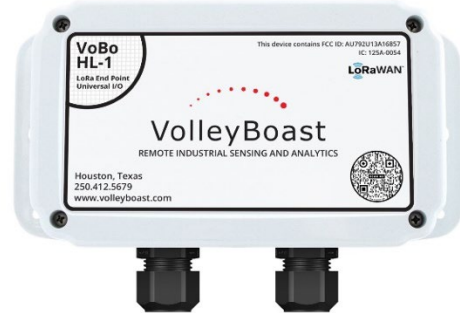# VolleyBoast

# User Manual

## VoBo GP-1

## VoBo HL-1

# VoBo Overview

The VoBo is a universal industrial grade general purpose LoRaWAN endpoint that converts wired process instruments into LoRaWAN enabled instrumentation. The VoBo is available as a general-purpose device (the GP-1) and as a device that is certified to be located in Hazardous Areas (the HL-1).  It operates on a timed wake/sleep cycle: it wakes up periodically to take and transmit sensor readings and minimizes power consumption when it is "sleeping". A primary D cell powers the VoBo and the connected analog sensors. This configuration allows for operational data to be collected inexpensively and transmitted to the User Interface (cloud based or local server) for further analysis and reporting.

**Highlights/Features**

- Provides three analog inputs, three discrete digital inputs, one "wake-up" input, one RS-485 input (for Modbus RTU devices).
- The GP-1 is provided with three entry points for sensor cables and the HL-1 has two entry points.  The VoBo comes equipped with cord grips and hole plug (s) to replace unused cord grips.  The HL-1 entry points will also accept ½ inch conduit fittings.
- Analog output can be adjusted for gain and offset.
- Designed for rugged outdoor use.
- Battery life under typical (cycle time of 30 minutes, 2 analog transmitters drawing 20 mA of current at 20 Vdc, 70 $^o$ F) operating conditions is expected to be 3 to 4 years when providing power to analog terminal blocks.  Battery life expected to be more than 7 years when only used to retrieve data from sensors/transmitters/analyzers.
- Range is up to 6 miles line-of-site to any LoRaWAN compliant gateway.  From the gateway, data can then be forwarded to the user's database or reporting system.
- Configuration can be done over-the-air or locally through a RS-232 connection.

Manufactured in Houston TX from US and non-US supplied components

# Important

 For installation assistance contact the VolleyBoast Operations team at: *support@volleyboast.com* (+1) 250-412-5679

If assistance is desired, it is best to confirm an appointment ahead of the actual installation effort.

The Volley Boast Terms and Conditions of Sale can be found at: (https://volleyboast.com/documentation/latest/termsandconditions-sale). The warranty covers VolleyBoast supplied hardware and software.

 Dispose of the battery properly according to local laws and regulations.  The supplied battery is a primary battery and cannot be recharged.  Do not attempt to recharge the battery.

The VoBo is rated to IP66, NEMA 4X standards. These standards require that the gasket be properly positioned, and the screws tightened to 8.00 in-lbs. Do not over tighten the screws.

# CONTENTS

## REVISION HISTORY

| Revision Date | Section | Revision |
|---|---|---|
| 2021.05.14 | | Original Issue of DCM-0002 Rev A5 |
| 2021.06.28 | Connecting the VoBo | Revised explanation of the Join Process |
| 2021.06.28 | Configuration | Added Stop Bits and Parity to Modbus Configuration |
| 2021.06.28 | Throughout | Corrected minor typos and prose. |
| 2021.08.16 | Analog Channels | Corrected error in 4-20 mA conversion |
| 2021.08.16 | Connect the VoBo to the Gateway | Added a caution regarding use of Adaptive Data Rate (ADR) |
| 2021.09.17 | Connect the VoBo to the Gateway | Corrected the operation of the LED during the join process |
| 2021.12.10 | Field Installation | Added supplemental information regarding current transmitters |
| 2022.05.11 | Connect the VoBo to the Gateway | Reflects changes included in firmware release 1.03.07. Cautionary notes added. |
| 2022.05.11 | VoBo Acknowledgement Process | Added section reflecting changes included in firmware release 1.03.07 |
| 2022..05.11 | Configure the Software | Added caution on how configuration impacts battery life. Added changes to configuration parameters reflecting firmware release 1.03.07 |
| 2022.07.20 | | Manual has been rewritten to reflect Firmware Version 1.03.08.  Please email support@volleyboast.com  if you require a previous version. |
| 2023.03.23 | Various clarifications and corrections | See Firmware rev 1.03.10 Release Notes<br>Added caution regarding VoBo implementation of TR-001<br>Added note regarding JP 4 (Shield to Ground jumper).<br>Note: Firmware version 1.03.09 consisted of minor cosmetic changes. |

## FIRMWARE RELEASE 1.03.10 NOTES

This release implements the following functionality:
The VoBo will reset after a customer specified number of back off events (see Join/Rejoin Process)
Implemented low battery voltage safeguards (see Configurable Fields)
Implemented saturation values for analog outputs in the event application of the analog gain and/or offset results in a negative number or a number greater than 2047 (see Analog Calibration).
Implemented downlink functionality to remotely reset the VoBo's CPU (see Configurable field).

## FIRMWARE RELEASE 1.03.08 NOTES

This release includes enhancements to the VoBo's join/rejoin process with the LoRaWAN network, Modbus RTU read functionality, the VoBo's serial menu functionality, and introduces a "Heartbeat" payload.

The firmware version that is installed in a VoBo is now noted at the top of the serial menu. Until further notice, all VoBo's shipped after June 13, 2022 will have rev 1.03.08 firmware installed.

Note that rev 1.03.08 does not change the structure of the data payloads (FPort 1 – FPort 9).

**Modbus RTU Enhancements**

This release provides for the capability to specify the modbus registers to be read in groups. When specifying in groups, the initial register is provided and the total number of consecutive registers to be read is specified. When specifying individual registers, the number of registers in the group is set to 1. Additionally, if the slave requires, the VoBo now reads multiple consecutive registers in one action. This capability is supported through the serial menu and the use of downlinks.

⚠ Polling or reading extraneous or unnecessary registers will shorten the battery life.

**Heartbeat Payload**

Firmware version 1.03.08 provides a Heartbeat payload using FPort 10. This payload is transmitted upon power up of the VoBo and every 24 hours thereafter. The Heartbeat payload can be turned off through a configuration downlink or from the serial menu.

The Heartbeat Payload includes the following information:
- The current Battery Voltage level.
- The firmware version the VoBo is running.
- The latest RSSI (received signal strength) between the VoBo and Gateway (as reported by the Gateway back to the VoBo).
- The configured analog voltage (Vdc)
- The configured amount of time power is supplied to the analog terminal blocks (seconds)
- The configured number of failed transmissions before the VoBo attempts to rejoin the network.
- Whether FSB cycling is configured on or off (only impacts upon power up).
- The configured Ack frequency, or the number of cycles between Ack requests.
- Whether Acks are configured to be on or off.
- The configured Low Battery Threshold

# SET UP

There are four key steps to setting up a VoBo, they are:
1. Connect the VoBo to the gateway/network server.
2. Configure the VoBo software.
3. Arrange the jumpers.
4. Field Installation (connect the transmitters/sensors and install the VoBo)

Steps (1) thru (3) are best accomplished in the office or lab.  It is recommended that the steps be performed in the order they are listed.

# Connect the VoBo to the Gateway/Network Server
Input the connection information for the VoBo into your gateway:
- Device ID (DevEUI)
- Application EUI (AppEUI)
- Application KEY (AppKey)

This information can be found on the paperwork included with the VoBo. The DevEUI is also provided on a label affixed to the exterior of the VoBo. The AppEUI (also referred to as the JoinEUI) is used for joining the VoBo to a gateway. The AppEUI for all VoBo GP-1's and HL-1's is the same.  It is " 56-4F-42-4F-32-30-31-36 ".  The AppKey is used for encryption purposes and should remain strictly confidential.

Please contact the gateway vendor or network server provider for instructions regarding entering this information on their platform.

The following LoRaWAN network specifications are used by the VoBo:
- Class: A
- LoRaWAN 1.0.4
The gateway or network server should reflect the above network parameters.  The VoBo is backwards compatible with LoRaWAN 1.0.2.

Once the VoBo's connection information is provided to the gateway/network server, test if it will join with the network:

1. Remove the enclosure top.
2. Ensure that the slider switch by the battery holder is switched to "OFF".
3. Install the battery, ensuring the polarity is correct.
4. Move the slider switch to the "ON" position.
5. Look at the LED and check the description below to see the status.

Check LED for status. The LED will light green for 1 second following successful initialization of the VoBo. The LED will briefly flash green each time the VoBo attempts to join the network.  If the VoBo fails to join after cycling through the FSBs, it will light red for 1 second.  The LED will briefly (0.1 second) flash red if the VoBo is joined with the gateway, makes a transmission and the payload (the data) fails to fit into the transmitted packet.  It is normal to see one or two red flashes due to the number of MAC commands being sent to the gateway after the join process.  This may also occur if the VoBo is near its maximum transmission range.  The LED will light green for 1 second upon successfully transmitting a payload (data) and receiving a confirmation back from the gateway. This data transfer response is common to all VoBo Payloads, from FPort 1 Payload to the newly added FPort 10 (Heartbeat) Payload.

Note: the LED only functions upon powering up the VoBo.  It is not designed to function at other times.

The VoBo will send transmissions at the default cycle time of 30 minutes (as described below). Pressing the WUP button will cause the VoBo to "wake up" from its sleep mode, read any connected sensors, and

send a transmission. It will then go back to its configured cycle. The cycle time can be changed using either the online or local configuration manager.

⚠️ *Leaving the VoBo powered on when it is not in the presence of a LoRaWAN network it is permitted to join can consume significant battery life since it will be repeatedly attempting to join the network.*

⚠️ *Do not turn the VoBo on if the battery voltage is below 3.0 Volts.  This may result in corruption of the flash memory and loss of the DevEUI.*

# Join/Rejoin Process

The Joined Rejoin process is compliant with the LoRaWAN 1.04 Link Layer specifications.   The join process works as follows.  Upon power up the VoBo will attempt to join the network at the configured FSB setting.  This default setting is 2.    It will attempt twice at the configured FSB, once at 500 MHz and once at 125Mhz.   If it fails to join at the configured FSB, it will attempt to join twice (500 MHz and 125 MHz) at each subsequent FSB, until it either joins or attempts at all 8 FSB's have been completed.   If it fails to join at all, it will enter its back off routine, repeating the join cycle at the following time intervals:
1. 5 minutes
2. 30 minutes
3. Every 2 hours (5 times)
4. Every 24 hours (thereafter)

Once the VoBo has joined the network, it will save the FSB it joined on, and only use this FSB if it is ever required to rejoin the network.  If power is cycled on and off, the VoBo will act as if it has never joined the network and begin at the configured FSB.

If desired, the VoBo's configuration parameters permit the user to set the VoBo's FSB to match the intended gateway(s) FSB and turn the cycling through the FSB's feature off.

VoBo's with Rev 1.03.10 firmware and higher can be configured to reset the CPU after defined number of back offs occur.  This will cause the VoBo to cycle through the FSB's (if this is enabled) and reset the AppNonce/JoinNonce counter.

TR 001
The VoBo implements the LoRa Alliance "Technical Recommendations for Preventing State Synchronization Issues around LoRaWAN 1.0.x Join Procedure", sometimes referred to as TR 001.  This recommendation provides that:

- Part 1 – Join Server Behavior:
  "The Join Server SHALL provide the AppNonce (or JoinNonce) as a device specific counter value (that never repeats itself) and that is incremented with every Join-accept message."

- Part 2 – End-device Behavior:

The device is expected to be aware of this behavior of its Join Server and SHALL keep track of the AppNonce (or JoinNonce) value used in the last successfully processed Join-Accept (corresponding to the last successful key derivation). The device SHALL accept the Join-Accept only if the MIC field is correct and the AppNonce (or JoinNonce) is strictly greater than the recorded one. In that case the new AppNonce (or JoinNonce) value replaces the previously stored one.

If your Join Server has not implemented this technical recommendation, it may result in the VoBo receiving an AppNonce (or JoinNonce) in the Join Accept transmission that it will reject and thus prevent the VoBo from joining with the server.  This will not happen on the initial join, but it is likely to occur on a subsequent rejoin effort.   It is recommended that the acknowledgment function be turned off (see below) if your join server has not implemented this recommendation.


# Acknowledgements and Rejoin

The VoBo contains 4 configurable parameters with respect to its Acknowledgements and Rejoin routine.
1. Acknowledgement Enable – permits the acknowledgment function to be turned on or off.  The default value is on.
2. Acknowledgment Frequency – permits the user to configure how frequently it wants the VoBo to request an acknowledgement from the gateway that it has received the payload.  This can be configured between 1 (every payload) and 10 (every tenth payload).  For this purpose, each Modbus transmission is counted as a payload.  The default value is 4.
3. Acknowledgment Request – this permits the user to configure how many times it wants the VoBo to request an acknowledgement for that specific payload.  Each time it requests an acknowledgment (for that cycle, it will resend the payload with the same f count and ask for the acknowledgment.  This can be configured between 1 and 8.  The default value is 2.  If the VoBo fails to receive an acknowledgement after completing the specified number of requests, it will count as a failed transmission.
4. Failed Transmissions Before Rejoin – permits the user to configure the number of failed transmissions before it will attempt to rejoin the network.  This can be configured between 1 and 15. The default value is 10.  If the VoBo reaches its configured limit of failed transmissions before rejoin, it will enter into its rejoin process, which is the same back off routine described for the join process, with the exception that it will only use the FSB it had previously joined on.

The VoBo firmware uses a feature called automatic data rate (ADR).  This balances the tradeoff between signal strength and battery life, providing enough transmit power to ensure a robust connection while preserving battery life.  It takes some time for this adjustment to be made.  *It is good practice to cycle power when relocating the VoBo a significant distance to a new location.  This will permit the VoBo to begin at the highest transmit power and then adjust downwards to the optimum level for that location.*


# Configure the Firmware

The VoBo can be configured either remotely or locally.

**Remote Configuration**

The VolleyBoast configuration portal ("The VoBo Configurator") is accessed through VolleyBoast's Customer Portal found at: https://portal.volleyboast.com.

The VoBo Configurator creates hexadecimal messages which are downloaded through network servers to the gateways. Each time a message is sent to the gateway, the VoBo checks to determine if a downlink message is waiting for it. If there is a configuration message, the VoBo will receive it and update its configuration.

The VoBo Configurator can be used to configure VoBos deployed on networks managed by VolleyBoast (through its Remote Monitoring Service) as well as those deployed on third-party networks.

Hexadecimal formatted configuration information derived by the VoBo Configurator can be copied or downloaded and provided to third-party networks.  The format for available downlinks can be found by clicking on the Downlink Field Definitions within the Tools section of the Customer Portal.

The VoBo Configurator also provides a management system for the VoBos. It tracks the most recent configuration file "sent" from the portal and organizes the VoBos by groups and sites.

## Configuration Process
Initial Account Setup Step 1: Go to https://portal.volleyboast.com/
Step 2: Select "Register"
Step 3: Enter account information
Step 4: Click the link on the confirmation email to activate the account
Step 5: Add users to the account via the "Account Information" tab on the portal

## Adding VoBos
Step 1: Select "VoBo Configurator"
Step 2: Select "Device".  Click on "New" to enter a new device.
Step 3: In the Add Device section, select the desired "Group" and "Site".  It is optional to use Groups and Sites.  If they are used, they need to be set up first within the respective tabs found in the main menu.  Once a VoBo is added the only way it can be removed is from the Equipment Management section of the portal.
Step 4: Enter the name you have chosen for the VoBo.
Step 5: Enter the DevEUI of the VoBo.
Step 6: If desired, enter a description.
Step 7: Select "Save Device"
Step 8: Repeat steps 1-7 for each additional VoBo

## Configuring VoBos
Step 1: Select VoBo Configurator in the dropdown menu
Step 2: Click the target Group and/or Site
Step 3: Select the VoBo
Step 4: Change default values where necessary
Step 5: A hexadecimal-equivalent string reflecting updates to the configuration changes dynamically as data is entered

Step 6: Select "Send Configuration" to transmit the configuration message to the selected Network Server Provider or to create a local download. This also saves the configuration for the chosen node for future use.
Note: The VoBo receives the updated configuration file the next time it communicates with the network. The VoBo will transmit its current payload, before receiving the message.  The configuration changes will be implemented in the next wake-up cycle.

## Local Configuration

It is important to follow all the steps outlined below.

1) Turn the power switch to the off position

   ⚠️ **_All power is to be removed from the VoBo.  The USB to RS232 cable should also be disconnected at this time as it provides enough power to prevent the VoBo from completely resetting._**

2) After ensuring all power is disconnected from the VoBo, connect a computer to the SERIAL (UART) terminal on the VoBo with a USB to RS-232 cable. (Note: FTDI manufactures a RS232 to USB connector that works well for this purpose. The part number is TTL-232R-RP I). For ease of repeated use – it may be beneficial to connect the individual wires to a RS-232 connector housing (Molex part number 50-57-9403). The Molex part number for the respective crimp connectors is 16020102. Please contact VolleyBoast if you would like to purchase a preassembled connector.

3) Set the SERIAL switch to "ENABLE".

4) Restore power to the VoBo by switching the power switch to "ON".

5) Open a communication software such as TeraTerm or Putty.

6) Set the following:

   Baud Rate = 9,600

   Data bits = 8

   Parity = N

   Stop bits = 1

   Flow Control = Off

7) When connecting to the screen you should have a blank screen.

8) Type "volleyboast" and then "enter" or "return".

9) Follow the prompts on your screen to change the configuration.  Note, after typing the item number/letter you wish to modify, you must then click "enter" or "return" to enter the prompt.

10) Once the changes have been made, follow the prompts to exit the local configuration mode and resume normal operation.

Note: The serial switch must be set to "DISABLE" before exiting the local configuration mode.  The VoBo will not resume normal operation if the serial switch is not set to "DISABLE".

Remove the USB-RS232 cable.

⚠️ **THE VoBo WILL NOT ENTER NORMAL OPERATION  WHEN THE SERIAL SWITCH IS IN THE ENABLE POSITION.  IT MUST BE RETURNED TO THE DISABLE POSITION TO RESUME FUNCTIONALITY!**

## Configurable Fields

Cycle Time
- Time between readings
- Default: 30
- Units: Minutes
- Range: 1 – 2880
- Source: user determined

Analog Voltage
- Voltage applied to sensors ADC channels
- Default: 12
- Units: Volts
- Range: 5 – 24 (whole numbers)
- Source: sensor documentation

Analog Power Time
- Time necessary for sensors to be sufficiently powered to take an accurate reading
- Default: 1.0
- Units: Seconds
- Range: 0.1 – 20.0
- Source: sensor documentation

Cycle Sub-Bands
- Yes enables the VoBo to cycle through all of the sub bands during the initial (upon power up) join process of the VoBo.
- Default: Yes
- Range: Yes – No
- Source: user determined

Cycles Between Acknowledgement Requests
- The number of transmissions between VoBo requests for acknowledgement of receipt from the gateway.
- Default:
- Range: 1 – 15
- Source: criticality of data receipt.

Acknowledgement Requests Sent on the Intended Cycle
- The number of times the VoBo will resend the payload (with the same fcount) and request the ack from the network server.
- Default: 2
- Range: 1-8
- Source: user determined

Failed Transmissions Before Rejoin
- Number of failed Acknowledgement Cycles allowed before initiating a new join process
- Default: 10
- Range: 1 – 15
- Source: user determined

Acknowledgement Enable
- Turns the entire Ack process on or off.
- Default: Yes (on)
- Range: Yes – No
- Source: user determined

Low Battery Threshold (Vdc)
- Sets the threshold battery voltage below which the VoBo will not attempt to read connected instrumentation.   It will not attempt to transmit data and will immediately go back to sleep.  It will wake up on its cycle.  If the voltage is above threshold it will complete its normal cycle.
- Default: 3.1
- Range: 2.5 – 3.3
- Source: user determined

Back Off Events Before Reset
- Sets the number of Back Offs that will occurs before the VoBo resets its CPU
- Default: 9
- Range: 1 - 35
- Source: user determined

Heartbeat Enable
- The VoBo sends a Heatbeat Payload once every 24 hours. This turns the Heartbeat Payload transmission on or off.
- Default: Yes (on)
- Range: Yes – No
- Source: user determined

Modbus Configuration
- Modbus Enable - The Modbus functionality must be enabled to read Modbus RTU registers. Enter "yes" to enable.  If not reading a Modbus device the Modbus functionality should be disabled.
- Modbus Parity - This can be configured to be 0 (None), 1 (odd), or 2 (Even).
- Modbus Stop Bits - This may be set to 1 or 2.

- Modbus Address - Slave devices are assigned addresses in the range 1 – 247. Normally, slave devices have a default address of 1.
- Modbus Delay - The transducer's data sheet specifies the minimum delay between transactions to return the content of the registers.  Typically, between 200 to 300 ms. The VoBo should be configured for a greater length of time.  The VoBo will terminate its delay period after it receives a transmission from the instrument.
- Modbus Baud - The Baud rate for which the process instrument is configured for.
- Modbus Group Count - Enter the number of groups of consecutive registers you wish to read. The VoBo will read up to 41 16-Bit registers.  If a register has 32 bits, generally they are in successive 16-bit registers and can be read in one group by entering the starting register and a register count of 2.
- Group X Starting Register - This is the first register in the group being read.  Modbus registers that begin with a 3 are input registers and those that begin with a 4 are holding registers.  The remaining digits specify the register where the data is located.  Data addresses in Modbus registers are referenced to zero.  Therefore, as a practical matter, enter a number that is one less than the register number provided on your device's data sheet.  A Modbus register of 30302 would be an input register and it would be addressed as register 30301.
- Group X Register Count – This is the number of registers in the Group.

🚨 *The VoBo serial communication with Modbus slave devices requires the use of 8 Data Bits.*

Analog Calibration
- Adjusts the output from the analog terminals for Gain and Offset. Additionally, the output can be modified to report in engineering units instead of raw ADC counts (or millivolts)
- Default: Gain =1, Offset = 0.
- Range: Gain; 0.1 - +2047, Offset; -2047 - +2047

🚨 Battery life is decreased to the extent Cycle Time is decreased, Analog Voltage Input is increased, and Analog Power Time is increased.  Use the VoBo Battery Life calculator found in the Tools section of the VolleyBoast Customer Portal to determine the impact on battery life for various settings.


# DECODING THE PAYLOAD

## Payload Structure
The VoBo sends an 11-byte payload.  If multiple Modbus registers are read, the VoBo will transmit the data in multiple 11-byte payloads. The VoBo utilizes a Port field (FPort) within the MAC command to distinguish between the different payloads.  A FPort of 1 denotes the first payload, which includes the data received by the analog and discrete terminals as well as the first Modbus register.  A FPort of 2 denotes the second payload which contains Modbus registers 2 through 6, FPort 3 includes Modbus registers 7 through 11, and so on, until FPort 9 which contains Modbus registers 37-41.

If the slave returns an error or there are other communication issues, the VoBo payload for the registers which could not be read will be "9999" to indicate an error.   If the VoBo is not communicating with the

slave and fails to read the first 4 registers, it will stop trying to read any subsequent registers to minimize power consumption.  It will try again on its next scheduled cycle.

The Heartbeat Payload is found in FPort 10

Payload decoders for each of the FPorts can be found in the Tools section of the Customer Portal.

The microprocessor uses a little-endian format.  The tables below map out how the payloads are structured.

# FPort 1 Payload

| BYTE | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|---|
| 1 | Last 4 Bits of adcCh1 | | | | WKUP | DI3 | DI2 | DI1 |
| 2 | First 8 Bits of adcCh1 | | | | | | | |
| 3 | Last 8 Bits of adcCh2 | | | | | | | |
| 4 | Last 4 Bits of adcCh3 | | | | First 4 Bits of adcCh2 | | | |
| 5 | First 8 Bits of adcCh3 | | | | | | | |
| 6 | Last 8 Bits of adcCh4 | | | | | | | |
| 7 | Last 4 Bits of adcTemperature | | | | First 4 Bits of adcCh4 | | | |
| 8 | First 8 Bits of adcTemperature | | | | | | | |
| 9 | Last 8 Bits of Modbus Register 1 | | | | | | | |
| 10 | First 8 Bits of Modbus Register 1 | | | | | | | |
| 11 | Reserved for Future Use | | | | | | | |

Notes:
- Digital Inputs - when circuit is open (or voltage is not detected) the payload is 1, when closed (or voltage is detected) the payload is 0.
- WKUP - when the circuit is open the payload is 0, when closed the payload is 1.
- adcCh1, adcCh2, adcCh3 correspond to the AI1, AI2, and AI3 analog terminal blocks.
- adcCh4 is raw battery voltage. Raw battery voltage * 4 = actual battery voltage (millivolts). The battery voltage is read while analog terminals are powered.
- adcTemperature is the reading from the temperature sensor integrated into the ADC. Temperature is in Celsius. When the first bit (left most) in the adcTemperature[0] is 0, the temperature is greater than zero. To convert to temperature multiply by 0.125. When the first bit in adcTemperature [0] is 1 the temperature is below zero and use [(4096-adcTemperature) * (-1) * 0.125] to get the temperature.

# Breakdown of FPort 1 Payload
Base64 string - "8zA/EwBKIwvSBAA="

Converted to Binary

11110011 00110000 00111111 00010011 00000000 01001010 00100011 00001011 11010010 00000100 00000000

Using the payload structure detailed above and keeping in mind the use of little-endian, the payload is broken up as follows:

Din1 – 1 - "1"
Din2 – 1 - "1"
Din3 – 0 - "0"
WKUP – 0 - "0"
adcCh1 – 001100001111 - "783"
adcCh2 – 001100111111 - "831"
adcCh3 – 000000000001 - "1"
adcCh4 – 001101001010 - "842"
adcTemperature – 000010110010 - "178"
modbus register 1 – 0000010011010010 - "1234"

# FPort 2-9 (Modbus Payloads)

| BYTE | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|------|------|------|------|------|------|------|------|------|
| 1 | Last 8 Bits of Modbus Register 2 | | | | | | | |
| 2 | First 8 Bits of Modbus Register 2 | | | | | | | |
| 3 | Last 8 Bits of Modbus Register 3 | | | | | | | |
| 4 | First 8 Bits of Modbus Register 3 | | | | | | | |
| 5 | Last 8 Bits of Modbus Register 4 | | | | | | | |
| 6 | First 8 Bits of Modbus Register 4 | | | | | | | |
| 7 | Last 8 Bits of Modbus Register 5 | | | | | | | |
| 8 | First 8 Bits of Modbus Register 5 | | | | | | | |
| 9 | Last 8 Bits of Modbus Register 6 | | | | | | | |
| 10 | First 8 Bits of Modbus Register 6 | | | | | | | |
| 11 | Reserved for Future Use | | | | | | | |

# Breakdown of FPort 2-9 Payload
Base64 string - "VxLDOBIAzRigFgA="

Converted to Binary

01010111 00010010 11000011 00111000 00010010 00000000 11001101 00011000 10100000 00010110 00000000

Using the payload structure detailed above and keeping in mind the use of little-endian, the payload is broken up as follows:

modbus register 2 – 00010010 01010111  - "4695"
modbus register 3 – 00111000 11000011  - "14531"
modbus register 4 – 00000000 00010010  - "18"
modbus register 5 – 00011000 11001101  - "6349"
modbus register 6 – 00010110 10100000  - "5792"

Note: the 11th Byte (Reserved For Future Use) is 0000 0000.

## FPort 10 (Heartbeat Payload)

| BYTE | Bit7 | Bit6 | Bit5 | Bit4 | Bit3 | Bit2 | Bit1 | Bit0 |
|---|---|---|---|---|---|---|---|---|
| 1 | Last 8 bits of ADC Battery Level | | | | | | | |
| 2 | Last 4 bits of FW Major Version | | | | First 4 bits of ADC Battery Level | | | |
| 3 | Last 4 bits of FW Minor Version | | | | First 4 bits of FW Major Version | | | |
| 4 | Last 4 bits of FW Patch Version | | | | First 4 bits of FW Minor Version | | | |
| 5 | FW Custom Version | | | | First 4 bits of FW Patch Version | | | |
| 6 | Received Signal Level (Last RSSI) | | | | | | | |
| 7 | Last 3 bits of Analog Power Time | | | Analog Voltage (5 bits) | | | | |
| 8 | Last 3 bits of Failed Transmission Before Rejoin | | | First 5 bits of Analog Power Time | | | | |
| 9 | Last bit of ACK Request | ACK Frequency | | | | ACK Enable | Cycle Through FSB | First bit of Failed Transmission Before Rejoin |
| 10 | Last 5 bits of Battery Level Threshold | | | | | First 3 bits of ACK Request | | |
| 11 | Reserved | First 7 bits of Battery Level Threshold | | | | | | |

## Breakdown of FPort 10 Payload

Base64 string – "fRNAAABCTEEncRc="

Converted to Binary
01111101 00010011 01000000 00000000 00000000 01000010 01001100 01000001 00100111 01110001 00010111

Using the payload structure detailed above and keeping in mind the use of little-endian, the payload is broken up as follows:

ADC Battery Level – 001101111101 – "893"
FW Major Version – 00000001 – "1"
FW Minor Version – 00000100 – "4"
FW Patch Version – 00000000 – "0"
FW Custom Version – 0000 – "0"
Received Signal Level (Last RSSI) – 01000010 – "66"
Analog Voltage – 01100 – "12"
Analog Power Time – 00001010 – "10"
Failed Transmission Before Rejoin – 1010 – "10"
Cycle Through FSB – 1 – "1"
Ack Enable – 1 – "1"

Ack Frequency – 0100 – "4"
Ack Request – 0010 – "2"
Low Battery Threshold – 001011101110 – "750"
Bit 7 of the 11th Byte is Reserved for Future Use.

Notes:
ADC Battery Level is reported at ¼ the voltage.
ADC Battery Level Threshold reported at ¼ the voltage.
Analog Power Time is the configured time multiplied by 10.

# Analog Channels

Each analog channel is read by a 12-bit ADC. Each channel can be configured with jumpers to go through one of three different circuits.

The circuit for reading a 0-5V sensor includes a voltage divider (R2 = 20,000 ohm, R1 = 30,000 ohm). The actual voltage output from a 0-5V sensor is reduced by 2/5 at the ADC input. The ADC output (adcChx) for a 0-5V sensor then will have a scale of between 0 and 2000 raw counts.

The circuit for reading a 0-10V sensor includes a R2 = 7,500 ohm, R1 = 30,000 voltage divider. The actual voltage output from a 0-10V sensor is reduced by 1/5 at the ADC input. The ADC output for a 0-10V sensor will also have a scale of between 0 and 2000 raw counts.

The circuit for reading a 4-20mA sensor has a current divider which includes a 250 Ohm resistor. 4mA of current from the sensor results in a voltage at the ADC input of 398mV and 20mA of current results in 1990mV at the ADC input.

**Converting ADC Raw Counts to Sensor Units for a 0-5V Sensor**

Example: A 0-5V pressure sensor, pressure range of 0-100psi, output load of 20,000 Ω.

**Step 1:** Calculate the slope (gain)
m = (Sensor Pressure at 5V - Sensor pressure at 0V)/(Voltage Range of the Sensor)) * ((50,000 Ω+Output Load)/20,000 Ω)
m = (100 / 5) * [(50000 + 20000) / 20000]
m = 70

**Step 2:** Calculate the y-intercept (offset)
b = (-1) * (0.4) * m * (Output Voltage Min) + (Measurement Value Min)
b = (-1) * (0.4) * m * (0) + (0)
b = 0

Resulting Equation:
Pressure = 70 * (ADC raw counts/1000)

Using adcCh1 raw counts of 783, sensor is measuring a pressure of 54.81psi.

**Converting ADC counts to Sensor Units for a 0-10V Sensor**

Example: A 0-10V pressure sensor, pressure range of 100 - 500psi, output load of 30,000 Ω.

**Step 1:** Calculate the slope (gain)
m = (Sensor Pressure at 10V - Sensor pressure at 0V)/(Voltage Range of the Sensor)) * ((37,500 Ω+ Output Load)/7,500 Ω)
m = (400 / 10) * [(37,500 + 30,000) / 7,500]
m = 360

**Step 2:** Calculate the y-intercept (offset)
b = (-1) * (0.2) * m * (Output Voltage Min) + (Measurement Value Min)
b = (-1) * (0.2) * m * (0) + (100)
b = 100

Resulting Equation:
Pressure = 360 * (ADC raw counts/1000) + 100

Using adcCh1 raw counts of 783, sensor is measuring a pressure of 381.8 psi.

**Converting ADC counts to Sensor Units for a 4-20 mA Sensor**

Example: A 4-20mA pressure sensor, pressure range of 0 - 2000psi.

**Step 1:** Calculate the slope (gain)
m = (Sensor Pressure at 20 mA - Sensor pressure at 4 mA)/(1.990-0.398)
m = (2000/ 1.592)
m = 1256.3

**Step 2:** Calculate the y-intercept (offset)
b = (-0.398 * m) + Sensor Pressure at 4 mA
b = (-0.398 * 1256.3) + 0
b = -500.0

Resulting Equation:
Pressure = 1256.3x(ADC raw counts/1000) - 500.0

Using adcCh1 raw counts of 783, Sensor is measuring a pressure of 483.68 psi.


# ANALOG CALIBRATION

The ADC raw count from the three analog terminals can be adjusted for gain and offset. This permits the storing of the calibration points at the VoBo level and using one conversion formula for a particular model sensor in the cloud or server. The gain and offset values can be entered through remote or local configuration parameters.

The gain should be expressed as (equivalent ADC raw counts from the test instrumentation/ADC raw counts from the installed sensor that corresponds to the test points). The offset should also be expressed in ADC raw counts.

Note the default Gain is set to 1 and the default Offset is set to 0. This provides the default payload explained above.   If after the application of the gain and offset the reported ADC count is greater than 2047, it will saturate at 2047.  If it is negative it will saturate at 0.


# TEST POINTS

There are several voltage measurement points provided on the board.

VPP is the voltage provided to the analog terminal blocks. No voltage is applied to VPP when the VoBo is in its sleep cycle. VPP should be equal to the configured supply voltage when it is awake and for the duration of its settling time.

VBat provides the current battery voltage.

+3.0 Volt should measure 3.0 volts when the VoBo is awake. Many of the components on the board function at 3.0 volts.

V_MTDOT is the reference voltage from the microprocessor, it is 3 volts.


# FIELD INSTALLATION

Refer to the VoBo GP-1 or HL-1 Installation Manual for instructions.   Supplemental information to the Installation Manuals may be found below.

**Current Sensors/Transmitters**

- Two-wire loop powered sensor/transmitter:
    - Connect the jumpers as indicated in the installation manual for 4-20 mA sensors.
    - Connect the VDC supply wire (typically red) in the AI+ and the signal wire (typically black) in AI- of the analog input terminal block. The Bare or shield wire goes into the Shield terminal.
- Three wire current sensor/transmitter, powered by the VoBo:
    - Connect the jumpers as indicated in the installation manual for 4-20 mA sensors.
    - Connect the VDC supply wire to AI+, the signal wire to AI-, and the common wire to the Shield terminal.
    - Close jumper JP4 (located adjacent to the AI3 terminal block).  This connects the shield to ground.
- Externally powered current transmitter:
    - Only close X8, X11, and/or X18 (for the AI1, AI2, and/or AI3 respectively).
    - Connect the signal wire to AI- and the common (or supply -) to the Shield.

o   Close jumper JP4 (located adjacent to the AI3 terminal block).  This connects the shield to ground.

**Jumper JP 4 Shield to Ground**

If your sensor/transmitter has a shield wire and it is connected to a ground outside the VoBo, leave this jumper off (open) and do not connect the shield wire to the VoBo terminal.   If the sensor/transmitter shield wire is not connected outside the VoBo, it may be connected to the SHIELD position on the terminal block and the JP 4 jumper should be installed, connecting the shield to ground.

# REGULATORY

## 47 CFR Part 15 Regulation Class B Devices
This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:
- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

## FCC Interference Notice
Per FCC 15.19(a)(3) and (a)(4) This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:
1. This device may not cause harmful interference.
2. This device must accept any interference received, including interference that may cause undesired operation.

**FCC Grant**

| FCC Part 15 | |
|---|---|
| FCC Identifier: | AU792U13A16857 |
| Equipment Class: | Digital Transmission System |
| Notes: | MTDOT-915 |
| FCC Rule Parts: | 15C |
| Approval: | Single Modular |

| Frequency Range: | 902.3-914.9 |
|---|---|
| Output Watts: | 0.0772 |

Output power is conducted. This transmitter is a hybrid per FCC 15.247(f) and FCC KDB 453039. The antenna(s) used for this transmitter must be installed to provide a separation distance of at least 20 cm from all persons and must not be collocated or operating in conjunction with any other antenna or transmitter within a host device, except in accordance with FCC multi-transmitter product procedures.

# Industry Canada Class B Notice

This Class B digital apparatus meets all requirements of the Canadian Interference-Causing Equipment Regulations.

*Cet appareil numérique de la classe B respecte toutes les exigences du Reglement Canadien sur le matériel brouilleur.*

This device complies with Industry Canada license-exempt RSS standard(s). The operation is permitted for the following two conditions:

1. The device may not cause interference.
2. This device must accept any interference, including interference that may cause undesired operation of the device.

*Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes:*

1. *L'appareil ne doit pas produire de brouillage*
2. *L'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.*

# Industry Canada

| Specification/ Cahier des Charges | Issue/ Édition | From Frequency/ De Fréquences | To Frequency/ Á Fréquences | Emmission Designation/ Designation D'émission | Minimum Power | Maximum Power |
|---|---|---|---|---|---|---|
| RSS247 | 1.0 | 902.3 MHz | 914.9 MHz | GXDXX | 77.2 mW | 77.2 mW |

| Certification Number/No. de Certification | 125A-0054 |
|---|---|
| Type of Radio Equipment/Genre de Matériel | Spread Spectrum/Digital Device (902-928MHz)/ |
| | Modular Approval/Approbation modulaire |
| Model/Modèle | MTDOT-915 |

Certification of equipment means only that the equipment has met the requirements of the above noted specification. License applications, where applicable to use certified equipment, are acted on

accordingly by the Industry Canada issuing office and will depend on the existing radio environment, service and location of operation. This certificate is issued on condition that the holder complies and will continue to comply with the requirements and procedures issued by Industry Canada. The equipment for which this certificate is issued shall not be manufactured, imported distributed, leased, offered for sale or sold unless the equipment complies with the applicable technical specifications and procedures issued by Industry Canada.

*La certification du matériel signifie seulement que le matériel a satisfait aux exigences de la norme indiquée ci- dessus. Les demandes de licences nécessaires pour l'utilisation du matériel certifié sont traitées en conséquence par le bureau de délivrance d'Industrie Canada et dépendent des conditions radio ambiantes, du service et de l'emplacement d'exploitation. Le présent certificat est délivré à la condition que le titulaire satisfasse et continue de satisfaire aux exigences et aux procédures d'Industrie Canada. Le matériel à l'égard duquel le présent certificat est délivré ne doit pas être fabriqué, importé, distribué, loué, mis en vente ou vendu à moins d'être conforme aux procédures et aux spécifications techniques applicable publiées par Industrie Canada.*

# CONTACT

For installation assistance contact the VolleyBoast team at: *support@volleyboast.com*

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