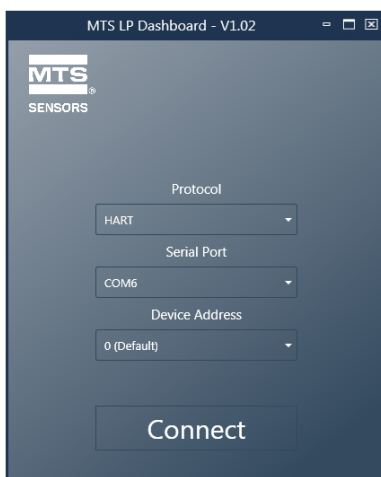


Fig. 3: Initial screen

9.1.2 Home screen

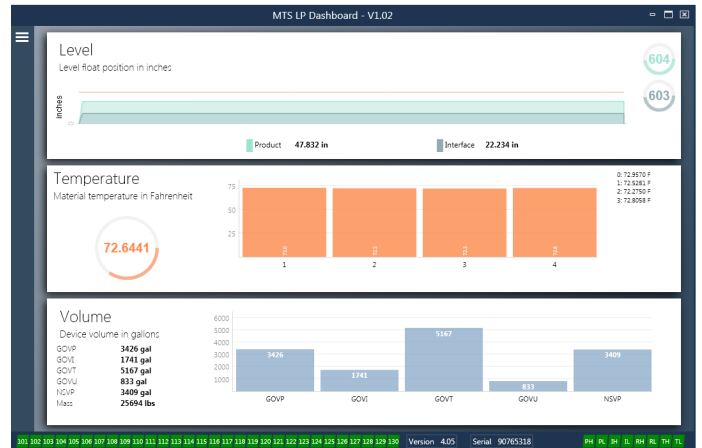


Fig. 4: Home screen

The LP Dashboard Home Screen will look different based on whether or not temperature has been ordered and volume measurement has been enabled. If the level transmitter includes temperature measurement and volume measurement is enabled then the Home Screen will look as shown. If the level transmitter does not include temperature measurement then the Home Screen will not show the middle panel for temperature. If the level transmitter does not have volume measurement enabled then the Home Screen will not show the bottom panel. The Home Screen can be accessed by pressing the three white bars on the top left.

The level panel on top shows the level measurement for the Product level and Interface level. If only the product float is selected then only the product float will be shown. The bold numbers are the numerical level and the graph is a time lapse of the graphical representation of the numbers. The red line is the approximate maximum level based off of the order length of the level transmitter. The numbers on the right of the level panel are the Trigger Level for the Product Float on top and the Interface Float on bottom. These are a representation of how strong of a return signal the level transmitter is experiencing.

The temperature panel will only show if temperature measurement was ordered and turned on. The left side shows the numerical value of the average temperature of all temperature sensors below the product level. The bar graph in the middle of the panel shows each individual temperature measurement point. Temperature 1 is always the lowest temperature closest to the bottom of the pipe or hose.

The volume panel is on the bottom. On the left side is the numerical value for GOVP, GOVI, GOVT, GOVU, NSVP, and mass including units. The bar graph in the middle is a graphical representation of the volume measurement.

Across the bottom of the Home Screen is the visual indication of the fault codes from section 8. Green indicates no fault and red indicates fault. Next is the firmware version in the middle followed by the serial number. On the far right are the lights for the soft alarms that can be set in the LP Dashboard. Green indicates the alarm is not tripped and red indicates that the alarm has been tripped.

9.1.3 Configuration

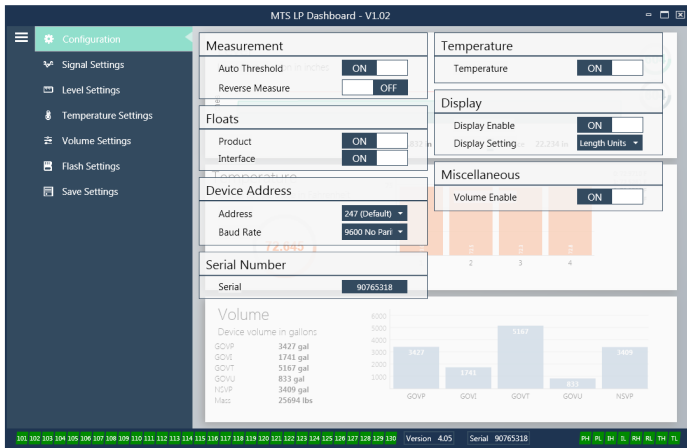


Fig. 5: Configuration

The Configuration tab allows the level transmitter to be configured for the specific application.

Factory Set:

Auto Threshold: Default setting is ON and should not be turned off. This feature allows the unit to automatically adjust the threshold for optimal performance.

Product Float: Default setting of ON for all applications.

Interface Float: Default setting of ON if ordering 2 Loops. Default setting of OFF if ordering 1 Loop. If the number of floats turned on is different from the number of floats physically on the level transmitter the level transmitter will go into Fault.

Serial Number: Serial Number assigned by MTS at the time of manufacture. The serial number is used for tracking and replacement parts. Do not change.

Temperature: Default setting of OFF if ordered without temperature. Default setting of ON if ordered with temperature. Turning temperature ON when the level transmitter was not ordered with temperature will not cause temperature to work and will force the level transmitter into Fault.

Display Enable: Default setting of ON. Display can be turned off by changing to OFF and cycling power.

User Configurable:

Reverse Measure: Allows the end user to change the direction in which the MTS level transmitter counts. The default setting is OFF and the level transmitter will reference the tip of the pipe/hose and count up from the tip. The ON setting will reference the head of the level transmitter and count up as it moves towards the tip.

Device Address: The end user can configure the Modbus address. Default address is 247. The default address should not be used in a network.

Baud Rate: Allows the end user to select the desired baud rate. Default setting is 4800.

Display Setting: Allows the end user to configure the display. Available options are level or volume. Default setting is level.

Volume Enable: Allows the end user to turn ON and OFF the volume calculation of the LP-Series.

9.1.4 Signal settings

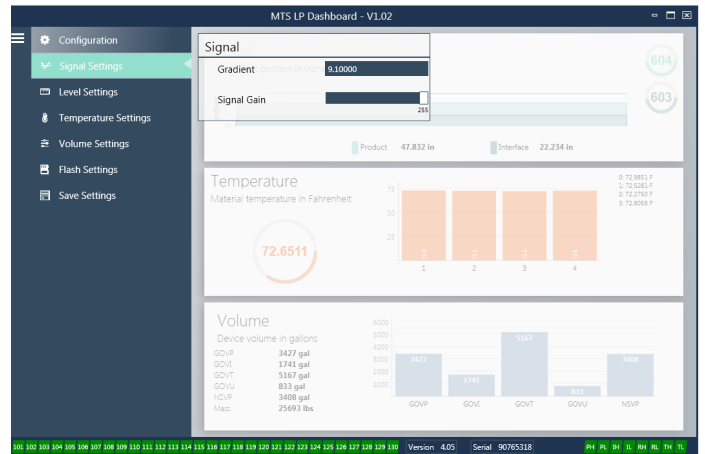


Fig.6: Signal settings

Factory Set:

Gradient: Is the speed at which the magnetostrictive signals travel along the sensing element. Typical range is from 8.9 to 9.2. Do not change unless replacing the sensing element. Changing this number will directly affect accuracy.

Signal Gain: Is the strength of the interrogation pulse. MTS uses the same electronics for all lengths and adjusts the signal based on the order length. Do not change unless instructed to do so by the MTS Factory.

9.1.5 Level settings

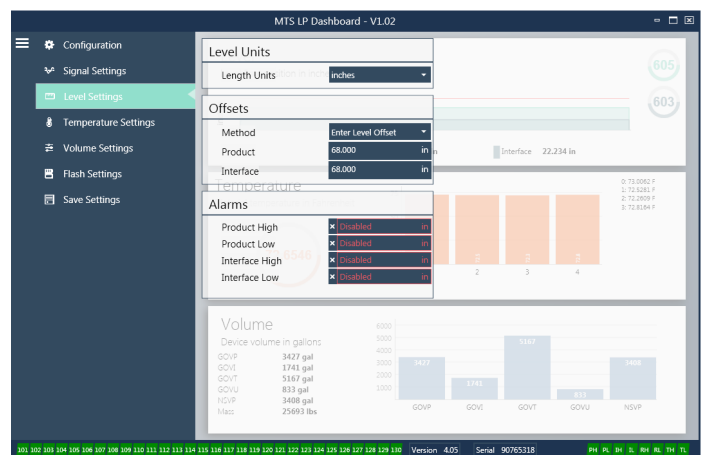


Fig. 7: Signal settings

9.1.5 Level settings (Cont.)

Factory Set:

Method – Enter Level Offset: a calibration method that directly changes the offset of the level measurement. The offset is the zero reference point used in determining the level output. Do not use without Factory guidance.

Product Offset: the full length of the level transmitter including order length, inactive zones, and mounting length. Do not change the Enter Level Offset method without Factory guidance. The offset will change after using the Enter Current Tank Level for the Product. The Product Offset and Interface Offset are independent of one another.

Interface Offset: the full length of the level transmitter including order length, inactive zones, and mounting length. Do not change the Enter Level Offset method without Factory guidance. The offset will change after using the Enter Current Tank Level for the Interface. The Product Offset and Interface Offset are independent of one another.

User Configurable:

Length Units: the unit of measurement used for engineering units. Default is inches if ordered in inches and mm if ordered in mm. Options include inches, feet, millimeters, centimeters, and meters.

Method - Enter Current Tank Level: a calibration method that calibrates the level transmitter based off of one point of measurement. Select Enter Current Tank Level from the Method drop down box. Go to Product Level and enter value of current product level based off of a manual measurement while the tank level is not changing. Go to Interface Level and enter value of current interface level based off of a manual measurement while the tank is not changing. Click Update box in lower left corner when it appears. Level transmitter is now calibrated.

Product High Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the product level exceeds the value in the box then the alarm will become active.

Product Low Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the product level is less than the value in the box then the alarm will become active.

Interface High Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the interface level exceeds the value in the box then the alarm will become active.

Interface Low Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the interface level is less than the value in the box then the alarm will become active.

9.1.6 Temperature settings

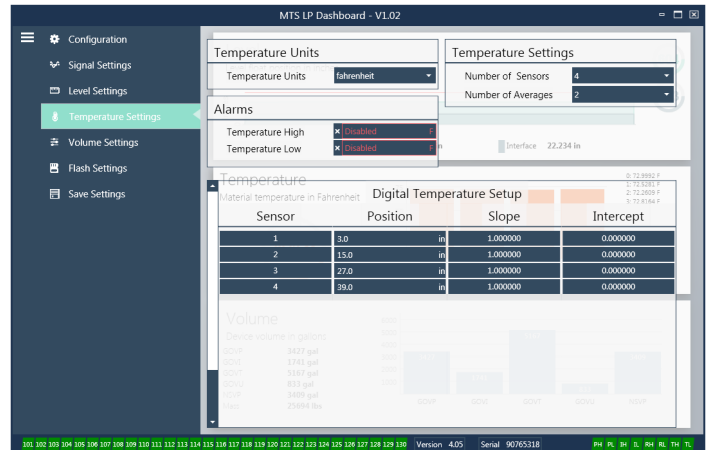


Fig. 8: Temperature settings

Factory Set:

Number of Sensors: Defines how many temperature sensors the level transmitter is looking for. The number should match the number of temperature sensors in the model number.

Number of Averages: This is the number of temperature readings that are averaged together for the temperature output. The higher the number the more temperature readings that are averaged. The higher the number the smoother the output but also the slower the update to changes in the process temperature.

Position: The location of the temperature sensor in reference to the end of the pipe.

Slope: Calibration factor for the temperature sensor. The defaults setting is 1.0. Do not change unless a new sensing element with temperature is ordered.

Intercept: Calibration factor for the temperature sensor. The default setting is 0.0. Do not change unless a new sensing element with temperature is ordered.

User Configurable:

Temperature Units: Change the units of measure for the temperature settings. Options are Fahrenheit or Celsius.

Temperature High Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the temperature exceeds the value in the box then the alarm will become active.

Temperature Low Alarm: Soft alarm that can be disabled or enabled by clicking the X and \checkmark next to the box. If the temperature is less than the value in the box then the alarm will become active.

9.1.7 Volume settings

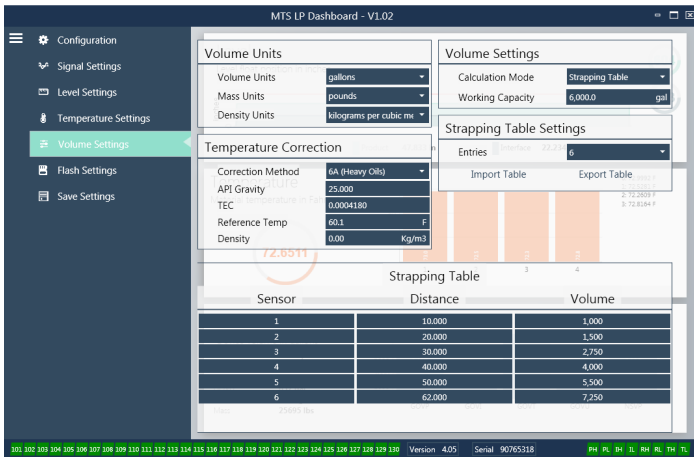


Fig. 9: Analog settings

User Configurable:

Volume Units: allows the user to select the unit of measure for the volume output. Available options are liters, cubic millimeters, cubic meters, cubic inches, cubic feet, gallons, and barrels.

Density Units: allows the user to select the unit of measure for the density input. Available options are grams per milliliter, grams per liter, kilograms per cubic meter, kilograms per liter, pounds per cubic inch, pounds per gallon, ton per cubic yard, and tonnes per cubic meter.

Mass Units: allows the user to select the unit of measure for the mass output. Available options are kilograms, grams, ounces, pounds, ton, and tonnes.

Correction Method: allows the end user to select the temperature correction method from the available API tables including 6A, 6B, 6C, 6C Mod, and Custom Table. Custom Table allows the end user to enter up to a 50 point custom temperature correction table.

API Gravity: allows the end user to enter the API gravity of the liquid as defined in the glossary. Used for 6A and 6B correction methods.

TEC: Thermal Expansion Coefficient used for temperature correction. Allowable values are 270 to 930. TEC units are 10 E-6/Deg F. Used for 6C Mod correction method.

Reference Temp: allows the user to specify the reference temperature for 6C Mod correction method.

Density: allows the user to input the measured density for mass calculations

Calculation Mode: allows the end user to select between using a strapping table and a sphere. Default setting is Sphere.

Working Capacity: allows the end user to enter the working capacity of the tank so ullage can be calculated.

Sphere Radius: the radius of the sphere to be used for volume calculations.

Sphere Offset: an offset value that should be added to the volume calculation of the sphere based on tank geometry.

Entries: allows the user to select how many strapping tables entry points to use. Maximum is 200.

Export Table: allows the user to export the strapping table from the level transmitter. This should always be done after completing the strapping table. Save as the site name, tank number, and any other unique identifier.

Import Table: allows the user to import the strapping table from a file. This can be used when replacing electronics or for tanks of the same size.

9.1.8 Flash settings

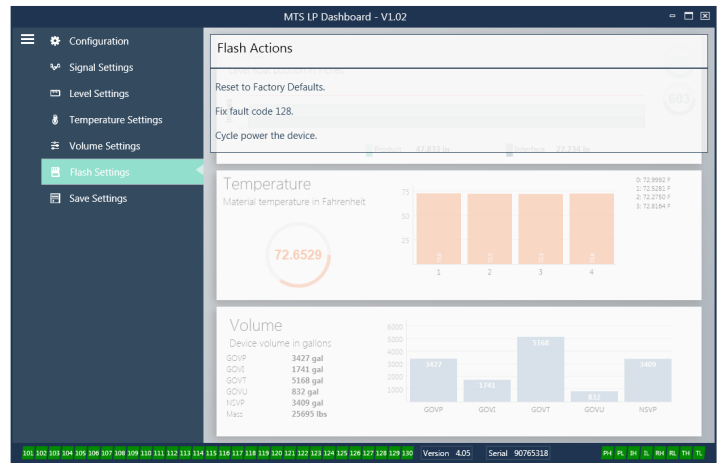


Fig. 10: Flash settings

User Configurable:

Reset to Factory Defaults: Allows the end user to reset all settings back to the original settings as they were when they left the MTS factory. This is intended to be used as a first step in troubleshooting. Do note, the Zero and Span set points will reset to factory settings.

Fix fault code 128: If fault code 128 appears red then click the link on the Dashboard to clear the fault.

Cycle power the device: Allows the end user to have the level transmitter automatically turn power off, turn power on, and reboot the device.

9.1.9 Save settings

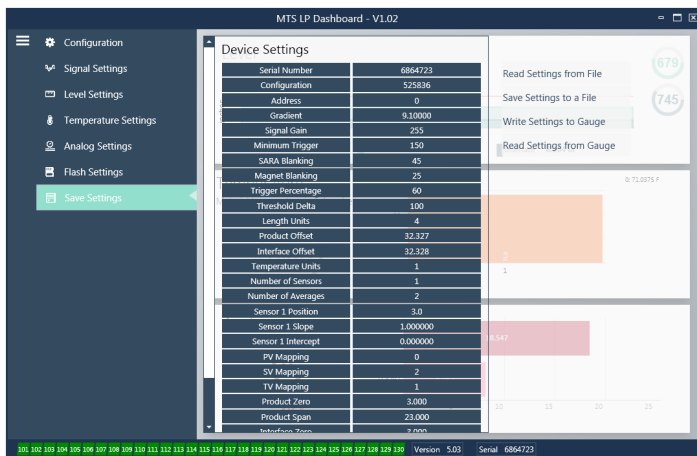


Fig. 11: Save settings

User Configurable:

Read Settings from File: Allows the end user to upload factory parameters from a backup file to the LP Dashboard. This task is usually performed from a saved backup file or the original backup file maintained by MTS.

Write Setting to a File: Allows the end user to download a backup file of factory parameters from the LP Dashboard to a PC. This task is usually performed after Read Settings from Gauge. Note – wait until all settings have changed from Red to White before writing as the color change signals that the settings have been updated.

Write Settings to Gauge: Allows the end user to program the level transmitter with the factory parameters displayed on the LP Dashboard. This task is usually performed after Read Settings from File.

Read Settings from Gauge: Allows the end user to update all of the factory parameters displayed on the screen. All settings will turn Red and then will turn white as they are updated.

Note:

A copy of the backup file is maintained by MTS including all factory parameters as the level transmitter was originally setup after completing testing and calibration at the MTS factory. MTS can provide a copy of the backup file upon request based off of the serial number of the level transmitter. Contact MTS Technical Support for assistance.

9.2 Programming the display

The display diagram is shown in section 6.2. The display menu structure is shown in section 6.3. This section of 9.2 explains the details of the programming available under the different sections of the display. The factory password for entering the display is **27513**.

9.2.1 Data from Device

Display

Allows the user to select if the display shows Length Units or Volume Units.

Units

Allows the user to change the selected Length Units, Volume Units and/or Temperature Units.

Address

Allows the user to change the address of the level transmitter. Default address is 247.

Signal Strength

Allows the user to view the strength of the return signal for the product float (Prod Trig Lvl), interface float (Int Trig Lvl), and roof level (Roof Trig Lvl). If the Interface float and or the roof level are not active no signal can be viewed.

9.2.2 Calibrate

Product Level

Allows the user to change the level in engineering units for calibration. The user should use the Current Level selection and enter the current position of the float. The user is advised not to use the Offset feature without help from Technical Support.

Interface Level

Allows the user to change the level in engineering units for calibration. The user should use the Current Level selection and enter the current position of the float. The user is advised not to use the Offset feature without help from Technical Support.

Roof Level

Allows the user to change the level in engineering units for calibration. The user should use the Current Level selection and enter the current position of the roof. The user is advised not to use the Offset feature without help from Technical Support.

9.2.3 Factory

Settings

Menu section that contains factory parameters. Do not edit these parameters without talking to Technical Support.

Gradient

The gradient is a calibration factor that is unique for each transmitter. Typical values are between 8.9 and 9.2 $\mu\text{s/in}$.

Serial Number

The Serial Number is the unique identifier for the unit from MTS and should not be changed. The serial number is used for tracking and determining spare parts.

9.2.3 Factory (Cont.)**SARA Blanking**

Initial blanking distance from the head of the level transmitter. Do not change.

Magnet Blanking

Blanking distance between two floats. Do not change.

Gain

Measurement of how large an interrogation signal is used. Do not change without Technical Support.

Min Trig Level

Threshold level for return signal to qualify as a valid signal and not noise.

Temp Setup

Allows the user to turn the temperature measurement on or off. Turning it on will not cause the temperature to work if no temperature measurement was ordered.

No. of Temp

Change the number of temperature points the level transmitter is looking for. Changing this number does not change the number of temperature measurement points that were ordered or whether or not temperature measurement was ordered.

Float Config

Allows the user to enable or disable the product float, interface float, and roof level. The first float measured by the electronics will be used as the product float. If the interface float is turned on and there is no second float the output will go into alarm.

Baud Rate

Allows the user to select the available baud rate. The default baud rate is 4800.

Volume

Allows the user to enable or disable the volume output. The volume output must be setup using the setup software. The volume output must be enabled for the display to show volume if selected.

Auto Threshold

Do not disable.

Reset to Factory

Allows the user to reset the electronics to the original factory settings. This should be used to return the electronics to a known good state when troubleshooting.

9.3 Modbus function codes**Communication parameters:**

Modbus:	4800 BAUD or 9600	8, N, 1
(Reference) Monitor:	Modbus RTU Variable BAUD Rate	8, E, 1

The following Modbus function codes are supported:

Function 03 - Read Holding Registers

Function 04 - Read Input Registers

Function 06 - Preset Single Register

Function 08 - Diagnostics (Subfunction 00, Return Query Data)

Function 08 - Diagnostics (Subfunction 01, Restart Communications Option)

Function 08 - Diagnostics (Subfunction 04, Force Listen Only Mode)

Function 16 - Preset Multiple Registers

Function 17 - Report Slave ID

Function 03 - Read Holding Registers

The device responds to this message by returning the contents of the requested data register(s).

(See 'Device Modbus Register Maps' on page 22).

The following implementation-specific considerations apply:

- » If an unsupported or reserved register is requested, exception code #2 is returned (See 'Device Modbus Register Maps' on page 22 for unsupported/reserved registers).
- » If a register contains a device error a maximum negative value is returned.
- » If a register is blank, indicating that the desired function is not enabled (e.g., volume calculations) a max negative value is returned.
- » Unsupported or reserved bits will always be set to 0. See 'Device Modbus Register Maps' on page 22 for alarm bit definitions.

Function 04 - Read Input Registers

This function is handled exactly the same as Function 03. (Be advised that all registers are read-only in this implementation).

Function 06 – Preset Single Registers

Confirmation of successful transmission is confirmed when the device responds by echoing back what was sent.

Function 08 - Diagnostics (Subfunction 00, Return Query Data)

The device responds to this request with the following data:

Slave address: echoed
 Function: 08H
 Subfunction high: 00H
 Subfunction low: 00H
 Query data (16-bit): echoed
 Error check: 16-bit CRC/8-bit LRC

Function 08 - Diagnostics

(Subfunction 01, Restart Communications Option)

9.3 Modbus function codes (Cont.)

Note:

The communications event log is not supported. The “Query data” field is irrelevant (normally, FF00H would clear the log).

If the device is in listen-only mode, the device responds to this message by switching out of listen-only mode - (resulting in no response being sent to the request).

If the device is not in listen only mode, it responds as follows:

Slave address: echoed
Function: 08H
Subfunction high: 00H
Subfunction low: 01H
Query data (16-bit): echoed (0000H or FF00H)
Error check: 16-bit CRC/8-bit LRC

Function 08 - Diagnostics

(Subfunction 04, Force Listen-Only Mode)

The device responds to this request by switching to listen-only mode. Messages are still received and parsed, but no responses are transmitted. To switch out of listen-only mode, issue a ‘**Restart Communications Option**’ request (function 08, subfunction 01) or cycle power.

Function 16 - Preset Multiple Registers

The device response returns the slave address, function code, starting address, and quantity of registers preset.

Function 17 - Report Slave ID

The device responds to this request with the following data:

Slave address: echoed
Function: 11H
Byte count: 05H
Slave ID: FFH
Run indicator status: FFH (ON)
Additional data: ‘DMS’
Error check: 16-bit CRC/8-bit LRC

Modbus Exception Codes

The following standard Modbus exceptions are implemented:

Error code 01 (Illegal Function)

Reported when:

- » A function other than 03, 04, 06, 08, 16 or 17 is requested
- » Function 08 is requested, and a subfunction other than 00, 01, or 04 is requested, or when invalid register within set is requested.
- » Handled by error code 07

Error code 02 (Illegal Data Address)

Reported when:

- » Function 03 or 04 is requested and the starting register number is greater than 5198 (register greater than 35198 or 45198)
- » Function 03 or 04 is requested and a register within the requested register set is invalid

Error code 03 (Illegal Data Value)

Reported when:

- » Function 03 or 04 is requested and the number of data points is greater than 800.

Error code 06 (Busy)

Reported when:

- » The device LCD menu is active.

Error code 07 (Illegal Operation)

Reported when:

- » Function 06 or 16 is requested while the device is write protected.
- » Function 08 is requested with an invalid subfunction.

9.4 Modbus register maps

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30001	0000	Product Level High Word (x 1000)	2, Page 19 3, Page 19
30002	0001	Product Level Low Word (x 1000)	
30003	0002	Interface Level High Word (x 1000)	
30004	0003	Interface Level Low Word (x 1000)	
30005	0004	Roof Level High Word (x 1000)	Inactive
30006	0005	Roof Level Low Word (x 1000)	Inactive
30007	0006	Temperature 1 High Word (x 10000)	4, Page 19
30008	0007	Temperature 1 Low Word (x 10000)	
30009	0008	Temperature 2 High Word (x 10000)	
30010	0009	Temperature 2 Low Word (x 10000)	
30011	0010	Temperature 3 High Word (x 10000)	
30012	0011	Temperature 3 Low Word (x 10000)	
30013	0012	Temperature 4 High Word (x 10000)	
30014	0013	Temperature 4 Low Word (x 10000)	
30015	0014	Temperature 5 High Word (x 10000)	
30016	0015	Temperature 5 Low Word (x 10000)	
30017	0016	Temperature Average High Word (x 10000)	5, Page 19
30018	0017	Temperature Average Low Word (x 10000)	
30019	0018	GOVP High Word	6, Page 19
30020	0019	GOVP Low Word	
30021	0020	GOVI High Word	7, Page 19
30022	0021	GOVI Low Word	
30023	0022	GOVT High Word	8, Page 19
30024	0023	GOVT Low Word	
30025	0024	GOVU High Word	9, Page 19
30026	0025	GOVU Low Word	
30027	0026	NSVP High Word	10, Page 19
30028	0027	NSVP Low Word	
30029	0028	MASS High Word	
30030	0029	MASS Low Word	

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30031	0030	Temperature Correction Method High Word	11, Page 19
30032	0031	Temperature Correction Method Low Word	
30033	0032	API Gravity High Word (x 100)	
30034	0033	API Gravity Low Word (x 100)	
30035	0034	Working Capacity High Word (x 10)	
30036	0035	Working Capacity Low Word (x 10)	
30037	0036	TEC High Word (x 10000000)	12, Page 19
30038	0037	TEC Low Word (x 10000000)	
30039	0038	Density High Word (x 100)	13, Page 19
30040	0039	Density Low Word (x 100)	
30041	0040	Reference Temperature High Word (x 10)	14, Page 19
30042	0041	Reference Temperature Low Word (x 10)	
30043	0042	Volume Calculation Mode High Word	15, Page 19
30044	0043	Volume Calculation Mode Low Word	
30045	0044	Sphere Radius High Word (x 10)	16, Page 19
30046	0045	Sphere Radius Low Word (x 10)	
30047	0046	Sphere Offset High Word (x 10)	17, Page 19
30048	0047	Sphere Offset Low Word (x 10)	
30049	0048	Average Interval High Word	18, Page 19
30050	0049	Average Interval Low Word	
30051	0050	Alarm/Status High Word	19, Page 20
30052	0051	Alarm/Status Low Word	
30053	0052	VCF Calculation Error Status	20, page 20
30054	0053	Volume Calculation Error Status	21, page 20
30055	0054	Resets the EEPROM CRC	

9.4 Modbus register maps (continued)

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30056	0055	Resets the EEPROM data to factory	
30057	0056	Resets the EEPROM data to defaults	
30058	0057	Temperature sensor status high word	
30059	0058	Temperature sensor status low word	
30060 - 30099	0059 - 0098	Reserved	22, page 20
30100	0099	Temperature Units High	23, page 20
30101	0100	Temperature Units Low	
30102	0101	Density Units High	24, page 20
30103	0102	Density Units Low	
30104	0103	Volume Units High	25, page 20
30105	0104	Volume Units Low	
30106	0105	Length Units High	26, page 20
30107	0106	Length Units Low	
30108	0107	Mass Units High	27, page 20
30109	0108	Mass Units Low	
30110	0109	Set New Device Address	28, page 20
30111	0110	Reboot the device	
30112-30199	0111-0108	Reserved	22, Page 20
30200	199	Product Level High Word (x1000) ‡	2, Page 19 3, Page 19
30201	200	Product Level Low Word (x1000) ‡	
30202	201	Interface Level High Word (x1000) ‡	
30203	202	Interface Level Low Word (x1000) ‡	
30204	203	Roof Level High Word (x1000) ‡	Inactive
30205	204	Roof Level Low Word (x1000) ‡	Inactive
30206	205	Temperature 1 High Word (x10000)	4, Page 19
30207	206	Temperature 1 Low Word (x10000)	
30208	207	Temperature 2 High Word (x10000)	
30209	208	Temperature 2 Low Word (x10000)	
30210	209	Temperature 3 High Word (x10000)	
30211	210	Temperature 3 Low Word (x10000)	

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30212	211	Temperature 4 High Word (x10000)	
30213	212	Temperature 4 Low Word (x10000)	
30214	213	Temperature 5 High Word (x10000)	
30215	214	Temperature 5 Low Word (x10000)	
30216	215	Temperature 6 High Word (x10000)	
30217	216	Temperature 6 Low Word (x10000)	
30218	217	Temperature 7 High Word (x10000)	
30219	218	Temperature 7 Low Word (x10000)	
30220	219	Temperature 8 High Word (x10000)	
30221	220	Temperature 8 Low Word (x10000)	
30222	221	Temperature 9 High Word (x10000)	
30223	222	Temperature 9 Low Word (x10000)	
30224	223	Temperature 10 High Word (x10000)	
30225	224	Temperature 10 Low Word (x10000)	
30226	225	Temperature 11 High Word (x10000)	
30227	226	Temperature 11 Low Word (x10000)	
30228	227	Temperature 12 High Word (x10000)	
30229	228	Temperature 12 Low Word (x10000)	
30230	229	Temperature Average High Word (x10000)	5, Page 19
30231	230	Temperature Average Low Word (x10000)	
30232	231	GOVP High Word ‡	6, Page 19
30233	232	GOVP Low Word ‡	
30234	233	GOVI High Word ‡	7, Page 19
30235	234	GOVI Low Word ‡	
30236	235	GOVT High Word ‡	8, Page 19
30237	236	GOVT Low Word ‡	
30238	237	GOVU High Word ‡	9, Page 19
30239	238	GOVU Low Word ‡	
30240	239	NSVP High Word ‡	10, Page 19
30241	240	NSVP Low Word ‡	
30242	241	MASS High Word ‡	

9.4 Modbus register maps (continued)

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30243	242	MASS Low Word ‡	
30244	243	Temperature Correction Method High Word ‡	11, Page 19
30245	244	Temperature Correction Method Low Word ‡	
30246	245	API Gravity High Word (x100) ‡	
30247	246	API Gravity Low Word (x100) ‡	
30248	247	Working Capacity High Word (x10) ‡	
30249	248	Working Capacity Low Word (x10) ‡	
30250	249	TEC High Word (x10000000) ‡	12, Page 19
30251	250	TEC Low Word (x10000000) ‡	
30252	251	Density High Word (x100) ‡	13, Page 19
30253	252	Density Low Word (x100) ‡	
30254	253	Reference Temperature High Word (x10) ‡	14, Page 19
30255	254	Reference Temperature Low Word (x10) ‡	
30256	255	Volume Calculation Mode High Word ‡	15, Page 19
30257	256	Volume Calculation Mode Low Word ‡	
30258	257	Sphere Radius High Word (x10) ‡	16, Page 19
30259	258	Sphere Radius Low Word (x10) ‡	
30260	259	Sphere Offset High Word (x10) ‡	17, Page 19
30261	260	Sphere Offset Low Word (x10) ‡	
30262	261	Average Interval High Word ‡	18, Page 19
30263	262	Average Interval Low Word ‡	
30264	263	Alarm/Status High Word ‡	19, Page 20
30265	264	Alarm/Status Low Word ‡	
30266	265	VCF Calculation Error Status ‡	20, Page 20

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30267	266	Volume Calculation Error Status ‡	21, page 20
30268	267	Temperature 13 High Word (x10000)	
30269	268	Temperature 13 Low Word (x10000)	
30270	269	Temperature 14 High Word (x10000)	
30271	270	Temperature 14 Low Word (x10000)	
30272	271	Temperature 15 High Word (x10000)	
30273	272	Temperature 15 Low Word (x10000)	
30274	273	Temperature 16 High Word (x10000)	
30275	274	Temperature 16 Low Word (x10000)	
30276	275	Temperature 17 High Word (x10000)	Inactive
30277	276	Temperature 17 Low Word (x10000)	Inactive
30278	277	Temperature 18 High Word (x10000)	Inactive
30279	278	Temperature 18 Low Word (x10000)	Inactive
30280	279	Temperature 19 High Word (x10000)	Inactive
30281	280	Temperature 19 Low Word (x10000)	Inactive
30282	281	Temperature 20 High Word (x10000)	Inactive
30283	282	Temperature 20 Low Word (x10000)	Inactive
30284	283	Temperature 21 High Word (x10000)	Inactive
30285	284	Temperature 21 Low Word (x10000)	Inactive
30286	285	Temperature 22 High Word (x10000)	Inactive
30287	286	Temperature 22 Low Word (x10000)	Inactive
30288	287	Temperature 23 High Word (x10000)	Inactive
30289	288	Temperature 23 Low Word (x10000)	Inactive
30290	289	Temperature 24 High Word (x10000)	Inactive
30291	290	Temperature 24 Low Word (x10000)	Inactive
30292	291	Temperature 25 High Word (x10000)	Inactive

9.4 Modbus register maps (continued)

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
30293	292	Temperature 25 Low Word (x10000)	Inactive
30294	293	Temperature 26 High Word (x10000)	Inactive
30295	294	Temperature 26 Low Word (x10000)	Inactive
30300	299	Temperature Units High ‡	23, page 20
30301	300	Temperature Units Low ‡	
30302	301	Density Units High ‡	24, page 20
30303	302	Density Units Low ‡	
30304	303	Volume Units High ‡	25, page 20
30305	304	Volume Units Low ‡	
30306	305	Length Units High ‡	26, page 20
30307	306	Length Units Low ‡	
30308	307	Mass Units High ‡	27, Page 20
30309	308	Mass Units Low ‡	
30310	309	Set New Device Address ‡	28, page 20
30311-31108	310-1107	Reserved	22, Page 20
31109	1108	Alarm Units High	29, Page 20
31110	1109	Alarm Units Low	
31111	1110	Interface High Alarm High (x 100)	30, Page 21
31112	1111	Interface High Alarm Low (x 100)	
31113	1112	Interface Low Alarm High (x 100)	31, Page 21
31114	1113	Interface Low Alarm Low (x 100)	
31115	1114	Product High Alarm High (x 100)	32, Page 21
31116	1115	Product High Alarm Low (x 100)	
31117	1116	Product Low Alarm High (x 100)	33, Page 21
31118	1117	Product Low Alarm Low (x 100)	
31119	1118	Roof High Alarm High (x 100)	34, Page 21
31120	1119	Roof High Alarm Low (x 100)	
31121	1120	Roof Low Alarm High (x 100)	35, Page 21
31122	1121	Roof Low Alarm Low (x 100)	
31123	1122	Temperature Average High Alarm High (x100)	36, Page 21

Modbus Register	Data Address	Data Description ‡ denotes duplicate register	Notes
31124	1123	Temperature Average High Alarm Low (x 100)	
31125	1124	Temperature Average Low Alarm High (x 100)	37, Page 21
31126	1125	Temperature Average Low Alarm Low	
31127-37216	1126-7215	Reserved	22, Page 20

9.5 How units are used

Registers that are read or preset are done so using the current unit type's programmed unit.

For example:

If the current unit type is 'Length' and you currently have selected 'Feet' as your unit, then the value returned will be in that unit. Make sure the value programmed is also done so using that unit.

9.6 Modbus Register Map Notes

1. All registers can be accessed using either Modbus Function 03 (Read Holding Registers) or Modbus Function 04 (Read Input Registers). However, all registers are read-only in this implementation.

For example:

Registers 30001 and 30002 (using Function 03) can also be read as registers 40001 and 40002 (using Function 04).

2. Pairs of registers identified as 'High Word' and 'Low Word' must be read together reading the 'High Word' first. Both values need to be concatenated by the master to form a 32-bit unsigned 'long word' quantity.

For example:

Register 30001 (16-bit high word) = 0002H (Must be read first)
 Register 30002 (16-bit low word) = 3F8CH
 Long word (32-bit) = 00023F8CH (decimal 147340)

Or:

Register 30001 (high word) = 2
 Register 30002 (low word) = 16268
 Multiply register 30001 x 65536 : 2 x 65536 = 131072
 Add result to register 30002 : 131072 + 16268 = 147340

3. All registers identified as '(x 10)', '(x 100)', '(x 10000)', '(x 100000000)' or '(x 1000)' have been scaled (multiplied) by a factor of 10, 100, 1000, 10000 or 10000000 before transmission to preserve the fractional portion of the data value. The master must divide these values by the scale factor as necessary.

For example:

Register 30001 (16-bit high word) = 0002H
 Long word (32-bit) = 00023F8CH (decimal 147340)
 Divide by 1000, actual value = 147.340

4. **Individual digital temperature**
5. **Average submerged temperature**
6. **GOVP = Gross Observed Volume Product**
7. **GOVI = Gross Observed Volume Interface**
8. **GOVT = Gross Observed Volume Total**
9. **GOVU = Gross Observed Volume Ullage**

10. **NVSP = Net Standard Volume of Product**
11. **Temperature Correction Method**
 There are five methods to choose from:
 - 1 = (6A) Heavy Oils
 - 2 = (6B) Light Oils
 - 3 = (6C) Chemicals
 - 4 = Chemicals with wider coefficients than 6C and a movable reference temperature (6C Mod).
 - 5 = Custom Table.
12. **Thermal Expansion Coefficient (TEC)**
 Temperature correction method '6C' uses the thermal expansion coefficient of the product being measured to determine the volume correction factor. Allowable values are 270.0 to 930.0. TEC Units are in 10E-6/Deg F.
13. **Density**
 Temperature correction method '6C' and 'Custom Table' requires you to enter the density (at the given reference temperature) of the product being measured for the net mass calculation.
14. **Reference Temperature**
 This is the desired base temperature for the VCF calculation when Temperature Correction Method '6C Mod' is used.
15. **Volume Calculation Mode**
 This is the mode you wish the volume calculations to be performed by:
 - 1 = Use Strap Table
 - 0 = Use Sphere Calculation
16. **Sphere Radius**
 The radius of the sphere when volume calculations are performed (using the sphere calculation mode).
17. **Sphere Offset**
 The offset of the sphere when volume calculations are performed (using the sphere calculation mode).
18. **Average Interval**
 All level, temperature and volume calculation can be averaged using timed method. Allowable values are as follows:
 - 0 = 1 second (default)
 - 5 = 5 seconds
 - 10 = 10 seconds
 - 15 = 15 seconds
 - 20 = 20 seconds
 - 25 = 25 seconds
 - 30 = 30 seconds
 - 35 = 35 seconds
 - 40 = 40 seconds
 - 45 = 45 seconds
 - 50 = 50 seconds
 - 55 = 55 seconds
 - 60 = 60 seconds

9.6 Modbus Register Map Notes (cont'd.)

19. Alarm/Status bit definitions

- D1 Interface Alarm High
- D2 Interface Alarm Low
- D3 Product Alarm High
- D4 Product Alarm Low
- D5 Roof Alarm High
- D6 Roof Alarm Low
- D7 Average Temperature Alarm High
- D8 Average Temperature Alarm Low
- D9 Magnet Is Missing
- D10 Digital Temperature 0 Error
- D11 Digital Temperature 1 Error
- D12 Digital Temperature 2 Error
- D13 Digital Temperature 3 Error
- D14 Digital Temperature 4 Error
- D15 Digital Temperature Average Error
- D16 – D32 Reserved

For each corresponding alarm bit:

- 0 = ALARM OFF
- 1 = ALARM ON

Reserved bits will always be set to 0 (OFF).

20. Volume Correction Factor Calculation Error Status

This value can only be read. If there is no error performing the volume correction factor then the value is zero otherwise, the value is a non-zero code and one of the following:

- 1 = Invalid API value or invalid temperature input value for 6A or 6B VCF calculation.
- 2 = Invalid API value or invalid temperature input range for 6A VCF calculation.
- 3 = Invalid API value or invalid temperature input range for 6B VCF calculation.
- 4 = Invalid API value or invalid temperature input value for 6C VCF calculation.
- 5 = Invalid API value or invalid temperature range for 6C VCF calculation.
- 6 = Invalid API value or invalid temperature range for 6C Wide VCF calculation.
- 7 = Invalid delta temperature for 6C VCF calculation.
- 8 = Interpolation error, temperature value not found in the table.
- 9 = Invalid or No VCF method selected.

21. Volume Calculation Error Status

This value can only be read. If there is no error performing the volume calculations then the value is zero otherwise the value is a non-zero code and one of the following:

- 1 = Negative table entries are not allowed.
- 2 = Interpolation error, level value not found in the table.
- 3 = Sphere Calculation error, level exceeds sphere radius x 2.
- 4 = Calculated a negative volume value.

22. **Undefined or reserved registers within the register map** will return a maximum negative value (8000H, or 80000000H for register pairs). Attempting to read registers outside the register map (35198 or higher) will cause a Modbus Exception Error Code 02 (Illegal Data Value) to be returned.

23. Temperature Units

The value for temperature units can be one of the following codes:

- 0 = Celsius
- 1 = Fahrenheit

24. Density Units High

The value for density units can be one of the following codes:

- 0 = Grams/Milliliters
- 1 = Grams/Liter
- 2 = Kilograms/Cubic Meters
- 3 = Kilograms/Liter
- 4 = Pounds/Cubic Inch
- 5 = Pounds/Cubic Foot
- 6 = Pounds/Gallon
- 7 = Tonnes/Cubic Meter
- 8 = Tons/Cubic Yard

25. Volume Units

The value for volume units can be one of the following codes:

- 0 = Liters
- 1 = Cubic Millimeters
- 2 = Cubic Meters
- 3 = Cubic Inches
- 4 = Cubic Feet
- 5 = Gallons
- 6 = Barrels

26. Length Units

The value for length units can be one of the following codes:

- 0 = Millimeters
- 1 = Centimeters
- 2 = Meters
- 3 = Kilometers
- 4 = Inches
- 5 = Feet
- 6 = Yards

27. Mass Units

The value for mass units can be one of the following codes:

- 0 = Kilograms
- 1 = Grams
- 2 = Ounces
- 3 = Pounds
- 4 = Tons
- 5 = Tonnes

28. Set New Device Address

This register will program the new device address. Valid values for Modbus are between: 1 – 247.

29. Alarm Units

This register programs the unit type for which you can configure alarms. Product and Interface can be 'Volume or 'Length' unit type, however Roof can only be 'Length' unit type.

Valid Values are as follows:

- 2 = Volume Units Type.
- 3 = Length Units Type.

- 30. **Interface High Alarm**
The value for which the Interface cannot be >=. Make sure the value is programmed in the current Alarm Units type. (See Note 29)
- 31. **Interface Low Alarm**
The value for which the Interface cannot be <=. Make sure the value is programmed in the current Alarm Units type. (See Note 29)
- 32. **Product High Alarm**
The value for which the Product cannot be >=. Make sure the value is programmed in the current Alarm Units type. (See Note 29)
- 33. **Product Low Alarm**
The value for which the Product cannot be <=. Make sure the value is programmed in the current Alarm Units type. (See Note 29)
- 34. **Roof High Alarm**
The value for which the Roof cannot be >=. This value can only be in unit type of Length. (See Note 29)
- 35. **Roof Low Alarm**
The value for which the Roof cannot be <=. This value can only be in unit type of Length. (See Note 29)
- 36. **Temperature Average High Alarm**
The value for which the Average Temperature cannot be >=.
- 37. **Temperature Average Low Alarm**
The value for which the Average Temperature cannot be <=.

9.7 Formulas used in volume calculation

- 1. **GOVP = GOVT - GOVI** (two float system)
GOVP = GOVT (one float system)
GOVT= GOVP + GOVI (two float system)
GOVT= GOVP (one float system)
GOVU = WORKING CAPACITY - GOVT (one or two float system)

The gross observed volume of the product (GOVP) is equal to the total volume of the tank (GOVT) minus the interface volume (GOVI). The GOVT is measured by the product float (the float closest to the flange of the transmitter) and the GOVI is measured by the interface float (the float closest to the tip of the transmitter). The level information from the transmitter is used along with the strap table to calculate the corresponding gross observed volumes.

- 2. **NSVP = GOVP x VCF**
The net standard volume of the product (NSVP) is equal to the gross observed volume of the product (GOVP) multiplied by the volume correction factor (VCF). The VCF is calculated from thermal expansion properties of the product (programmed by the user) and the temperature information from the gauge. (see 4. VOLUME CORRECTION FACTOR) for details.

- 3. **MASS = NSVP x DENSITY**
The mass of the product (MASS) is equal to the net standard volume of the product (NSVP) multiplied by the density of the product (DENSITY) programmed by the user.

- 4. **VOLUME CORRECTION FACTOR**
 $VCF = EXP \{- A(T) \times (t-T) \times [1 + (0.8 \times A(T) \times (t-T))]\}$

Where:
t = any temperature*
T = BASE TEMPERATURE (60 DEGREES F)
A(T) = coefficient of thermal expansion at the base temperature T

Where:
EXP is the exponential function (eX).

The coefficient of thermal expansion at the base temperature is related to the density of the product at the base temperature T by:

$$A(T) = [K0 + K1 \times DEN(T)] / [DEN(T) \times DEN(T)]$$

Where:
Density is defined in units of KG/M3
K0 and K1 are constants related to each product.
*API 2540 states that temperature data is rounded to the nearest tenth (0.1) degree.

This section includes all the constants used by the software to calculate the volume correction factors and valid ranges for the API (density) and temperature data.

Constants	K0 = 341.0952
	K1 = 0.0
Valid temperature range	Valid gravity ranges (API)
0 to +300.0 °F	0 to 40.0 °API
0 to +250.0 °F	40.1 to 50.0 °API
0 to +200.0 °F	50.1 to 100.0 °API

Table 1: 6A heavy oils

Product type	Constants	Valid gravity ranges (API)
Fuel oil	K0 = 103.8720 K1 = 0.2701	0.0 to 37.0 °API
Jet group	K0 = 330.3010 K1 = 0.0	37.1 to 47.9 °API
Transition group	K0 = 1489.0670 K1 = -0.0018684	48.0 to 52.0 °API
Gasoline	K0 = 192.4571 K1 = 0.2438	52.1 to 85.0 °API

Table 2: 6B light oils

Valid temperature range	Valid TEC ranges
0 to +300.0 °F	0 to 40.0 °API
0 to +250.0 °F	40.1 to 50.0 °API
0 to +200.0 °F	50.1 to 85.0 °API

Table 3: 6B light oils

Valid temperature range	Valid TEC ranges
0 to +300.0 °F	270.0 to 510.0 * 10E-6/ °F
0 to +250.0 °F	510.5 to 530.0 * 10E-6/ °F
0 to +200.0 °F	530.5 to 930.0 * 10E-6/ °F

*For the transition group, $A(T) = [K1 + K0 (DEN (T) \times DEN (T))]$

**TEC is the thermal expansion coefficient of the product being measured

Table 4: 6C chemicals

Valid temperature range	Valid TEC ranges
0 to +300.0 °F	100.0 to 999.0 * 10E-6/ °F

*For the transition group, $A(T) = [K1 + K0 (DEN (T) \times DEN (T))]$ measured

Table 5: 6C MOD

Note:

Volumetric modes 6C MOD and CUST TAB are not intended for custody transfer applications since they do not follow API standard 2540 exactly. The software for 6C MOD incorporates a moveable temperature reference and allows for a wider range of TEC values.

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LOCATIONS

USA
MTS Systems Corporation
Sensors Division
3001 Sheldon Drive
Cary, N.C. 27513, USA
Tel. +1 919 677-0100
Fax +1 919 677-0200
info.us@mtssensors.com
www.mtssensors.com

JAPAN
MTS Sensors Technology Corp.
737 Aihara-machi,
Machida-shi,
Tokyo 194-0211, Japan
Tel. +81 42 775-3838
Fax +81 42 775-5512
info.jp@mtssensors.com
www.mtssensors.com

FRANCE
MTS Systems SAS
Zone EUROPARC Bâtiment EXA 16
16/18, rue Eugène Dupuis
94046 Creteil, France
Tel. +33 1 58 4390-28
Fax +33 1 58 4390-03
info.fr@mtssensors.com
www.mtssensors.com

GERMANY
MTS Sensor Technologie
GmbH & Co. KG
Auf dem Schüffel 9
58513 Lüdenscheid, Germany
Tel. +49 2351 9587-0
Fax +49 2351 56491
info.de@mtssensors.com
www.mtssensors.com

CHINA
MTS Sensors
Room 504, Huajing Commercial Center,
No. 188, North Qinzhou Road
200233 Shanghai, China
Tel. +86 21 6485 5800
Fax +86 21 6495 6329
info.cn@mtssensors.com
www.mtssensors.com

ITALY
MTS Systems Srl.
Sensor Division
Via Camillo Golgi, 5/7
25064 Gussago (BS), Italy
Tel. +39 030 988 3819
Fax +39 030 982 3359
info.it@mtssensors.com
www.mtssensors.com

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