# ProStar PWM
# MODBUS® Specification

**v1.0**
**8 February 2017**

Morningstar Corporation
8 Pheasant Run
Newtown, PA 18940
www.morningstarcorp.com
info@morningstarcorp.com

# General Information

The ProStar PWM supports the industry standard MODBUS® application protocol via its Meter RJ-11 interface. A *Meterbus to Serial Converter* (MSC) is required to adapt the Meter interface to an isolated RS-232 interface**. This document assumes the user is familiar with the MODBUS® protocol and its terminology. Please refer to the documents listed in the References section for more information.

** The MSC adapter is a Morningstar accessory. Contact your dealer for more information.



# Parameters

The ProStar PWM supports RTU mode only.
16bit MODBUS® addresses (per the modbus.org spec)
The serial communication parameters are

- BPS: 9600 baud
- Parity: None
- Data bits: 8
- Stop bits: 2
- Flow control: None

All addresses listed are for the request PDU.
The ProStarPWM default server address: 0x01.

Floating point values are represented in half-precision (designated at f16 or Float16)

# Supported MODBUS® Functions

## *Read Holding Registers (0x03) and Read Input Registers (0x04)*

## RAM

| PDU Addr | Logical Addr | Variable name | Variable description | Units | Scaling or Range |
|---|---|---|---|---|---|
| 0x0000 | 1 | sw_ver | Software Version | - | |
| 0x0001 | 2 | n_sys_v | Battery Voltage Settings multiplier (1 for 12V nominal, 2 for 24V nominal) | - | |
| 0x0002 - 0x0003 | 3 - 4 | RESERVED | | | |
| **RAW ADC** | | | | | |
| 0x0004 | 5 | vdd_actual | 3.3V Supply Voltage | V | Float16 |
| 0x0005 | 6 | adc_fgdrive | Gate Drive Voltage | V | Float16 |
| 0x0006 | 7 | adc_pmeter | MeterBus Supply Voltage | V | Float16 |
| 0x0007 | 8 | adc_vrefint | Internal Reference Voltage | V | Float16 |
| 0x0008 | 9 | adc_FN3 | Negative Supply rail for current measurement | V | Float16 |
| 0x0009 | 10 | adc_gload | Load FET gate voltage | V | Float16 |
| 0x000A | 11 | adc_gatepv | Array FET gate voltage | V | Float16 |
| 0x0009 - 0x000F | 12-16 | RESERVED | | | |
| **FILTERED ADC** | | | | | |
| 0x0010 | 17 | RESERVED | | | |
| 0x0011 | 18 | adc_ia | Array Current | A | Float16 |
| 0x0012 | 19 | adc_vbterm | Battery Terminal Voltage | V | Float16 |
| 0x0013 | 20 | adc_va | Array Voltage | V | Float16 |
| 0x0014 | 21 | adc_vl | Load Voltage | V | Float16 |
| 0x0015 | 22 | RESERVED | | | |
| 0x0016 | 23 | adc_il | Load Current | A | Float16 |
| 0x0017 | 24 | adc_vbsense | Battery Sense Voltage | V | Float16 |
| 0x0018 | 25 | adc_vb_f_1m | Battery Voltage, slow filter (60s) | V | Float16 |
| 0x0019 | 26 | adc_ib_f_1m | Battery Current (net), slow filter (60s) | A | Float16 |
| **TEMPERATURES** | | | | | |
| 0x001A | 27 | T_hs | Heatsink Temperature | ºC | Float16 |
| 0x001B | 28 | T_batt | Battery Temperature (Either Ambient or RTS if connected) | ºC | Float16 |
| 0x001C | 29 | T_amb | Ambient (local) Temperature | ºC | Float16 |
| 0x001D | 30 | T_rts | Remote Temperature Sensor Temp. | ºC | Float16 |
| 0x001E-0x0020 | 31-33 | RESERVED | | | |
| **CHARGER STATUS** | | | | | |
| 0x0021 | 34 | charge_state | Charge State | - | |
| 0x0022 | 35 | array_fault | Array Fault Bitfield | - | |
| 0x0023 | 36 | vb_f | Battery Voltage, slow filter (25s) | V | Float16 |
| 0x0024 | 37 | vb_ref | Battery Regulator Reference Voltage | V | Float16 |
| 0x0025 | 38 | RESERVED | | | |
| 0x0026 | 39 | Ahc_r_HI | Ah Charge Resettable, HI word | Ah | n*0.1 |
| 0x0027 | 40 | Ahc_r_LO | Ah Charge Resettable, LO word | - | |
| 0x0028 | 41 | Ahc_t_HI | Ah Charge Total, HI word | Ah | n*0.1 |
| 0x0029 | 42 | Ahc_t_LO | Ah Charge Total, LO word | - | |

| | | | | | |
|---|---|---|---|---|---|
| 0x002A | 43 | kWhc_r | kWh Charge Resettable | kWh | n*0.1 |
| 0x002B | 44 | kWhc_t | Kwh Charge Total | kWh | n*0.1 |
| 0x002C | 45 | Tb_lo_limit_100 | Battery Temp Foldback 100% Output Limit | ºC | Float16 |
| 0x002D | 46 | Tb_lo_limit_0 | Battery Temp Foldback 0% Output Limit | ºC | Float16 |
| **LOAD STATUS** | | | | | |
| 0x002E | 47 | load_state | Load State | - | |
| 0x002F | 48 | load_fault | Load Fault Bitfield | - | |
| 0x0030 | 49 | V_lvd | Load Current Compensated LVD Voltage | V | Float16 |
| 0x0031 | 50 | V_lhvd | Load HVD Voltage | V | Float16 |
| 0x0032 | 51 | Ahl_r_HI | Ah Load Resettable, HI word | Ah | n*0.1 |
| 0x0033 | 52 | Ahl_r_LO | Ah Load Resettable, LO word | - | |
| 0x0034 | 53 | Ahl_t_HI | Ah Load Total, HI word | Ah | n*0.1 |
| 0x0035 | 54 | Ahl_t_LO | Ah Load Total, LO word | - | |
| **MISC** | | | | | |
| 0x0036 | 55 | hourmeter_HI | Hourmeter, HI word | hours | |
| 0x0037 | 56 | hourmeter_LO | Hourmeter, LO word | - | |
| 0x0038 | 57 | alarm_HI | Alarm Bitfield – HI word | - | |
| 0x0039 | 58 | alarm_LO | Alarm Bitfield – LO word | - | |
| 0x003A | 59 | dip_switch | DIP Switch Settings at Power On (switch[1..8] in bits[0..7]) | - | |
| 0x003B | 60 | led_state | SOC LED State | - | |
| 0x003C-0x0040 | 61-65 | RESERVED | | | |
| **LOGGER** | | | | | |
| 0x0041 | 66 | Vb_min_daily | Minimum Battery Voltage (daily) | V | Float16 |
| 0x0042 | 67 | Vb_max_daily | Maximum Battery Voltage (daily) | V | Float16 |
| 0x0043 | 68 | Ahc_daily | Ah Charge (daily) | Ah | Float16 |
| 0x0044 | 69 | Ahl_daily | Ah Load (daily) | Ah | Float16 |
| 0x0045 | 70 | array_fault_daily | Array Fault Bitfield (daily) | - | |
| 0x0046 | 71 | load_fault_daily | Load Fault Bitfield (daily) | - | |
| 0x0047 | 72 | alarm_daily_HI | Alarm Bitfield (daily), HI word | - | |
| 0x0048 | 73 | alarm_daily_LO | Alarm Bitfield (daily), LO word | - | |
| 0x0049 | 74 | time_ab_daily | Time in Absorption (daily) | sec | 0 to ($2^{16}$-1) |
| 0x004A | 75 | time_eq_daily | Time in Equalization (daily) | sec | 0 to ($2^{16}$-1) |
| 0x004B | 76 | time_fl_daily | Time in Float (daily) | sec | 0 to ($2^{16}$-1) |
| 0x004C | 77 | Va_max_daily | Maximum Array Voltage (daily) | V | Float16 |
| **MISC 2** | | | | | |
| 0x004D | 78 | charge_led_state | Charge Status LED State | - | |
| 0x004E | 79 | lighting_should_be_on | In lighting mode, non-zero indicates load ON | - | |

# EEPROM

| PDU Addr | Logical Addr | Variable name | Variable description | Units | Scaling or Range |
|---|---|---|---|---|---|
| **CHARGE SETTINGS** | | | | | |
| 0xE000 | 57345 | EV_reg | Regulation Voltage @ 25ºC | V | Float16 |
| 0xE001 | 57346 | EV_float | Float Voltage @ 25ºC<br>(Set to zero to disable float) | V | Float16 |
| 0xE002 | 57347 | Et_float | Time Before Entering Float (Absorption Time) | sec | 0 to ($2^{16}$-1) |
| 0xE003 | 57348 | Et_floatlb | Time Before Entering Float due to Low Battery<br>(Absorption Extension Time) | sec | 0 to ($2^{16}$-1) |
| 0xE004 | 57349 | EV_floatlb_trip | Voltage Trigger for Low Battery Float Time | V | Float16 |
| 0xE005 | 57350 | EV_float_cancel | Voltage to Cancel Float | V | Float16 |
| 0xE006 | 57351 | Et_float_exit_cum | Exit Float Time | sec | 0 to ($2^{16}$-1) |
| 0xE007 | 57352 | EV_eq | Equalize Voltage @ 25ºC (Set to zero to disable equalize) | V | Float16 |
| 0xE008 | 57353 | Et_eqcalendar | Days Between EQ Cycles | days | 0 to 255 |
| 0xE009 | 57354 | Et_eq_above | Equalize Time Limit above EV_reg | sec | 0 to ($2^{16}$-1) |
| 0xE00A | 57355 | Et_eq_reg | Equalize Time Limit at EV_eq | sec | 0 to ($2^{16}$-1) |
| 0xE00B - 0xE00F | 57356 - 57360 | RESERVED | | | |
| 0xE010 | 57361 | Evb_ref_charge_lim | Reference Charge Voltage Limit | V | Float16 |
| 0xE011 - 0xE012 | 57362 - 57363 | RESERVED | | | |
| 0xE013 | 57364 | Eib_lim | Battery Charge Current Limit | A | Float16 |
| 0xE014 - 0xE019 | 57365 - 57370 | RESERVED | | | |
| 0xE01A | 57371 | EV_tempcomp | Temperature Compensation Coefficient | V | Float16 |
| 0xE01B | 57372 | EV_hvd | High Voltage Disconnect @ 25ºC<br>(Set to zero to disable HVD) | V | Float16 |
| 0xE01C | 57373 | EV_hvr | High Voltage Reconnect | V | Float16 |
| 0xE01D | 57374 | Evb_ref_lim | Maximum Charge Voltage Reference (0 disables) | V | Float16 |
| 0xE01E | 57375 | ETb_max | Max Battery Temp Compensation Limit | ºC | -128 to +127 |
| 0xE01F | 57376 | ETb_min | Min Battery Temp Compensation Limit | ºC | -128 to +127 |
| 0xE020 - 0xE021 | 57377 - 57378 | RESERVED | | | |
| **LOAD SETTINGS** | | | | | |
| 0xE022 | 57379 | EV_lvd | Low Voltage Disconnect | V | Float16 |
| 0xE023 | 57380 | EV_lvr | Low Voltage Reconnect | V | Float16 |
| 0xE024 | 57381 | EV_lhvd | Load High Voltage Disconnect<br>(Set to zero to disable HVD) | V | Float16 |
| 0xE025 | 57382 | EV_lhvr | Load High Voltage Reconnect | V | Float16 |
| 0xE026 | 57383 | ER_icomp | LVD Load Current Compensation | Ω | Float16 |
| 0xE027 | 57384 | Et_lvd_warn | LVD Warning Timeout | sec | 0 to ($2^{16}$-1) |
| 0xE028 - 0xE02F | 57385 - 57392 | RESERVED | | | |
| **MISC SETTINGS** | | | | | |
| 0xE030 | 57393 | EV_soc_g_gy | LED Green to Green&Yellow Limit | V | Float16 |
| 0xE031 | 57394 | EV_soc_gy_y | LED Green&Yellow to Yellow Limit | V | Float16 |
| 0xE032 | 57395 | EV_soc_y_yr | LED Yellow to Yellow&Red Limit | V | Float16 |
| 0xE033 | 57396 | EV_soc_yr_r | LED Yellow&Red to Red Flashing Limit | V | Float16 |
| 0xE034 | 57397 | Emodbus_id | Modbus ID | - | 1 to 247 |
| 0xE035 | 57398 | Emeter_id | Meterbus ID | - | 1 to 15 |
| **PWM SETTINGS** | | | | | |
| 0xE036- | 57399- | RESERVED | | | |

| | | | | | |
|---|---|---|---|---|---|
| 0xE037 | 57400 | | | | |
| 0xE038 | 57401 | Eic_lim | Charge Current Limit | A | Float16 |
| 0xE039 - 0xE03F | 57402 - 57408 | RESERVED | | | |
| **READ ONLY SECTION** | | | | | |
| 0xE040 | 57409 | Ehourmeter_LO | Hourmeter, LO Word | hours | 0 to ($2^{32}$-1) |
| 0xE041 | 57410 | Ehourmeter_HI | Hourmeter, HI Word | | |
| 0xE042 | 57411 | EAhl_r_LO | Ah Load Resettable, LO Word | Ah | n*0.1 |
| 0xE043 | 57412 | EAhl_r_HI | Ah Load Resettable, HI Word | - | |
| 0xE044 | 57413 | EAhl_t_LO | Ah Load Total, LO Word | Ah | n*0.1 |
| 0xE045 | 57414 | EAhl_t_HI | Ah Load Total, HI Word | - | |
| 0xE046 | 57415 | EAhc_r_LO | Ah Charge Resettable, LO Word | Ah | n*0.1 |
| 0xE047 | 57416 | EAhc_r_HI | Ah Charge Resettable, HI Word | - | |
| 0xE048 | 57417 | EAhc_t_LO | Ah Charge Total, LO Word | Ah | n*0.1 |
| 0xE049 | 57418 | EAhc_t_HI | Ah Charge Total, HI Word | - | |
| 0xE04A | 57419 | EkWhc_r | kWhc Resettable | kWh | n*0.1 |
| 0xE04B | 57420 | EkWhc_t | kWhc Total | kWh | n*0.1 |
| 0xE04C | 57421 | EVb_min | Battery Voltage Minimum | V | Float16 |
| 0xE04D | 57422 | EVb_max | Battery Voltage Maximum | V | Float16 |
| 0xE04E | 57423 | EVa_max | Array Voltage Maximum | V | Float16 |
| 0xE04F | 57424 | Etmr_eqcalander | Time Since Last Equalize | days | |

# Logged Data

The PS-PWM stores up to 256 days of data. This data is stored in a circular buffer where the oldest data is over-written by the newest data. The log data must be requested and sorted into correct order before the data will be useful.

- The logged data is mapped from 0x8000-0x8FFF
- The data consists of up to 256 blocks of data.
- Each block is 32bytes (16 modbus variables)
- It is written in a circular buffer format. All blocks must be read and then put in linear order via the hourmeter field. Ignore blocks w/ hourmeters of 0x000000 or 0xFFFFFF. The largest hourmeter block is the most recent.

| PDU Addr | Logical Addr | Variable name | Variable description |
|---|---|---|---|
| 0x8000-800F | 32769-32795 | logger[0] | |
| … | … | | |
| 0x8FF0-8FFF | 36848- 36863 | logger[255] | |

Data is stored in big endian format.

```
struct {
        Uint32 hourmeter;
        Uint32 alarm_daily;
        Uint32 load_fault_daily;
        Uint32 array_fault_daily;
        Float16 Vb_min_daily;
        Float16 Vb_max_daily;
        Float16 Ahc_daily;
        Float16 Ahl_daily;
        Float16 Va_max_daily;
        Uint16 time_ab_daily;
        Uint16 time_eq_daily;
        Uint16 time_fl_daily;
}
```

| Byte Offset | Variable name | Bytes | Variable description | Units | Scaling or Range |
|---|---|---|---|---|---|
| 0 | hourmeter | 4 | | hours | 0 to ($2^{32}$-1) |
| 4 | alarm_daily | 4 | Alarm Bitfield – daily | - | |
| 8 | load_fault_daily | 4 | Load Fault Bitfield – daily | - | |
| 12 | array_fault_daily | 4 | Array Fault Bitfield – daily | - | |
| 16 | Vb_min_daily | 2 | Battery Voltage Minimum – daily | V | Float16 |
| 18 | Vb_max_daily | 2 | Battery Voltage Maximum – daily | V | Float16 |
| 20 | Ahc_daily | 2 | Ah Charge – daily | Ah | Float16 |
| 22 | Ahl_daily | 2 | Ah Load – daily | Ah | Float16 |
| 24 | Va_max_daily | 2 | Maximum Array Voltage – daily | V | Float16 |
| 26 | time_ab_daily | 2 | Time in Absorption – daily | min | |
| 28 | time_eq_daily | 2 | Time in Equalize – daily | min | |
| 30 | time_fl_daily | 2 | Time in Float – daily | min | |

## *Read Coils (0x01), Read Discrete Inputs (0x02), Write Single Coil (0x05)*

| PDU Addr | Logical Addr | Variable description |
|---|---|---|
| 0x0000 | 1 | Equalize triggered |
| 0x0001 | 2 | Load disconnect (1 will force load into a disconnect state) |
| 0x0002 | 3 | Charge disconnect (1 will force charger into a disconnect state) |
| 0x0003 - 0x000F | 4 - 16 | RESERVED |
| 0x0010 | 17 | Clear Ah Resettable (set only, will always read 0) |
| 0x0011 | 18 | Clear Ah Total (set only, will always read 0) |
| 0x0012 | 19 | Clear kWh Resettable (set only, will always read 0) |
| 0x0013 | 20 | RESERVED |
| 0x0014 | 21 | Clear Faults |
| 0x0015 | 22 | Clear Alarms |
| 0x0016 | 23 | Force EEPROM Update (set only, will always read 0) |
| 0x0017 | 24 | RESERVED |
| 0x0018 | 25 | Clear kWh Total (set only, will always read 0) |
| 0x0019 | 26 | Clear Vb (Battery Voltage) Min/Max |
| 0x0020 | 27 | Lighting Mode Test - when lighting mode is enabled, turns on load output for 10 minutes (set only, will always read 0). |
| 0x0021 - 0x00FD | 28 - 254 | RESERVED |
| 0x00FE | 255 | Factory Reset - revert settings to factory defaults (display settings are not reset) |
| 0x00FF | 256 | Reset Control |

## *Write Single Register (0x06)*

Any write to EEPROM will set an "EEPROM changed" fault. The control must be reset to clear this fault.
***Note:*** *No verify is performed on the write.*

See EEPROM table in Read Input Registers(0x04).

## *Read Device Identification (0x2B, subcode 0x0E)*

Only supports "basic device identification (stream access)" (ID code 0x01)

| Object Id | Object Name/Description | Typical Value |
|---|---|---|
| 0x00 | VendorName | "Morningstar Corp." |
| 0x01 | Product Code | "PS-PWM-15"<br>"PS-PWM-15M"<br>"PS-PWM-30"<br>"PS-PWM-30M" |
| 0x02 | MajorMinorRevision<br>(hardware major.minor. software revision) | "v01.01.01" |

# Variables and Definitions

### Variable_name
[Logical Address][PDU Address] (Units). *Short description*.
Definition.

## *Read Holding and Read Input Registers*
Located in processor RAM, updated continuously.

### ver_sw
[1][0x0000] (-). *Software version.*
Firmware version for the controller. The value is stored in binary coded decimal (BCD) format. Decimal version 12 is thus stored as 0x0012 not as 0x000c.

### n_sys_v
[2][0x0001] (-). *Battery Voltage Settings Multiplier.*
Multiplication factor for charging and load voltage settings. Voltage settings are stored as 12V nominal in the controller. A value of 1 indicates these settings are used unmodified. A value of 2 indicates these settings are multiplied by 2 for use in a 24V nominal battery system.

## *RAW ADC*

### vdd_actual
[05][0x0004] (V). *Internal 3.3V Supply Voltage.*
Voltage of the internal 3.3V power supply.

### adc_fgdrive
[06][0x0007] (V). *Internal Gate Drive Voltage.*
Voltage of the internal MOSFET gate drive.

### adc_vmeter
[07][0x0008] (A). *Internal MeterBus Supply Voltage.*
Voltage of the MeterBus supply.

### adc_vrefint
[07][0x0008] (A). *Internal voltage Reference*
Voltage of the internal voltage reference.

### adc_FN3
[07][0x0008] (A). *Negative supply rail for current measurement*
Voltage on the Negative supply rail for current measurement.

### adc_gload

[07][0x0008] (A). *Load FET gate drive*
Voltage on the Load FET gate drive

### adc_gatepv

[07][0x0008] (A). *Array FET gate drive*
Voltage on the Array FET gate drive

## *FILTERED ADC*

### adc_ia

[18][0x0011] (A). *Array Current.*
Current into the array terminal connections of the ProStar PWM.

### adc_vbterm

[19][0x0012] (V). *Battery Terminal Voltage.*
Voltage measured at the battery terminal connections of the ProStar PWM.

### adc_va

[20][0x0013] (V). *Array Voltage.*
Input voltage measured at the array terminal connections of the ProStar PWM.

### adc_vl

[21][0x0014] (V). *Load Voltage.*
Output voltage measured at the load terminal connections of the ProStar PWM.

### adc_il

[23][0x0016] (A). *Load Current.*
Current out of the load terminal connections of the ProStar PWM.

### adc_vbsense

[24][0x0017] (V). *Battery Sense Voltage.*
Voltage measured at the battery sense connections of the ProStar PWM.

### adc_vb_f_1m

[25][0x0018] (V). *Battery Voltage, slow filter.*
Slow filtered value of the battery voltage. 60 second filtering time.

### adc_ib_f_1m

[26][0x0019] (A). *Battery Current (net), slow filter.*
Slow filtered value of the net battery current into / out of the battery terminal connections of the ProStar PWM. 60 second filtering time.

# *TEMPERATURES*

## T_hs

[27][0x001A] (C). *Heatsink Temperature.*
ProsStar PWM Heatsink temperature. Reported in degrees C.

## T_batt

[28][0x001B] (C). *Battery Temperature.*
Battery temperature measured by the ambient temperature sensor or the optional RTS (if connected). Reported in degrees C.

## T_amb

[29][0x001C] (C). *Ambient (local) Temperature.*
Ambient temperature measured by the local ambient temperature sensor. Reported in degrees C.

## T_rts

[30][0x001D] (C). *RTS Temperature.*
Temperature measured by the optional Remote Temperature Sensor(RTS). Reported in degrees C.

# *CHARGER STATUS*

## charge_state

[34][0x0021] (-). *Charge State.*
Reports the present charge state.

| Value | Charge State |
|---|---|
| 0 | START |
| 1 | NIGHT_CHECK |
| 2 | DISCONNECT |
| 3 | NIGHT |
| 4 | FAULT |
| 5 | BULK |
| 6 | ABSORPTION |
| 7 | FLOAT |
| 8 | EQUALIZE |

## array_fault

[35][0x0022] (bit-field). *Solar Input Self-Diagnostic Faults.*
Reports faults identified by self diagnostics. Each bit corresponds to a specific fault.

| Array Faults Table | |
|---|---|
| **BIT** | **FAULT** |
| 0 | Overcurrent Phase 1 |
| 1 | FET(s) Shorted |
| 2 | Software Bug |
| 3 | Battery HVD (High Voltage Disconnect) |
| 4 | Array HVD (High Voltage Disconnect) |
| 5 | EEPROM Setting Edit (reset required) |
| 6 | RTS Shorted |
| 7 | RTS was valid, now disconnected |
| 8 | Local temp. sensor failed |
| 9 | Battery LVD (Low Voltage Disconnect) |
| 10 | DIP Switch Changed (excl. DIP 8) |
| 11 | Processor Supply Fault |

## vb_f

[36][0x0023] (V). *Battery Voltage, slow filter.*
Slow filtered value of the battery voltage. 25 second filtering time.

## vb_ref

[37][0x0024] (V). *Battery Regulator Reference Voltage.*
Present target battery voltage. The controller is attempting to charge the batteries to this voltage.

## Ahc_r (HI / LO)

[39-40][0x0026-0x0027] (Ah). *Amp-Hours Charge Resettable.*
Resettable counter which reports charging amp-hours. Reset of this counter is achived with a Coil Command (see Coil information section above).

## Ahc_t (HI / LO)

[41-42][0x0028-0x0029] (Ah). *Amp-Hours Charge Total.*
Counter which reports charging amp-hours. This counter can also be reset using a Coil Command (see Coil information section above).

## kWhc_r

[43][0x002A] (kWh). *kiloWatt-Hours Charge Resettable.*
Resettable counter which reports charging kilowatt-hours. Reset of this counter is achived with a Coil Command (see Coil information section above).

## kWhc_t

[44][0x002B] (kWh). *kiloWatt-Hours Charge Total.*
Counter which reports total charging kilowatt-hours. This counter can also be reset using a Coil Command (see Coil information section above).

### Tb_lo_limit_100

[45][0x002C] (C). *Battery Temp Foldback 100% Output Limit.*
Upper limit for low temperature charging foldback. At this temperature, 100% charging output is provided to the batteries.

### Tb_lo_limit_0

[46][0x002D] (C). *Battery Temp Foldback 0% Output Limit.*
Lower limit for low temperature charging foldback. At this temperature, 0% charging output is provided to the batteries.

## *LOAD STATUS*

### load_state

[47][0x002E] (-). *Load State.*
Reports the present load output state.

| Value | Load State |
|---|---|
| 0 | START |
| 1 | LOAD_ON |
| 2 | LVD_WARNING |
| 3 | LVD |
| 4 | FAULT |
| 5 | DISCONNECT |
| 6 | LOAD_OFF |
| 7 | OVERRIDE |

### load_fault

[48][0x002F] (bit-field). *Load Output Self-Diagnostic Faults.*
Reports faults identified by self diagnostics. Each bit corresponds to a specific fault.

| Load Faults Table | |
|---|---|
| **BIT** | **FAULT** |
| 0 | External Short Circuit |
| 1 | Overcurrent |
| 2 | FET(s) Shorted |
| 3 | Software Bug |
| 4 | High Voltage Disconnect |
| 5 | Heatsink Over-Temperature |
| 6 | DIP Switch Changed (excl. DIP 8) |
| 7 | EEPROM Setting Edit (reset required) |
| 8 | FP10 Fault |
| 9 | Processor Supply Fault |

### V_lvd

[49][0x0030] (V). *Load LVD Voltage.*
Low voltage disconnect setpoint, current compensated.

### V_lvd

[50][0x0031] (V). *Load HVD Voltage.*
High voltage disconnect setpoint.

### Ahl_r_HI / Ahl_r_LO

[51, 52][0x0032, 0x0033] (Ah). *Load Amp-Hours Resettable.*
Resettable counter which reports load amp-hours. Reset of this counter is achived with a Coil Command (see Coil information section above).

### Ahl_t_HI / Ahl_t_LO

[53, 54][0x0034, 0x0035] (Ah). *Load Amp-Hours Total.*
Counter which reports load amp-hours. This counter can also be reset using a Coil Command (see Coil information section above).

## *MISCELLANEOUS*

### hourmeter (HI / LO)

[55,56][0x0036, 0x0037] (hrs). *Hourmeter.*
Reports total hours of operation since installed.

### Alarm (HI / LO)

[57, 58][0x0038, 0x0039] (bitfield).*Controller Self-Diagnostics Alarms.*
Reports alarms identified by self diagnostics. Each bit corresponds to a specific alarm.

| Alarms Table | |
|---|---|
| **BIT** | **ALARM** |
| 0 | RTS Open |
| 1 | RTS Shorted |
| 2 | RTS Disconnected |
| 3 | Ths (heatsink temp sensor) Open |
| 4 | Ths (heatsink temp sensor) Shorted |
| 5 | Heatsink Hot (active temp limiting) |
| 6 | Current Limit |
| 7 | I Offset |
| 8 | Battery Sense Out of Range |
| 9 | Battery Sense Disconnected |
| 10 | Uncalibrated |
| 11 | Battery Temp out of range |
| 12 | FP10 Supply Out of Range |

| | |
|---|---|
| 13 | FET Open |
| 14 | IA Offset |
| 15 | IL Offset |
| 16 | 3V Supply Out of Range |
| 17 | Reserved |
| 18 | |
| 19 | Reset |
| 20 | LVD |
| 21 | Log Timeout |
| 22 | EEPROM Access Failure |

## dip_switch

[59][0x003A] (bit-field). *DIP Switch Settings.*
Each bit in the bit-field corresponds to an individual DIP switch setting. Useful for remote applications where access to ProStar PWM to verify DIP positions is not feasible. Bit 0 (LSB) corresponds to settings switch 1. (Only valid for DIP settings at controller power-up)

## LED_state

[60][0x003B] ( ).
Reports the State-of-Charge LED state.

| Value | LED State |
|---|---|
| 0 | LED_START |
| 1 | LED_START2 |
| 2 | LED_BRANCH |
| 3 | EQUALIZE (FAST GREEN BLINK) |
| 4 | FLOAT (SLOW GREEN BLINK) |
| 5 | ABSORPTION (GREEN BLINK, 1HZ) |
| 6 | GREEN LED |
| 7 | GREEN / YELLOW LED |
| 8 | YELLOW LED |
| 9 | YELLOW / RED LED |
| 10 | BLINK RED LED |
| 11 | RED LED |
| 12 | R-Y-G ERROR |
| 13 | R/Y-G ERROR |
| 14 | R/G-Y ERROR |
| 15 | R-Y ERROR |
| 16 | R-G ERROR |
| 17 | R/Y-G/Y ERROR |
| 18 | G/Y/R ERROR |
| 19 | G/Y/R x2 |
| 20 | OFF |
| 21 | G/Y/R x2 – GREEN x2 |
| 22 | G/Y/R x2 – RED x2 |

# *LOGGER*

## Vb_min_daily

[66][0x0041] (V). *Today's minimum battery voltage.*
Minimum battery voltage measured today (value resets after dark).

## Vb_max_daily

[67][0x0042] (V). *Today's maximum battery voltage.*
Maximum battery voltage measured today (value resets after dark).

## Ahc _daily

[68][0x0043] (Ah). *Today's total charge amp-hours.*
Total charging amp-hours accumulated today (value resets after dark).

## Ahl _daily

[69][0x0044] (Ah). *Today's total load amp-hours.*
Total load amp-hours accumulated today (value resets after dark).

## Array_fault_daily

[70][0x0045] (bit-field). *Today's solar input self-diagnostic faults (sticky).*
Reports array faults identified by self diagnostics that occurred today. Each bit corresponds to a specific fault. If a bit is set, that fault occurred at least once today. Bit order is identical to the **Array_fault** bitfield.

## Load_fault_daily

[71][0x0046] (bit-field). *Today's load output self-diagnostic faults (sticky).*
Reports load faults identified by self diagnostics that occurred today. Each bit corresponds to a specific fault. If a bit is set, that fault occurred at least once today. Bit order is identical to the **Load_fault** bitfield.

## alarm_daily (HI / LO)

[72, 73][0x0047, 0x0048] (bitfield). *Today's controller self-diagnostics alarms (sticky).*
Reports alarms identified by self diagnostics that occurred today. Each bit corresponds to a specific alarm. If a bit is set, that alarm occurred at least once today. Bit order is identical to the **alarm_hi/alarm_lo** bitfield.

## time_ab_daily

[74][0x0049] (s). *Cumulative time in Absorption today.*
Reports the cumulative number of seconds the battery has been in the Absorption charge stage today. Counter resets at night.

### time_eq_daily

[75][0x004A] (s). *Cumulative time in Equalization today.*
Reports the cumulative number of seconds the battery has been in the Equalization charge stage today. Counter resets at night.

### time_fl_daily

[76][0x004B] (s). *Cumulative time in Float today.*
Reports the cumulative number of seconds the battery has been in the Float charge stage today. Counter resets at night.

### Va_max_daily

[77][0x004C] (V). *Array Voltage max today.*
Reports the maximum array voltage seen today. Value resets after dark.

## *MISCELLANEOUS 2*

### LED_state

[78][0x004D] ( ).
Reports the Status LED state.

| Value | LED State |
|---|---|
| 0 | LED_START |
| 1 | LED_START2 |
| 2 | LED_BRANCH |
| 3 | EQUALIZE (FAST GREEN BLINK) |
| 4 | FLOAT (SLOW GREEN BLINK) |
| 5 | ABSORPTION (GREEN BLINK, 1HZ) |
| 6 | GREEN LED |
| 7 | GREEN / YELLOW LED |
| 8 | YELLOW LED |

### lighting_should_be_on

[79][0x004E] ( ). *Lighting (load) on/off indication*
A non-zero value here indicates that the load output should be ON. A zero value indicates the load output should be OFF.

# *CHARGING SETTINGS*

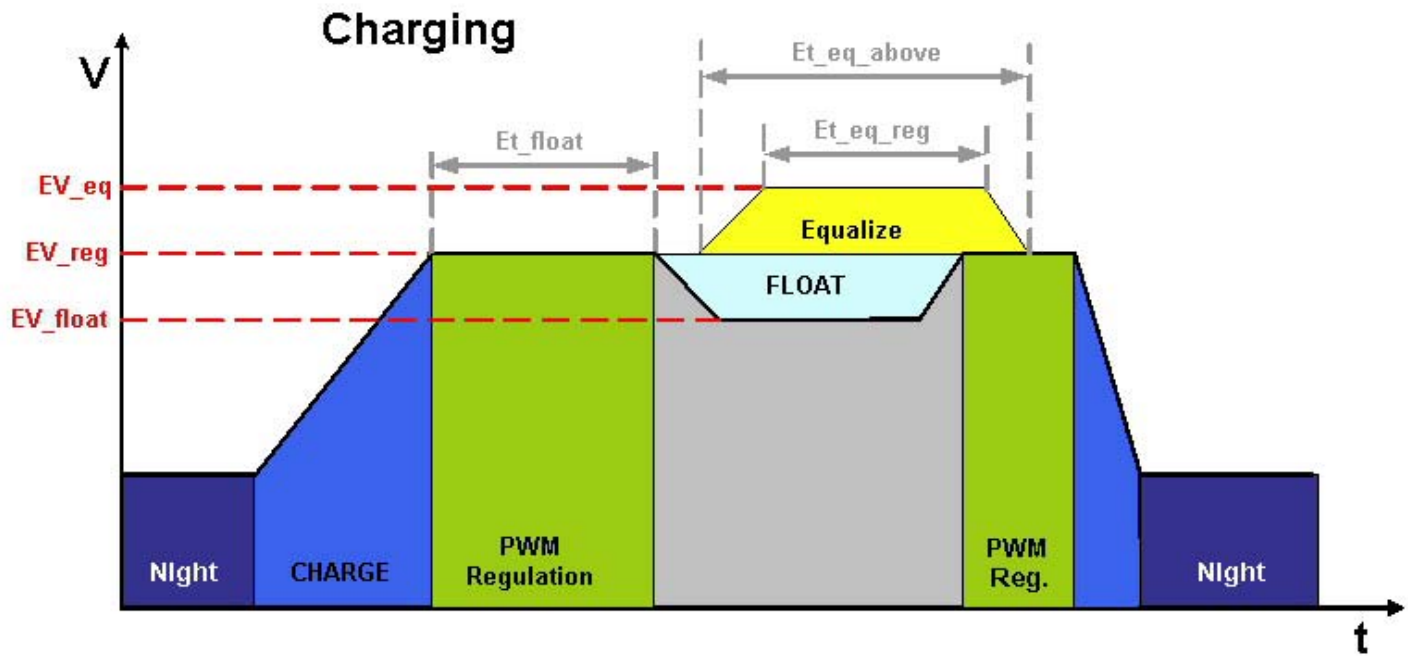


Diagram A Charging stages and defining variables.

## EV_reg

[57345][0xE000] (V). *Regulation voltage (absorption), @ 25ºC.*
The battery will charge at 100% charge current until battery voltage reaches this setpoint. The controller will begin to taper input current so that this setpoint is maintained, but not exceeded. See diagram A.

## EV_float

1. [57346][0xE001] (V). *Float voltage, @ 25ºC*

After Et_float seconds in absorption, when the battery is fully charged, the battery will transition to this lower voltage charge setting to reduce gassing. See diagram A.
Set to zero to disable float stage

## Et_float

[57347][0xE002] (s) *Time before entering float.*
Defines the length of time in absorption before transitioning to the float stage. See diagram A.

## Et_floatlb

[57348][0xE003] (s) *Time before entering float due to low battery.*
If the battery voltage drops too low during the previous night, this value allows the user to specify a longer period of time before entering float stage.

## EV_floatlb_trip

[57349][0xE004] (V). *Voltage that triggers low battery float time.*
Battery voltage that will trigger a longer period of time before entering float. - See Et_floatlb -

## EV_float_cancel

[57350][0xE005] (V). *Voltage that cancels float.*
Specify the battery voltage that will cancel float for the next charge cycle. If the battery discharged too low the previous night, the user may want to cancel float for the next day.

## Et_float_exit_cum

[57351][0xE006] (V). *Exit float timer.*
Specify (cumulative) amount of time below float voltage before exiting the float stage. Battery voltage may drop below the target float voltage due to insufficient charge current or a system load draws more current from the battery than the array can provide.

## EV_eq

[57352][0xE007] (V). *Equalize voltage, @ 25ºC.*
Battery equalize voltage. Periodic equalization equalizes cell voltages, bubbles the electrolyte, and helps prevent sulfation of the battery. See diagram A.
Set to zero to disable equalization

## Et_eqcalendar

[57353][0xE008] (days). *Days between equalize cycles.*
Specify the number of days between equalizations. Equalizing on a calendar basis ensures proper maintenance of batteries.

## Et_eq_above

[57354][0xE009] (s) *Equalize time limit above Vreg.*
Equalization will timeout after the specified number of seconds above PWM regulation voltage. If the battery is charged above absorption voltage but has not yet reached the equalization setting, this value serves as a safety timeout to prevent partial equalizations for extended periods of time. See diagram A.

## Et_eq_reg

[57355][0xE00A] (s) *Equalize time limit at Veq.*
Equalization will stop after the specified number of seconds at the equalization setpoint voltage. See diagram A.

## EVb_ref_charge_lim

[57361][0xE010] (V). *Reference charge limit.*
Battery charge voltage limit.

## Eib_lim

[57364][0xE013] (V). *Battery current.*
Charger battery current limit

## EV_tempcomp

[57371][0xE01A] (V/ºC). *Temperature compensation.*
Battery chemistry changes with temperature. Temperature compensation coefficient specifies the amount that regulation voltage will be shifted with temperature. 25ºC reference, the negative is implied (write a positive value). 12V lead-acid battery temperature compensation is approximately 0.03 V/C

## EV_hvd

[57372][0xE01B] (V). *High Voltage Disconnect, @ 25ºC.*
Flag a fault/alarm if the battery voltage exceeds this setpoint. Also attempts to open the MOSFETs to stop charging. Set to zero to disable HVD

## EV_hvr

[57373][0xE01C] (V). *High Voltage Reconnect.*
The HVD fault/alarm will be cleared once the battery voltage drops below this setpoint.

## Evb_ref_lim

[57374][0xE01D] (V). *Maximum regulation limit*
An absolute limit on the battery regulation voltage. This is not a temperature compensated value. Protects high voltage sensitive system loads. Set to zero to disable.

## ETb_max

[57375][0xE01E] (C). *Maximum temperature compensation limit.*
Maximum temperature to clamp temperature compensation.

## ETb_min

[57376][0xE01F] (C). *Minimum temperature compensation limit.*
Maximum temperature to clamp temperature compensation.

## ETb_lo_limit_100

[57377][0xE020] (C). *Battery current limit upper temperature.*
Battery temperature limit for 100% charging output to batteries. Battery temperatures above this value will allow for up to 100% charging current. Linear charging current taper from ETb_lo_limit_100 to Etb_lo_limit_0. ETb_lo_limit_100 must be greater that ETb_lo_limit_0 to operate.

## ETb_lo_limit_0

[57378][0xE021] (C). *Battery current limit low temperature.*
Battery temperature limit for 0% charging output to batteries. Battery temperatures below this value will provide 0% charging current. Linear charging current taper from ETb_lo_limit_100 to ETb_lo_limit_0. ETb_lo_limit_100 must be greater that ETb_lo_limit_0 to operate.

# *LOAD SETTINGS*

### EV_lvd

[57379][0xE022] (V). *Low Voltage Disconnect.*
Setpoint to determine the load turn off voltage. When the battery has discharged too far, the load should be turned off to prevent over-discharge of the battery.

### EV_lvr

[57380][0xE023] (V). *Low Voltage Reconnect.*
Battery setpoint that determines when the load will be reconnected. After the battery recharges to this setpoint, the load will be reconnected.

### EV_lhvd

[57381][0xE024] (V). *Load High Voltage Disconnect.*
Disconnect the loads if the battery voltage rises too high. This function can protect DC loads that are sensitive to high input voltage. Set to zero to disable HVD

### EV_lhvr

[57382][0xE025] (V). *Load High Voltage Reconnect.*
Setpoint at which the loads will reconnect after a high voltage condition.

### ER_icomp

[57383][0xE026] (V/A). *LVD Load current compensation.*
The LVD setpoint can be compensated in proportion to load current, lowering the disconnect value when the battery is under load. Note that the LED setpoints are also compensated accordingly.

### Et_lvd_warn

[57384][0xE027] (s). *LVD warning timeout.*
Defines the period of time to wait before disconnecting the loads, once battery voltage has dropped to the Low Voltage Disconnect setpoint.

# *MISCELLANEOUS SETTINGS*

### EV_soc_g_gy

[57393][0xE030] (V). *LED green to green/yellow limit.*
LED transition setpoint. Specifies the battery voltage at which the LED state will change from Green to Green/Yellow.

### EV_soc_gy_y

[57394][0xE031] (V). *LED green/yellow to yellow limit.*
LED transition setpoint. Specifies the battery threshold voltage at which the LEDs will change from Green/Yellow to Yellow indication.

### EV_soc_y_yr

[57395][0xE032] (V). *LED yellow to yellow/red limit.*
LED transition setpoint. Specifies the battery threshold voltage at which the LEDs will change from Yellow to Yellow/Red indication.

### EV_soc_y2r0

[57396][0xE033] (V). *LED yellow/red to blinking red limit.*
LED transition setpoint. Specifies the battery threshold voltage at which the LEDs will change from Yellow/Red to Blinking Red indication.

### Emodbus _id

[57397][0xE034] ( ). *MODBUS ID.*
MODBUS address which uniquely identifies the controller on the MODBUS network.

### Emeter _id

[57398][0xE035] ( ). *MeterBus ID.*
Address which uniquely identifies the controller on the Morningstar proprietary Meter Bus network. Devices are daisy-chained on the Meter Bus network via the RJ-11 connections. Addresses are limited to the range of 1-15
**Warning: do not change this value unless necessary.**

## *PWM SETTINGS*

### Eic _lim

[57401][0xE038] (A). *Charge current limit.*
Specify a battery charging current limit. 0-15A for 15A models, 0-30A for 30A models.

## *READ ONLY VARIABLES*

### Ehourmeter (LO / HI)

[57409,57410][0xE040,0xE041] (hours). *Hourmeter.*
Cumulative hours the controller has been running. Non-volatile, written every 24hrs.

### EAhl_r (LO / HI)

[57411,57412][0xE042,0xE043] (amp-hours). *Load resettable Ah.*
Cumulative amp-hours typically used for short-term logging. Resettable.

### EAhl_t (LO / HI)

[57413,57414][0xE044,0xE045] (amp-hours). *Load total Ah.*
Cumulative amp-hours for long term logging. Can be reset if needed.

### Eahc_r (LO / HI)

[57415,57416][0xE046,0xE047] (amp-hours). *Load resettable Ah.*
Cumulative amp-hours typically used for short-term logging. Resettable.

### Eahc_t (LO / HI)

[57417,57418][0xE048,0xE049] (amp-hours). *Load total Ah.*
Cumulative amp-hours for long term logging. Can be reset if needed.

### EkWhc_r

[57419][0xE04A] (kWh). *Charge Kilowatt hours resettable.*
Cumulative charging kilowatt hours typically used for short-term logging. Resettable.

### EkWhc_t

[57420][0xE04B] (kWh). *Charge Kilowatt hours total.*
Cumulative charging kilowatt hours for long term logging. Can be reset if needed.

### EVb_min

[57421][0xE04C] (V). *Minimum battery voltage.*
Minimum battery voltage over last 24 hours. Written once every 24hrs.

### EVb_max

[57422][0xE04D] (V). *Maximum battery voltage*
Maximum battery voltage over last 24 hours. Written once every 24hrs.

### EVa_max

[57423][0xE04E] (V). *Maximum array voltage.*
Maximum array voltage over last 24 hours. Written once every 24hrs.

### Etmr_eqcalendar

[57424][0xE04F] (V). *Equalize calendar timer.*
Number of days since last equalize.

## *COILS*

### Equalize Triggered

[01] [0x0000]
Trigger an equalize charge. Controller must be configured to a battery type that has equalization stage and the equalize DIP switch must not be set to “disabled”. After the equalize charge has been administered, the equalize calendar will be reset.

## Load Disconnect

[02] [0x0001]
Forces load controller into disconnect state. Load will remain off until this coil is cleared.
Values:
0 = normal operation
0xFF00= load disconnect

## Charge Disconnect

[03] [0x0002]
Forces charge controller into disconnect state. Charging will cease until this coil is cleared.
Values:
0 = normal charging
1= charging stopped

## Clear Ah Resettable

[17] [0x0010]
Resets solar and load Ah (resettable) counters back to 0.
(set only, will always read 0)

## Clear Ah Total

[18] [0x0011]
Resets solar and load Ah (total) counters back to 0.
(set only, will always read 0)

## Clear kWh Resettable

[19] [0x0012]
Resets kilowatt hours charge (resettable) counter back to 0.
(set only, will always read 0)

## Clear Faults

[21] [0x0014]
Clears active faults
(set only, will always read 0)

## Clear Alarms

[22] [0x0015]
Clears active alarms
(set only, will always read 0)

## Force EEPROM update

[23] [0x0016]
Force the controller to update EEPROM with RAM values.
(set only, will always read 0)

## Clear kWh Total

[25] [0x0018]
Resets total solar kilowatt-hour counter back to 0.
(set only, will always read 0)

## Clear VB Min/Max

[26] [0x0019]
Resets battery voltage minimum and maximum.

## Lighting Test

[27] [0x0020]
If lighting is enabled, turns on lighting output for 10 minutes.
(set only, will always read 0)

## Factory Reset

[255][0x00FE]

Reverts controller back to Factory Default settings.

## Reset control

[256] [0x00FF]
Reset control will force a reboot of the processor software.

# Examples

## *Read Holding Register, 2 Word values*

**Variable (RAM):** hours (hourmeter)
**LO Register Address:** 0x0037
**HI Register Address:** 0x0036
**Scaling for this variable:** none

```
1. read LO Register value(hex):     0x13D8
2. read HI Register value(hex):     0x0022
3. combine register values(hex):    0x002213D8
4. Convert to decimal:              2,233,304 hours
```

# C Float32 Conversion to Float16 example

```
// Convert a float32 (IEEE754 Single precision binary32) to float16 (IEEE754 half precision binary16)
#include <stdint.h>
#include <math.h>

uint16_t F32ConvertToF16(float f32) {
	uint16_t f16 = 0;
	uint32_t f32_u = *(uint32_t*)&f32;
	unsigned sign		=	(f32_u & 0x80000000) >> 31;
	unsigned exponent	=	(f32_u & 0x7f800000) >> 23;
	unsigned fraction	=	(f32_u & 0x007fffff) >> 13;
	//check for inf and NaN
	if (exponent == 0xFF) {
		if (fraction == 0) { //inf detected
			f16 = (sign == 1) ? 0xfc00 : 0x7c00;
		} else { // NaN detected
			f16 = 0x7c01;// output a NaN
		}
	} else {
		//verify the number if within range
		if (((int)exponent - 127) >= 15) {
			//overflow, if exponent values are too high, we should return an inf
			f16 =  (sign == 1) ? 0xfc00 : 0x7c00; // negative and positive infinity, respectively
		} else if (((int)exponent - 127) <= -14) {
			//underflow
		} else {
			// normal numbers
			f16 =  (sign << 15) + ((unsigned)((int)exponent - 127) << 10) + (fraction);
		}
	}
	return f16;
}
```

# C Float16 Conversion to Float32 example

```
// Convert a float16 (IEEE754 half-precision binary16) to float32 (IEEE754 Single precision binary32)
#include <stdint.h>
#include <math.h>

float F16ConvertToF32(uint16_t f16) {
	float f32 = 0;

	unsigned sign = (f16 & 0x8000) >> 15;		//extract out the sign
	unsigned exponent = ((f16 & 0x7C00) >> 10);	//extract out the exponent
	float fraction = (f16 & 0x03ff) / 1024.0;	//extract out the fraction

	//check for inf & NaN, 0x7F800000 = +inf  0xFF800000 = -inf
	if (exponent == 0x1f) {
		if (fraction == 0) {
			int positveInf = 0x7f800000;
			int negativeInf = 0xff800000;
			return (sign == 0) ? *(float*)&positveInf : *(float*)&negativeInf;
		}
		else {
			return 0.0 / 0.0; //use 0.0 to generate NaN
		}
	}
	//check for 0 or subnormal
	if (exponent == 0 ) {
		if (fraction == 0 ) { // if it is 0
			if(sign == 1 )
				return -0.0;
			return 0.0; // use 0.0 to return a zero in float
		}
		else {
			f32 = fraction * pow(2.0, -14.0);
			if (sign == 1)
				f32 *= -1.0;
			return f32;
		}
	}
	//the number is not a NaN or 0 or subnormal
	f32 = (fraction + 1.0) * pow(2.0, ((int)exponent - 15));
	if (sign == 1)
		f32 *= -1.0;

	return f32;

}
```

# JavaScript Float16 conversion example

```
/*
Converts an integer read by modbus to float16 (IEEE754 half-precision binary16)
Modbus result is likely sign extended but we will ignore that
*/
function ScaleF16(passedVal)
{
	var s = 0;	// sign
	var e = 0;	// exponent
	var currentVal = 0;	// mantissa/result

	currentVal = (passedVal & 0x03ff) / 1024.0;// 10 bit mantissa (normalized)
	passedVal >>= 10;
	e = (passedVal & 0x001f);	// 5 bit exponent (stored w/ 15 offset)
	passedVal >>= 5;
	s = passedVal & 0x0001;		// 1 bit sign

	if (e == 0) {	// zero or subnormal
		if (currentVal == 0) return(0);		// zero

		// else subnormal (no leading 1.xxx)
		currentVal *= Math.pow(2.0,-14);
		if (s != 0) currentVal *= -1.0;
		return (currentVal);
	}

	if (e == 0x1f) {		// infinity or NaN
		if (currentVal == 0) {
			if (s==0) return(Number.POSITIVE_INFINITY);	// +infinity
			else return (Number.NEGATIVE_INFINITY);		// -infinity
		} else return(Number.NaN);	// NaN
	}

	currentVal += 1.0;	// add in leading 1
	currentVal *= Math.pow(2.0,e-15);
	if (s != 0) currentVal *= -1.0;

	return (currentVal);
}
```

# References


- Visit http://www.modbus-ida.org/ for full protocol documentation, news, and technical resources
- MODBUS® Protocol Reference Guide, Modicon, June 1996, PI-MODBUS-300 Rev.J
- MODBUS® Application Protocol Specification, modbus.org, 8May02,
- Modbus_application_protocol_v1


# Document Revision History

**v01: First Release**