ELKOR

WattsOn

MARK II

PRECISION ENERGY METER

METER USER MANUAL

Installation Considerations

Installation and maintenance of the WattsOn device must only be performed by qualified, competent personnel who have appropriate training and experience with electrical high voltage and current installations. The WattsOn device must be installed in accordance with all Local and National Electrical Safety Codes.

WARNING

Failure to observe the following may result in severe injury or death:

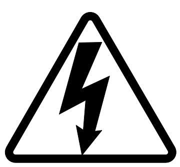
- During normal operation of this device, hazardous voltages are present on the input terminals of the device and throughout the connected power lines, including any potential transformers (PTs). With their primary circuit energized, current transformers (CTs) may generate high voltage when their secondary windings are open. Follow standard safety precautions while performing any installation or service work (i.e. remove line fuses, short CT secondaries, etc).

- This device is not intended for protection applications.

- Do not HIPOT and/or dielectric test any of the digital outputs. Refer to this manual for the maximum voltage level the meter can withstand.

- Do not exceed rated input signals as it may permanently damage the device.

- The power supply input should be connected via a rated 12-35 VDC / 24VAC power supply and properly isolated from the line voltage.



Danger

Line voltages up to 600 VRMS may be present on the input terminals of the device and throughout the connected line circuits during normal operation. These voltages may cause severe injury or death. **Installation and servicing must be performed only by qualified, properly trained personnel.**

Limitation of Liability

Elkor Technologies Inc. ("Elkor") reserves the right to make changes to its products and/or their specifications without notice. Elkor strongly recommends obtaining the latest version of the device specifications to assure the most current information is available to the customer. Specifications and manual are available at http://www.elkor.net

Elkor assumes no liability for applications assistance, customer's system design, or infringement of patents or copyrights of third parties by/or arising from the use of Elkor's devices.

ELKOR TECHNOLOGIES INC. SHALL NOT BE LIABLE FOR CONSEQUENTIAL DAMAGES SUSTAINED IN CONNECTION WITH ELKOR PRODUCTS, EXCEPT TO THE EXTENT PROHIBITED BY APPLICABLE LAW. FURTHERMORE, ELKOR NEITHER ALLOWS NOR AUTHORIZES ANY OTHER PERSON TO ASSUME FOR IT ANY SUCH OBLIGATION OR LIABILITY.

Although the information contained in this document is believed to be accurate, Elkor assumes no responsibility for any errors which may exist in this publication.

TABLE OF CONTENTS

1. INTRODUCTION

1.1. Electrical Wiring

Because of possible electrical shock or fire hazards, connection of this equipment should only be made by qualified personnel in compliance with the applicable electrical codes and standards.

1.2. Disclosure

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1.3. Revision History

Version	Date	Changes
Revision 1	October 2014	Original Version
Revision 2	December 2014	Clarified reserved registers in tables from section 5.4.1 through to 5.5.4. Corrected default threshold voltage in section 2.1 from 5V to 20V. Corrected frequency channel selection in section 5.6.15 to state that changes occur on voltages below 5V
Revision 3	February 2015	Corrected description of Report Slave ID in Appendix B to include the byte count
Revision 4	September 2015	Added Total Capacitive/Reactive Energy (FW > v10.52)

1.4. Warranty

The WattsOn-Mark II is warranted against defective material and workmanship. During the warranty period Elkor will repair or replace, at its option, all defective equipment that is returned freight prepaid. There will be no charge for repair provided there is no evidence that the equipment has been mishandled or abused. If the equipment is found to be in proper working order, a service fee will be billed to the customer. Warranty claims must be made via the original purchaser.

Standard Warranty duration is one (1) year from date of sale. Extended warranties are available to OEMs.

1.5. Product Description

The WattsOn-Mark II Precision Energy Meter utilizes advanced metering technology to implement a multi-functional power and energy meter into a small, cost-effective package. WattsOn-Mark II incorporates three meters into one to provide a unique solution for monitoring up to single phase, split phase and three phase loads.

The meter provides comprehensive per phase data, as well as cumulative data, including Volts, Amps, Real Power, Reactive Power, Apparent Power, Voltage Angle, Power Factor and Frequency, Quadrant, Import/Export/Net Wh/VAh and per Quadrant VARh.

WattsOn-Mark II features full four-quadrant metering, and all parameters are metered and accumulated on a per-phase basis. Additionally, the meter may be configured with per-phase CT ratios allowing for metering asymmetrical loads such as individual building branch circuits. Therefore, it is possible to use different CT sizes and ratios on each input.

The unit accepts up to 600V (line-to-line) directly without needing potential transformers. It may be configured for use with 333mV output CTs, mA output CTs (such as Elkor's "safe" mA split and solid core CTs) or industry standard 5A CTs.

The WattsOn-Mark II meter features a proven high performance metering architecture, which allows for accurate and extremely high resolution measurements over a very wide dynamic range input. The data is updated up to two times per second. The true-RMS inputs may be used even with distorted waveforms such as those generated by variable frequency drives and SCR loads.

Information is available via the RS-485 (Modbus RTU) output port. In addition, two solid-state relay outputs are available and may be software configured for Wh pulse outputs, or alarm triggers, as well as direction of power. An on-board graphic LCD display, real-time clock and data logging is optionally available.

2. SPECIFICATIONS

Inputs		
Control Power Input Rating	12-35V VDC / 24VAC, 100 mA max	
System Types Supported	120/208V Delta, Wye 277/480V Delta, Wye 347/600V Delta, Wye Single-phase installations up to 347V RMS Split-phase (two phase) installations	
Frequency	40-70 Hz	
Voltage Input Rating	5 to 347V L-N (600 V L-L)	
Voltage Continued Overload Rating	20%	
Voltage Absolute Maximum Rating	450V L-N, 780V L-L	
Voltage Input Impedance	1.5MΩ (line-to-neutral) minimum, 3.0MΩ (line-to-line) minimum	
Voltage Wire Size	AWG 30-12, solid / stranded (AWG 16-22 recommended)	
Current Input Rating	Up to 200 mA RMS (–mA model) Up to 333 mV RMS (–mV model) Up to 10A RMS (–5A model)	
Current Continued Overload Rating	+20%	
Current Absolute Maximum Rating	400 mA RMS (–mA model) 666 mV RMS (–mV model) 20A RMS (–5A model)	
Current Burden/Input Impedance	1.5Ω total maximum(–mA model) 800kΩ minimum, 1.2MΩ typical (–mV model) 0.05Ω total maximum (–5A model)	
Current Wire Size	AWG 24-12, solid / stranded (AWG12-16 recommended for 5A CTs)	
Tightening Torque	7.0 Lb-In (Voltage), 4.4 Lb-In (Other)	
Outputs		
Serial	RS-485 2-wire Modbus RTU, 9600 (default) to 230400 baud Elkor Expansion Bus Port	
Relay	2x Solid-State Relay Outputs (100 mA @ 50V max)	
Indicators	LEDs for: Status, Voltage, Current, Relay State, Communication	
Display	Back-lit Graphic LCD Display 128x32 (–DL models only)	
Accuracy		
Current (A)	0.05% typical	0.1% max
Voltage, Line-to-Neutral (V)	0.1% typical	0.2% max
Voltage, Line-to-Line (V)	0.2% typical	0.3% max
Real Power (W)	0.1% typical	0.2% max
Apparent Power (VA)	0.1% typical	0.2% max
Reactive Power (VAR)	0.1% typical	0.2% max
Energy	0.1% typical	0.2% max
Power Factor	0.2% max	
Frequency	0.01% max	
Sampling Rate	2 KHz	
Data Update Time	2 Hz	
Environmental		
Operating Temperature	–40°C to +70°C	
Storage Temperature	–65°C to +85°C	
Humidity	10 to 90% non-condensing	
Mechanical		
Mass	0.15 kg (–mA and –mV models) - 0.23 kg (–5A-DL model)	
Mounting	DIN Rail mounting 2-point screw mounting	
Regulatory		
Electromagnetic Emissions	FCC part 15 Class B (residential and industrial)	
Safety	UL 508 listed	
Accuracy	ANSI C12.20 Class 0.2	

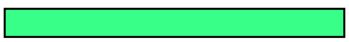
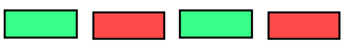
2.1. Indicators

A number of indicator LEDs are present on the WattsOn. They are described in the table below.

Label	Color	Description
STATUS	**Green/Red**	Indicates the status of the device. See the Status Indicator Codes, below.
MB	**Green/Red**	Indicates Modbus RS-485 communication. Green indicates transmission, red indicates reception. Solid red indicates that Modbus is wired backwards (+ and – terminals are reversed).
XB	**Green/Red**	Indicates Elkor Expansion Bus communication. Green indicates transmission, red indicates reception. Solid red indicates that the Expansion bus is wired backwards (+ and – terminals are reversed).
K1	**Yellow**	Indicates the state of the first relay output. Off indicates open, on indicates closed.
K2	**Yellow**	Indicates the state of the second relay output. Off indicates open, on indicates closed.
V	**3x Green**	Voltage indicators. By default, the LED is on when the voltage is greater than 20V.
I	**3x Green/Red**	Current & Power Indicators. See Current & Power Indicators, below.

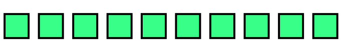
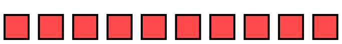
2.1.1. Status Indicator Codes

The status indicator uses a variety of patterns to indicate the device's status, as described by the following table.

Code	Description
	Solid green indicates that the device is operating normally.
	Two periodic green blinks indicates that the meter has started in bootloader mode. See section **7**, **Firmware Updates and the Bootloader** (p. 35) for details.
	Alternating green and red indicates that the Modbus address is set to 0, which is used for debugging purposes. See section **5.7.2, Configuring Serial Parameters** (p. 28) for details on using address 0.
	Two periodic red blinks indicates that corrupt firmware has been on the device, halting the device in bootloader mode.
	Flashing red indicates a product malfunction that prevents it from reading correctly.

2.1.2. Current & Power Indicators

The WattsOn features three indicator LEDs which display the status of the metering inputs. The table below summarizes the LED states. The LED will not turn on (in any state) if the input current is less than 0.1% (default) of the full scale input.

Code	Description
	Solid green indicates that current is present. If voltage is present, solid green indicates that active power (kW) is being *imported*.
	Blinking green indicates that power is being *exported*. (Voltage must be present).
	Solid red indicates that active power (kW) is being *imported*, but absolute reactive power (kVAR) exceeds absolute active power (kW). (Voltage must be present).
	Blinking red indicates that active power is being *exported*, but absolute reactive power (kVAR) exceeds absolute active power (kW). (Voltage must be present).
	By default, the LED is off when the current is less than 0.1% of the full scale input.

3. INSTALLATION

3.1. Grounding Considerations

Output signal ground is usually provided by the controller (RTU, DDC, PLC etc). The output common (GND) **IS ISOLATED** (3500VAC minimum) from the input reference (N terminal), however the "-" terminal of the input power supply and the output common (GND) are tied together internally.

3.2. Power Supply

The power supply must be properly isolated from the measurement line to maintain the required isolation voltage. A small dedicated transformer or DIN mount switching power supply is recommended to ensure the best isolation between system components. Contact Elkor to purchase recommended accessories.

For DC power supplies, the polarity must be observed. For AC power supplies, it must be noted that the RS-485 output common (G) and "-" power supply terminal are tied together. Care must be taken if multiple devices are powered using one AC supply to prevent shorting the supply.

The power supply may be shared by multiple devices.

3.3. Line Circuits Wiring

The WattsOn meter is a true 'three element' meter that can be used in any electrical system. For four-wire systems ('wye', with distributed neutral) the meter requires current and voltage information from each phase, therefore three current transformers (CTs) and three line voltages plus neutral must be wired to the unit.

WattsOn may be used in three wire systems ('delta', without a distributed neutral) as a 'three element' meter (three CTs required). The 5A meter version may be wired as a 'two element' meter utilizing only two CTs (and two PTs). When no neutral is present, the neutral connection should be omitted.

Standard wiring principles for electricity meters apply to the WattsOn meter, as for any other '3 element' electricity meter. The polarity of interfacing transformers must be observed. The left terminal of each current input connector is always associated with the 'X1' wire of the responding CT. Please refer to Appendix A for details on CT wiring.

All mV and mA CTs must be wired independently to the corresponding current inputs (two wires from each CT without shunts or jumpers). **mA and mV CTs must *NOT* be grounded, or interconnected with each other (or any other components) in any way.**

The use of a metering test switch containing fuses for voltage lines and shorting terminals for 5A CTs is recommended. A pre-assembled Elkor *i-Block*™ may be used as a convenient and economical solution.

A CT shorting mechanism is not required for mV and Elkor mA style CTs, since these are voltage clamped, however appropriate protection (fuse or breaker) for input line voltages is required.

See **Section 8, Appendix A, Wiring Diagrams** (p. 36) for details on wiring the meter for various system configurations.

3.4. Fusing of Voltage Sensing Inputs

The input voltage lines should be protected as per electrical code requirements. This is also good practice to facilitate an easy disconnect means for servicing the meter. In some cases, the voltage may be tapped off of existing fuses or breakers. If this is not possible, Elkor recommends a 1A or lower fuse (fast acting) for protection of the installation wiring. The WattsOn voltage inputs are high impedance (> 1.5MΩ) and draw negligible current (less than 0.3mA max).

3.5. Enclosure Mounting

The WattsOn is housed in a UL 94V-0 plastic enclosure intended for either DIN mount installation or wall mounted installation All of the input (bottom) and output (top) signals are available on the exterior of the enclosure. The unit does not contain any user serviceable parts and thus should not be accessed by the user.

3.6. Commissioning Flowchart

The following chart summarizes the procedure to install and set up the WattsOn device for basic use.

Connect up to three current transformers to the current input terminals (bottom-right green) on the device. Observe the polarity as indicated on the CTs – reversing the leads or mounting the CTs backwards will result in negative power and energy accumulation.

For safety reasons, ensure that any live voltages are turned off while connecting the voltage leads. Connect line voltage leads to the voltage input terminals (bottom-left green. The device will accept up to 347V L-N (or 600V L-L) without a transformer. For higher voltages, potential transformers are required.

Connect the two or three-wire RS-485 line to the device's top-right green terminal. The ground wire may be optional for short distances. The Modbus specification recommends the use of shielded RS-485 cabling. Twisted pair is recommended for noisy environments. Bus termination may be required for complex networks.

Connect the other end of the Modbus line to the Modbus master device (PLC, PC, etc.).

Relay outputs may be wired (for example, with pulse counters).

Configure the device's Modbus address by setting the hardware address switch. The address of each device on the RS-485 line must be unique. If only one device on the line, it can be left at the default setting (1). Addresses from 1 to 15 can be set via the switch, and if necessary higher addresses can be set over Modbus once communication is established; see **3.7, Digital Communications** (p. 10). The address must **not** be set to 0 for normal operation.

Connect a 12-35 VDC / 24VAC power supply to the device's black power terminal.

Program the CT Ratio primary (for 5A or millivolt CTs) or turn count (for milliamp CTs) into register **0x500** using the Modbus master device. See *Setting CT Ratios* (p. 21) for details. If voltage transformers are being used, program the transformer ratio into register **0x508** and **0x509.**

Read the *Debug Register* **0x509** to test that the communications are functioning correctly. The register should read 12345 (0x3039 in hexadecimal).

3.7. Digital Communications

The WattsOn has an RS-485 port which communicates using the Modbus RTU protocol.

The RS-485 port comes factory-programmed with the indicated settings below. The baud rate, parity, and stop bit settings can be changed via Modbus; see **5.7.2, Configuring Serial Parameters** (p. 28).

Parameter	Default Setting
Modbus address	1
Baud rate	9600
Parity	None
Data bits	8
Stop bits	1

Every Modbus device on an RS-485 network must be assigned a unique Modbus Address. This address is used to specifically identify the target device for querying by the master. Valid Modbus addresses are between 1-247.

Using the rotary switch, addresses from 1-15 can be set. The switch indicates numbers as hexadecimal values, with 1-9 being shown as normal, "A" representing 10, "B" representing 11, and so on. When the rotary switch is set to F (15) the device will instead use an address programmed into the unit. The internally programmed address defaults to 15, to match the rotary switch setting. See section **5.7.1, Modbus Addresses above 15** (p. 28) for details on setting extended Modbus addresses using Modbus.

Address 0 is not a valid Modbus address; it is used for troubleshooting purposes only. See section **5.7.2, Configuring Serial Parameters** (p. 28) for details on using address 0.

4. COMMUNICATION

4.1. Modbus Protocol

The WattsOn communicates using Modbus RTU, a digital communication protocol over an RS-485 port. This protocol is supported by various PC software applications, PLCs, data logging devices, and other Modbus "master" devices, which can be used to communicate with the WattsOn. The WattsOn is defined as a Modbus "slave" device, meaning that it responds to queries sent by the Modbus "master" device.

A Modbus slave device defines blocks of "registers" that contain information, each with a particular address. Each register contains a 16-byte field of data which can be read by the master device. The registers defined by the WattsOn are described in section **5, Register Map** (p. 13).

> For technical details on the Modbus protocol, see **Appendix B, Modbus Protocol Details** (p. 41), or see the official Modbus Application Specification available for free from http://www.modbus.org/specs.php.

4.2. Modbus Functions

The WattsOn supports a number of different Modbus functions used to query the device or issue commands. Some Modbus software/devices require the user specify specific Modbus functions. Others are more sophisticated, and will automatically use the appropriate functions as needed, without requiring detailed knowledge of the Modbus protocol.

4.2.1. Supported Functions

The WattsOn supports the following Modbus functions:

<table>
<tr><th>Function Name</th><th>Function Code</th><th colspan="3">Description</th></tr>
<tr><td>Read Holding Registers</td><td>03 (0x03)</td><td colspan="3">Reads the data contained in one or more registers (identical to function 04 on this device).</td></tr>
<tr><td>Read Input Registers</td><td>04 (0x04)</td><td colspan="3">Reads the data contained in one or more registers (identical to function 03 on this device).</td></tr>
<tr><td>Write Register</td><td>06 (0x06)</td><td colspan="3">Writes data to a single register.</td></tr>
<tr><td rowspan="6">Diagnostics</td><td rowspan="6">08 (0x08)</td><td>Return Query Data</td><td>00 (0x00)</td><td rowspan="6">The Diagnostics function is a series of sub-functions that assist in diagnosing communication problems.

See Diagnostic Functions (below) for details on each one.</td></tr>
<tr><td>Clear Counters</td><td>10 (0x0A)</td></tr>
<tr><td>Bus Message Count</td><td>11 (0x0B)</td></tr>
<tr><td>Bus Comm Error Count</td><td>12 (0x0C)</td></tr>
<tr><td>Bus Exception Count</td><td>13 (0x0D)</td></tr>
<tr><td>Slave Message Count</td><td>14 (0x0E)</td></tr>
<tr><td>Get Event Counter</td><td>11 (0x0B)</td><td colspan="3">Reads a count of successful messages since power-on, excluding function 11 messages.</td></tr>
<tr><td>Write Multiple Registers</td><td>16 (0x10)</td><td colspan="3">Writes data to one or more registers.</td></tr>
<tr><td>Report Slave ID</td><td>17 (0x11)</td><td colspan="3">Returns various information used to identify this device. See Slave ID (below).</td></tr>
<tr><td>Write Mask Register</td><td>22 (0x16)</td><td colspan="3">Modifies data in a single register based on an OR mask and an AND mask.</td></tr>
<tr><td>Read/Write Registers</td><td>23 (0x17)</td><td colspan="3">Writes data to one or more registers, and then reads data from one or more registers.</td></tr>
<tr><td>Read Device ID</td><td>43 (0x2B)/14 (0x0E)</td><td colspan="3">Reads various text strings giving device parameters. See Device ID (next page).</td></tr>
</table>

4.2.2. Diagnostic Functions

The WattsOn implements various diagnostic functions to assist in verifying and diagnosing communication problems. The Diagnostic function is divided into a number of sub-functions each identified by a sub-function code. The following table summarizes the diagnostic sub-functions implemented by this device.

Description	Sub-Function	Description
Return Query Data	00 (0x00)	Sends dummy data to the device, which is then returned as-is. Used for testing communication.
Clear Counters	10 (0x0A)	Clears all counters associated with the communication system, including the Bus Message Counter, the Bus Comm Error Counter, the Bus Exception Counter, the Slave Message Counter, and the Event Counter (also used in function 11).
Bus Message Count	11 (0x0B)	Returns the number of messages that the device has detected since power-up. These messages were not necessarily valid or addressed to this device.
Bus Comm Error Count	12 (0x0C)	Returns the number of CRC errors detected by the device since power-up. The messages containing these CRC errors were not necessarily addressed to this device.
Bus Exception Count	13 (0x0D)	Returns the number of exception responses returned by this device since power-up.
Slave Message Count	14 (0x0E)	Returns the count of messages addressed to this device that were received since power-up.

4.2.3. *Slave ID*

The WattsOn implements function 17, Report Slave ID, which returns three separate pieces of information. It returns an ID code identifying this particular device, a status code indicating if the device is running or not, and a null-terminated text string identifying this particular device.

Field	Data
ID Code	130
Status	0xFF (ON) when running normally, 0x00 (OFF) when in bootloader mode.
Text String	An ASCII text string containing the name of the product, its input configuration (mA, mV, or 5A), and its hardware and software version. The string is null-terminated, meaning a 0 is transmitted after the last character. For example, "Elkor Technologies W2-M1-mA Hardware 1.00 Firmware 1.00". While in bootloader mode, the string returned contains the bootloader version, for example, "Elkor Technologies Bootloader 1.00".

4.2.4. *Device ID*

The WattsOn implements the Read Device ID function, which provides access to various strings that identify various device properties. This is sub-function 14 (0x0E) of function 43 (0x2B), Encapsulated Interface Transport. The WattsOn implements this function at the highest Conformity Level of 0x83 (basic, regular, and extended identification, stream or individual access).

Each string, called an "object", is accessed with a number, called the object ID. The WattsOn defines the following objects, which can be read using this function.

Object	Object ID	Category	Value
VendorName	0 (0x00)	Standard (Basic)	"Elkor Technologies"
ProductCode	1 (0x01)	Standard (Basic)	"W2"
MajorMinorRevision	2 (0x02)	Standard (Basic)	The firmware version of the device, such as "1.00"
VendorUrl	3 (0x03)	Standard (Regular)	"http://www.elkor.net"
ProductName	4 (0x04)	Standard (Regular)	"WattsOn-Mark II"
ModelName	5 (0x05)	Standard (Regular)	The device's model name, for example, "W2-M1-mA"
UserApplicationName	6 (0x06)	Standard (Regular)	"Elkor Firmware"
HardwareRevision	128 (0x80)	Extended	The hardware version on the device, such as "1.00"
BootloaderRevision	129 (0x81)	Extended	The bootloader version on the device, such as "1.00"
SerialNumber	130 (0x82)	Extended	The serial number of the device, such as "12345"
DeviceID	131 (0x83)	Extended	130

5. REGISTER MAP

5.1. Register Addressing Conventions

There are several different conventions for specifying the address of a particular register. Various conventions are used in different software programs, PLCs, and other devices. Three common conventions are described below.

- **Offsets:** Addresses are presented as hexadecimal numbers (shown with the "0x" prefix) with the first address starting at address 0. This is how addresses are transmitted digitally over the serial cable, and many software packages describe Modbus addresses.

- **PLC-style addresses:** Addresses are presented as 5-digit decimal numbers, starting with a "3" or a "4" indicating whether they are considered "input registers" which are read-only, or "holding registers" which are read-write (respectively). The first input register is defined as 30001, and the first holding register is defined as 40001. For ease of integration, this device treats both Holding Registers and Input Registers as identical; therefore, either 30000-based addresses or 40000-based addresses will work with the WattsOn, though only 40000-based addresses can be written to. Many PLCs and some other devices describe Modbus addresses in this manner.

Examples

Offset:	0x0
PLC-style:	40001
Register No:	1
Offset:	0x10
PLC-style:	40017
Register No:	17
Offset:	0x200
PLC-style:	40513
Register No:	513

- **Register numbers:** Addresses are presented as decimal numbers, with the first register defined as register 1. These are similar to the PLC-style addresses described above, without "3" or "4" prefix. Some software packages describe Modbus addresses in this manner.

The address of each register is presented in the first two styles in this manual. The required convention that is used depends on the Modbus master software or device.

5.2. Register Size

Modbus registers are defined as each containing 16 bits of information. In this document, some registers are described as being 32-bits wide, rather than 16. In these cases, two consecutive registers are concatenated together in order to obtain the 32-bit value. Most modern Modbus software and hardware devices understand the notion of 32-bit registers, and will do this processing, provided the data is configured as a 32-bit register.

> **Example:** Register **0x100** is a 32-bit register. Suppose a read of register **0x100** returns 0x0003, and a read of register **0x101** returns 0x0D40. Concatenate these two registers together to get a hexadecimal value of 0x00030D40, or a decimal value of 200,000.

By default, the higher-order 16-bit word of a 32-bit register is the register with the lower address, and the lower-order word is at the higher address. Most Modbus software and devices will interpret 32-bit registers this way. Alternatively, the WattsOn can be configured to reverse the byte ordering, so that the higher-order word is at the higher address, and the lower-order word is at the lower address. See **5.6.6, Setting 32-bit Endianness** (p. 23) for details on how to configure this setting.

5.3. Data Types

Registers contain data in one of four different types. Data types are given in the register tables with a single letter code in the "Type" column to indicate the type. The types are as follows.

Type	Code	Description
Unsigned Integer	U	Positive whole numbers (no sign). Can range from 0 to 65,535 for 16-bit registers, and 0 to 4,294,967,295 for 32-bit registers.
Signed Integer	S	Positive or negative whole numbers. Represented in 2's complement format. Can range from -32,768 to +32,767 for 16-bit registers and -2,147,483,648 to +2,147,483,647 for 32-bit registers.
Floating-Point	F	Positive or negative decimal numbers. Represented in IEEE 754 format. Can represent values from negative infinity to positive infinity, at decreasing levels of resolution as the number because larger.
Boolean	B	True or false. False is represented by the value 0, true is represented by the value 1.

5.4. <u>Instantaneous Data Registers</u>

Instantaneous data registers contain the real-time measurements from the input channels on the device, including current, voltage, power, power factor, and frequency. For energy registers, see **5.5, Accumulated Data Registers** (p. 15). The instantaneous registers are presented in two different formats, each in a separate block of registers – as floating-point data (for modern systems), and as integer data (for systems which do not support floating-point data). It is recommended to read the floating-point data if possible, as there is then no need to scale the registers manually.

Both integer and floating-point registers incorporate the CT and PT ratios entered into the configuration registers described in section **5.6, Configuration and** Status Registers (p. 21).

5.4.1. Integer Instantaneous Data Registers

The following registers are 32-bit integer representations of the measured parameters. To allow integer registers to represent decimal numbers, the integer registers are scaled according to a scaling factor. Divide the value read from these registers by the scaling factor in the *Scale* column to get a decimal value in the units specified by the *Units* column.

> **Example:** If you read the value "4501" from the Current A register, divide 4501 by the scaling factor of 1000, to get a value of 4.501 Amps on channel A.

Name	Offset	Address	Size	Type	R/W	Units	Scale
Active Power Total	0x100	40257	32	S	R	W	10
Reactive Power Total	0x102	40259	32	S	R	VAR	10
Apparent Power Total	0x104	40261	32	S	R	VA	10
Voltage Average	0x106	40263	32	S	R	V	100
Voltage L-L Average	0x108	40265	32	S	R	V	100
Current Average	0x10A	40267	32	S	R	A	1000
System Power Factor	0x10C	40269	32	S	R	-	10000
System Frequency	0x10E	40271	32	S	R	Hz	1000
Voltage Phase Angle Average	0x110	40273	32	S	R	°	10
System Quadrant	0x112	40275	32	U	R	-	-
Reserved	*0x114*	*40277*	*32*	-	*R*	-	-
		...					
Reserved	*0x11E*	*40287*	*32*	-	*R*	-	-
Voltage A	0x120	40289	32	S	R	V	100
Voltage B	0x122	40291	32	S	R	V	100
Voltage C	0x124	40293	32	S	R	V	100
Voltage AB	0x126	40295	32	S	R	V	100
Voltage BC	0x128	40297	32	S	R	V	100
Voltage AC	0x12A	40299	32	S	R	V	100
Current A	0x12C	40301	32	S	R	A	1000
Current B	0x12E	40303	32	S	R	A	1000
Current C	0x130	40305	32	S	R	A	1000
Active Power A	0x132	40307	32	S	R	W	10
Active Power B	0x134	40309	32	S	R	W	10
Active Power C	0x136	40311	32	S	R	W	10
Reactive Power A	0x138	40313	32	S	R	VAR	10
Reactive Power B	0x13A	40315	32	S	R	VAR	10
Reactive Power C	0x13C	40317	32	S	R	VAR	10
Apparent Power A	0x13E	40319	32	S	R	VA	10
Apparent Power B	0x140	40321	32	S	R	VA	10
Apparent Power C	0x142	40323	32	S	R	VA	10
Power Factor A	0x144	40325	32	S	R	-	10000
Power Factor B	0x146	40327	32	S	R	-	10000
Power Factor C	0x148	40329	32	S	R	-	10000
Voltage Phase Angle AB	0x14A	40331	32	S	R	°	10
Voltage Phase Angle BC	0x14C	40333	32	S	R	°	10
Voltage Phase Angle AC	0x14E	40335	32	S	R	°	10
Quadrant A	0x150	40337	32	U	R	-	-
Quadrant B	0x152	40339	32	U	R	-	-
Quadrant C	0x154	40341	32	U	R	-	-
Sliding Window Power	0x156	40343	32	S	R	W	10

5.4.2. *Floating-Point Instantaneous Data Registers*

The following registers are 32-bit floating-point representations of the measured parameters, expressed in IEEE 754 format. Unlike the integer registers described above, these registers are capable of representing decimal numbers and therefore do not require any scaling.

Name	Offset	Address	Size	Type	R/W	Units
Active Power Total	0x200	40513	32	F	R	kW
Reactive Power Total	0x202	40515	32	F	R	kVAR
Apparent Power Total	0x204	40517	32	F	R	kVA
Voltage Average	0x206	40519	32	F	R	V
Voltage L-L Average	0x208	40521	32	F	R	V
Current Average	0x20A	40523	32	F	R	A
System Power Factor	0x20C	40525	32	F	R	-
System Frequency	0x20E	40527	32	F	R	Hz
Voltage Average Angle	0x210	40529	32	F	R	°
System Quadrant	0x212	40531	32	F	R	-
Reserved	*0x214*	*40533*	*32*	-	*R*	-
		…				
Reserved	*0x21E*	*40543*	*32*	-	*R*	-
Voltage A	0x220	40545	32	F	R	V
Voltage B	0x222	40547	32	F	R	V
Voltage C	0x224	40549	32	F	R	V
Voltage AB	0x226	40551	32	F	R	V
Voltage BC	0x228	40553	32	F	R	V
Voltage AC	0x22A	40555	32	F	R	V
Current A	0x22C	40557	32	F	R	A
Current B	0x22E	40559	32	F	R	A
Current C	0x230	40561	32	F	R	A
Active Power A	0x232	40563	32	F	R	kW
Active Power B	0x234	40565	32	F	R	kW
Active Power C	0x236	40567	32	F	R	kW
Reactive Power A	0x238	40569	32	F	R	kVAR
Reactive Power B	0x23A	40571	32	F	R	kVAR
Reactive Power C	0x23C	40573	32	F	R	kVAR
Apparent Power A	0x23E	40575	32	F	R	kVA
Apparent Power B	0x240	40577	32	F	R	kVA
Apparent Power C	0x242	40579	32	F	R	kVA
Power Factor A	0x244	40581	32	F	R	-
Power Factor B	0x246	40583	32	F	R	-
Power Factor C	0x248	40585	32	F	R	-
Voltage Angle AB	0x24A	40587	32	F	R	°
Voltage Angle BC	0x24C	40589	32	F	R	°
Voltage Angle AC	0x24E	40591	32	F	R	°
Quadrant A	0x250	40593	32	F	R	-
Quadrant B	0x252	40595	32	F	R	-
Quadrant C	0x254	40597	32	F	R	-
Sliding Window Power	0x256	40599	32	F	R	kW

5.5. Accumulated Data Registers

Accumulated data registers contain energy data accumulated over time from the input channels on the device, including real energy, apparent energy, and reactive energy. For instantaneous registers such as power and current, see **5.4, Instantaneous Data Registers** (p. 14).

There are four blocks of accumulated data registers in total. Two blocks reflect resets – they can be reset to 0 at any time. The remaining two blocks do not reflect resets, and retain their total accumulated value despite any number of resets issued by the user. Revenue-grade metering applications or applications that do not require the ability to reset the meter should always read the non-resettable registers.

Resettable and non-resettable registers each have a floating-point block (for modern systems) and an integer block (for systems that do not support floating-point data). It is recommended to read the floating-point data if possible, as there is then no need to multiply the results by any scaling factors in that case.

The WattsOn's internal accumulated energy will never overflow; however, when reading 32-bit integer representations of the energy registers in combination with large CT or PT ratios, 32-bit integers may not be large enough to contain the information. To address this problem, the WattsOn has an *Energy Integer Divider Register*, **0x52E** which is applied to the energy values as they are read. By default, this is set to 100. This sets the resolution of the energy registers to 100 Wh/VAh/VARh by default. The maximum resolution is 1 Wh/VAh/VARh (including CT/PT scaling) with the divider set to 1.

This divider can be adjusted if desired, either to accommodate larger CT/PT ratios, or if greater resolution is desired. Multiply the value read from the registers by the value of the *Energy Integer Divider* register to obtain the units expressed in the *Units* column of the following tables. See **5.6.13, Energy Integer Divider** (p. 26) for details on the *Energy Integer Divider* register.

> **Example:** If you read the value "45" from the *Net Energy A* register, and "100" from the *Energy Integer Divisor* register. Multiply 45 by 100 to get a value of 4500 Wh (or 4.5 kW) on channel A.

The floating-point representations of the energy registers do not use the *Energy Integer Divider Register*, as they can represent arbitrarily large values. For this reason, reading the floating-point registers is recommended. However, their resolution will decrease as values grow larger.

5.5.1. Resettable Integer Accumulated Data Registers

These registers reflect resets made using the *Energy Reset* register **0x524**; see **5.6.8, Resetting Accumulated Energy** (p. 24) for details.

Name	Offset	Address	Size	Type	R/W	Units
Net Total Energy (Resettable)	0x1000	44097	32	S	R	Wh
Total Net Apparent Energy (Resettable)	0x1002	44099	32	S	R	VAh
Total Import Energy (Resettable)	0x1004	44101	32	S	R	Wh
Total Export Energy (Resettable)	0x1006	44103	32	S	R	Wh
Total Import Apparent Energy (Resettable)	0x1008	44105	32	S	R	VAh
Total Export Apparent Energy (Resettable)	0x100A	44107	32	S	R	VAh
Q1 Total Reactive Energy (Resettable)	0x100C	44109	32	S	R	VARh
Q2 Total Reactive Energy (Resettable)	0x100E	44111	32	S	R	VARh
Q3 Total Reactive Energy (Resettable)	0x1010	44113	32	S	R	VARh
Q4 Total Reactive Energy (Resettable)	0x1012	44115	32	S	R	VARh
Q1+Q2 Total Inductive Reactive Energy (Resettable)	0x1014	44117	32	S	R	VARh
Q3+Q4 Total Capacitive Reactive Energy (Resettable)	0x1016	44119	32	S	R	VARh
Reserved	*0x1018*	*44121*	*32*	-	*R*	-
	...					
Reserved	*0x101E*	*44127*	*32*	-	*R*	-
Net Energy (Resettable) A	0x1020	44129	32	S	R	Wh
Net Energy (Resettable) B	0x1022	44131	32	S	R	Wh
Net Energy (Resettable) C	0x1024	44133	32	S	R	Wh
Net Apparent Energy (Resettable) A	0x1026	44135	32	S	R	VAh
Net Apparent Energy (Resettable) B	0x1028	44137	32	S	R	VAh
Net Apparent Energy (Resettable) C	0x102A	44139	32	S	R	VAh
Import Energy (Resettable) A	0x102C	44141	32	S	R	Wh
Import Energy (Resettable) B	0x102E	44143	32	S	R	Wh
Import Energy (Resettable) C	0x1030	44145	32	S	R	Wh
Export Energy (Resettable) A	0x1032	44147	32	S	R	Wh
Export Energy (Resettable) B	0x1034	44149	32	S	R	Wh
Export Energy (Resettable) C	0x1036	44151	32	S	R	Wh
Import Apparent Energy (Resettable) A	0x1038	44153	32	S	R	VAh
Import Apparent Energy (Resettable) B	0x103A	44155	32	S	R	VAh
Import Apparent Energy (Resettable) C	0x103C	44157	32	S	R	VAh
Export Apparent Energy (Resettable) A	0x103E	44159	32	S	R	VAh
Export Apparent Energy (Resettable) B	0x1040	44161	32	S	R	VAh
Export Apparent Energy (Resettable) C	0x1042	44163	32	S	R	VAh
Q1 Reactive Energy (Resettable) A	0x1044	44165	32	S	R	VARh
Q1 Reactive Energy (Resettable) B	0x1046	44167	32	S	R	VARh
Q1 Reactive Energy (Resettable) C	0x1048	44169	32	S	R	VARh
Q2 Reactive Energy (Resettable) A	0x104A	44171	32	S	R	VARh
Q2 Reactive Energy (Resettable) B	0x104C	44173	32	S	R	VARh
Q2 Reactive Energy (Resettable) C	0x104E	44175	32	S	R	VARh
Q3 Reactive Energy (Resettable) A	0x1050	44177	32	S	R	VARh
Q3 Reactive Energy (Resettable) B	0x1052	44179	32	S	R	VARh
Q3 Reactive Energy (Resettable) C	0x1054	44181	32	S	R	VARh
Q4 Reactive Energy (Resettable) A	0x1056	44183	32	S	R	VARh
Q4 Reactive Energy (Resettable) B	0x1058	44185	32	S	R	VARh
Q4 Reactive Energy (Resettable) C	0x105A	44187	32	S	R	VARh

5.5.2. Resettable Floating-Point Accumulated Data Registers

The following registers are 32-bit floating-point representations of the accumulated energy parameters, expressed in IEEE 754 format. These registers reflect resets made using the *Energy Reset* register **0x524**; see **5.6.8, Resetting Accumulated Energy** (p. 24) for details.

Name	Offset	Address	Size	Type	R/W	Units
Net Total Energy (Resettable)	0x1100	44353	32	F	R	kWh
Total Net Apparent Energy (Resettable)	0x1102	44355	32	F	R	kVAh
Total Import Energy (Resettable)	0x1104	44357	32	F	R	kWh
Total Export Energy (Resettable)	0x1106	44359	32	F	R	kWh
Total Import Apparent Energy (Resettable)	0x1108	44361	32	F	R	kVAh
Total Export Apparent Energy (Resettable)	0x110A	44363	32	F	R	kVAh
Q1 Total Reactive Energy (Resettable)	0x110C	44365	32	F	R	kVARh
Q2 Total Reactive Energy (Resettable)	0x110E	44367	32	F	R	kVARh
Q3 Total Reactive Energy (Resettable)	0x1110	44369	32	F	R	kVARh
Q4 Total Reactive Energy (Resettable)	0x1112	44371	32	F	R	kVARh
Q1+Q2 Total Inductive Reactive Energy (Resettable)	0x1114	44373	32	F	R	VARh
Q3+Q4 Total Capacitive Reactive Energy (Resettable)	0x1116	44375	32	F	R	VARh
Reserved	*0x1118*	*44377*	*32*	-	*R*	-
	...					
Reserved	*0x111E*	*44383*	*32*	-	*R*	-
Net Energy (Resettable) A	0x1120	44385	32	F	R	kWh
Net Energy (Resettable) B	0x1122	44387	32	F	R	kWh
Net Energy (Resettable) C	0x1124	44389	32	F	R	kWh
Net Apparent Energy (Resettable) A	0x1126	44391	32	F	R	kVAh
Net Apparent Energy (Resettable) B	0x1128	44393	32	F	R	kVAh
Net Apparent Energy (Resettable) C	0x112A	44395	32	F	R	kVAh
Import Energy (Resettable) A	0x112C	44397	32	F	R	kWh
Import Energy (Resettable) B	0x112E	44399	32	F	R	kWh
Import Energy (Resettable) C	0x1130	44401	32	F	R	kWh
Export Energy (Resettable) A	0x1132	44403	32	F	R	kWh
Export Energy (Resettable) B	0x1134	44405	32	F	R	kWh
Export Energy (Resettable) C	0x1136	44407	32	F	R	kWh
Import Apparent Energy (Resettable) A	0x1138	44409	32	F	R	kVAh
Import Apparent Energy (Resettable) B	0x113A	44411	32	F	R	kVAh
Import Apparent Energy (Resettable) C	0x113C	44413	32	F	R	kVAh
Export Apparent Energy (Resettable) A	0x113E	44415	32	F	R	kVAh
Export Apparent Energy (Resettable) B	0x1140	44417	32	F	R	kVAh
Export Apparent Energy (Resettable) C	0x1142	44419	32	F	R	kVAh
Q1 Reactive Energy (Resettable) A	0x1144	44421	32	F	R	kVARh
Q1 Reactive Energy (Resettable) B	0x1146	44423	32	F	R	kVARh
Q1 Reactive Energy (Resettable) C	0x1148	44425	32	F	R	kVARh
Q2 Reactive Energy (Resettable) A	0x114A	44427	32	F	R	kVARh
Q2 Reactive Energy (Resettable) B	0x114C	44429	32	F	R	kVARh
Q2 Reactive Energy (Resettable) C	0x114E	44431	32	F	R	kVARh
Q3 Reactive Energy (Resettable) A	0x1150	44433	32	F	R	kVARh
Q3 Reactive Energy (Resettable) B	0x1152	44435	32	F	R	kVARh
Q3 Reactive Energy (Resettable) C	0x1154	44437	32	F	R	kVARh
Q4 Reactive Energy (Resettable) A	0x1156	44439	32	F	R	kVARh
Q4 Reactive Energy (Resettable) B	0x1158	44441	32	F	R	kVARh
Q4 Reactive Energy (Resettable) C	0x115A	44443	32	F	R	kVARh

5.5.3. Revenue (Non-Resettable) Integer Accumulated Data Registers

These registers **do not** reflect resets made using the *Energy Reset* register.

Name	Offset	Address	Size	Type	R/W	Units
Net Total Energy (Revenue)	0x1200	44609	32	S	R	Wh
Total Net Apparent Energy (Revenue)	0x1202	44611	32	S	R	VAh
Total Import Energy (Revenue)	0x1204	44613	32	S	R	Wh
Total Export Energy (Revenue)	0x1206	44615	32	S	R	Wh
Total Import Apparent Energy (Revenue)	0x1208	44617	32	S	R	VAh
Total Export Apparent Energy (Revenue)	0x120A	44619	32	S	R	VAh
Q1 Total Reactive Energy (Revenue)	0x120C	44621	32	S	R	VARh
Q2 Total Reactive Energy (Revenue)	0x120E	44623	32	S	R	VARh
Q3 Total Reactive Energy (Revenue)	0x1210	44625	32	S	R	VARh
Q4 Total Reactive Energy (Revenue)	0x1212	44627	32	S	R	VARh
Q1+Q2 Total Inductive Reactive Energy (Revenue)	0x1214	44629	32	S	R	VARh
Q3+Q4 Total Capacitive Reactive Energy (Revenue)	0x1216	44631	32	S	R	VARh
Reserved	*0x1218*	*44633*	*32*	-	*R*	-
	...					
Reserved	*0x121E*	*44639*	*32*	-	*R*	-
Net Energy (Revenue) A	0x1220	44641	32	S	R	Wh
Net Energy (Revenue) B	0x1222	44643	32	S	R	Wh
Net Energy (Revenue) C	0x1224	44645	32	S	R	Wh
Net Apparent Energy (Revenue) A	0x1226	44647	32	S	R	VAh
Net Apparent Energy (Revenue) B	0x1228	44649	32	S	R	VAh
Net Apparent Energy (Revenue) C	0x122A	44651	32	S	R	VAh
Import Energy (Revenue) A	0x122C	44653	32	S	R	Wh
Import Energy (Revenue) B	0x122E	44655	32	S	R	Wh
Import Energy (Revenue) C	0x1230	44657	32	S	R	Wh
Export Energy (Revenue) A	0x1232	44659	32	S	R	Wh
Export Energy (Revenue) B	0x1234	44661	32	S	R	Wh
Export Energy (Revenue) C	0x1236	44663	32	S	R	Wh
Import Apparent Energy (Revenue) A	0x1238	44665	32	S	R	VAh
Import Apparent Energy (Revenue) B	0x123A	44667	32	S	R	VAh
Import Apparent Energy (Revenue) C	0x123C	44669	32	S	R	VAh
Export Apparent Energy (Revenue) A	0x123E	44671	32	S	R	VAh
Export Apparent Energy (Revenue) B	0x1240	44673	32	S	R	VAh
Export Apparent Energy (Revenue) C	0x1242	44675	32	S	R	VAh
Q1 Reactive Energy (Revenue) A	0x1244	44677	32	S	R	VARh
Q1 Reactive Energy (Revenue) B	0x1246	44679	32	S	R	VARh
Q1 Reactive Energy (Revenue) C	0x1248	44681	32	S	R	VARh
Q2 Reactive Energy (Revenue) A	0x124A	44683	32	S	R	VARh
Q2 Reactive Energy (Revenue) B	0x124C	44685	32	S	R	VARh
Q2 Reactive Energy (Revenue) C	0x124E	44687	32	S	R	VARh
Q3 Reactive Energy (Revenue) A	0x1250	44689	32	S	R	VARh
Q3 Reactive Energy (Revenue) B	0x1252	44691	32	S	R	VARh
Q3 Reactive Energy (Revenue) C	0x1254	44693	32	S	R	VARh
Q4 Reactive Energy (Revenue) A	0x1256	44695	32	S	R	VARh
Q4 Reactive Energy (Revenue) B	0x1258	44697	32	S	R	VARh
Q4 Reactive Energy (Revenue) C	0x125A	44699	32	S	R	VARh

5.5.4. Revenue (Non-Resettable) Floating-Point Accumulated Data Registers

The following registers are 32-bit floating-point representations of the accumulated energy parameters, expressed in IEEE 754 format. These registers **do not** reflect resets made using the *Energy Reset* register.

Name	Offset	Address	Size	Type	R/W	Units
Net Total Energy (Revenue)	0x1300	44865	32	F	R	kWh
Total Net Apparent Energy (Revenue)	0x1302	44867	32	F	R	kVAh
Total Import Energy (Revenue)	0x1304	44869	32	F	R	kWh
Total Export Energy (Revenue)	0x1306	44871	32	F	R	kWh
Total Import Apparent Energy (Revenue)	0x1308	44873	32	F	R	kVAh
Total Export Apparent Energy (Revenue)	0x130A	44875	32	F	R	kVAh
Q1 Total Reactive Energy (Revenue)	0x130C	44877	32	F	R	kVARh
Q2 Total Reactive Energy (Revenue)	0x130E	44879	32	F	R	kVARh
Q3 Total Reactive Energy (Revenue)	0x1310	44881	32	F	R	kVARh
Q4 Total Reactive Energy (Revenue)	0x1312	44883	32	F	R	kVARh
Q1+Q2 Total Inductive Reactive Energy (Revenue)	0x1314	44885	32	S	R	VARh
Q3+Q4 Total Capacitive Reactive Energy (Revenue)	0x1316	44887	32	S	R	VARh
Reserved	*0x1318*	*44889*	*32*	-	*R*	-
	...					
Reserved	*0x131E*	*44895*	*32*	-	*R*	-
Net Energy (Revenue) A	0x1320	44897	32	F	R	kWh
Net Energy (Revenue) B	0x1322	44899	32	F	R	kWh
Net Energy (Revenue) C	0x1324	44901	32	F	R	kWh
Net Apparent Energy (Revenue) A	0x1326	44903	32	F	R	kVAh
Net Apparent Energy (Revenue) B	0x1328	44905	32	F	R	kVAh
Net Apparent Energy (Revenue) C	0x132A	44907	32	F	R	kVAh
Import Energy (Revenue) A	0x132C	44909	32	F	R	kWh
Import Energy (Revenue) B	0x132E	44911	32	F	R	kWh
Import Energy (Revenue) C	0x1330	44913	32	F	R	kWh
Export Energy (Revenue) A	0x1332	44915	32	F	R	kWh
Export Energy (Revenue) B	0x1334	44917	32	F	R	kWh
Export Energy (Revenue) C	0x1336	44919	32	F	R	kWh
Import Apparent Energy (Revenue) A	0x1338	44921	32	F	R	kVAh
Import Apparent Energy (Revenue) B	0x133A	44923	32	F	R	kVAh
Import Apparent Energy (Revenue) C	0x133C	44925	32	F	R	kVAh
Export Apparent Energy (Revenue) A	0x133E	44927	32	F	R	kVAh
Export Apparent Energy (Revenue) B	0x1340	44929	32	F	R	kVAh
Export Apparent Energy (Revenue) C	0x1342	44931	32	F	R	kVAh
Q1 Reactive Energy (Revenue) A	0x1344	44933	32	F	R	kVARh
Q1 Reactive Energy (Revenue) B	0x1346	44935	32	F	R	kVARh
Q1 Reactive Energy (Revenue) C	0x1348	44937	32	F	R	kVARh
Q2 Reactive Energy (Revenue) A	0x134A	44939	32	F	R	kVARh
Q2 Reactive Energy (Revenue) B	0x134C	44941	32	F	R	kVARh
Q2 Reactive Energy (Revenue) C	0x134E	44943	32	F	R	kVARh
Q3 Reactive Energy (Revenue) A	0x1350	44945	32	F	R	kVARh
Q3 Reactive Energy (Revenue) B	0x1352	44947	32	F	R	kVARh
Q3 Reactive Energy (Revenue) C	0x1354	44949	32	F	R	kVARh
Q4 Reactive Energy (Revenue) A	0x1356	44951	32	F	R	kVARh
Q4 Reactive Energy (Revenue) B	0x1358	44953	32	F	R	kVARh
Q4 Reactive Energy (Revenue) C	0x135A	44955	32	F	R	kVARh

5.6. Configuration and Status Registers

The following registers are used for configuring the WattsOn.

5.6.1. Setting CT Ratios

Current transformer (CT) ratios allow the device to scale the data to report the real-world current values on the input of the current transformers. Typically, the same type of CT is used on all three current channels. In this case, write the CT ratio primary (in the case of 5A or mV CTs) or the number of turns (in the case of mA CTs) into the *Primary CT Ratio (All)* register, at address **0x500**. Setting the secondary CT ratio, register **0x501** is not generally necessary, as it will default to the correct value depending on the meter input type (5 for 5A CTs, 333 for 333 millivolt CT, and 1 for milliamp CTs).

Example 1: If a 100A:5A CT is being used, write the value "100" to register 0x500. Leave register 0x501 at its default value of "5".

Example 2: If an Elkor MCTA is being used, which has a turns ratio of 2500, write the value "2500" to register 0x500. Leave register 0x501 at its default value of "1".

The turn counts of various Elkor Milliamp CTs are listed in the table below. Contact Elkor for further details if the CT ratio is unknown. A correct setting of the CT ratio is critical to obtaining accurate measurements.

Current Transformer	Number of Turns
MCTA	2500
MCTB	4000
MSCT1	7500
MSCT2	7500
MSCT3	7500
MSCT5	11000
MS160	3000
MS360	2000

(i) Setting CT Ratios Per-Channel

It is permissible to use different CT ratios in each channel, provided the CTs are of the same output type (mA, 5A or 333mV). In this case, it is necessary to enter the CT ratio primary (in the case of 5A or mV CTs) or the number of turns (in the case of mA CTs) into three separate registers, one for each channel. Write the value for channels A, B, and C into registers **0x502**, **0x504**, and **0x506**, respectively. Setting secondary CT ratios (registers **0x503**, **0x505**, and **0x507**) is not generally necessary, as they will default to correct values (5 for 5A CTs, 333 for 333 mV CT, and 1 for mA CTs).

Example: Suppose 50A:5A CTs are connected to channels A and B, and a 250A:5A CT is connected to channel C. Write the value "50" to registers 0x502 and 0x504, and the value "250" to register 0x506. Leave registers 0x503, 0x505, and 0x507 at their default values of "5".

Note: While it is possible to use CTs with different full scale ratings or turns ratios together on the same unit, it is not possible to mix 5A CTs, millivolt CTs, or milliamp CTs together on the same unit.

(ii) Greater Accuracy

To maximize accuracy, many Elkor milliamp CTs are factory-tested to quantify the precise effective turns ratio. In this case, the number of turns is indicated on the CT itself. The values account for manufacturing variations, resulting in greater accuracy. For each channel, enter the precise number of turns for the CT connected to the corresponding input channel. Write the value for channels A, B, and C into registers **0x502**, **0x504**, and **0x506**, respectively.

Example: Suppose there are three MSCT1 CTs connected to the device. The CTs have the effective turn count indicated on each of them. The CT connected to channel A lists 7492, the CT connected to channel B lists 7490, and the CT connected to channel C lists 7493. Write the value "7492" to register 0x502, the value "7490" to register 0x504, and the value "7493" to register 0x506**.** Leave registers 0x503, 0x505, and 0x507 at their default values of "1".

Note: 5A and millivolt CTs are not generally factory-tested in this way.

Name	Offset	Address	Size	Type	R/W	Default	Description
Primary CT Ratio (All)	0x500	41281	16	U	RW	*	Used for setting the CT ratios of each phase. Writing to the "All" registers globally sets the CT ratios for all of the phases simultaneously. If the CT ratios are not identical in all three channels, the "All" values are read as "0". See p. 21.
Secondary CT Ratio (All)	0x501	41282	16	U	RW	*	
Primary CT Ratio A	0x502	41283	16	U	RW	*	
Secondary CT Ratio A	0x503	41284	16	U	RW	*	
Primary CT Ratio B	0x504	41285	16	U	RW	*	
Secondary CT Ratio B	0x505	41286	16	U	RW	*	
Primary CT Ratio C	0x506	41287	16	U	RW	*	
Secondary CT Ratio C	0x507	41288	16	U	RW	*	
Primary PT Ratio (All)	0x508	41289	16	U	RW	1	Used for setting the PT ratios for each phase. Writing to the "All" registers globally sets the PT ratios for all of the phases simultaneously. If the PT ratios are not identical in all three channels, the "All" values are read as "0". See p. 23.
Secondary PT Ratio (All)	0x509	41290	16	U	RW	1	
Primary PT Ratio A	0x50A	41291	16	U	RW	1	
Secondary PT Ratio A	0x50B	41292	16	U	RW	1	
Primary PT Ratio B	0x50C	41293	16	U	RW	1	
Secondary PT Ratio B	0x50D	41294	16	U	RW	1	
Primary PT Ratio C	0x50E	41295	16	U	RW	1	
Secondary PT Ratio C	0x50F	41296	16	U	RW	1	
Debug 16-bit	0x510	41297	16	S	R	12345	These registers always output their default values. They are useful for debugging communication with the device.
Debug 32-bit	0x511	41298	32	S	R	1234567	
Debug Floating-Point	0x513	41300	32	F	R	1234.567	
Uptime	0x515	41302	32	U	RW	-	Seconds since the device was last powered on or reset. See p. 23.
Masking Enabled	0x517	41304	16	B	RW	False	Indicates whether Modbus Masking is enabled. See p. 23.
Masking Override	0x518	41305	16	B	RW	False	Indicates whether masks can override existing registers. See p. 23.
Noise Filtering Enabled	0x519	41306	16	B	RW	True	Indicates whether low current noise filtering is enabled. See p. 23.
32-bit Little Endian Mode	0x51A	41307	16	B	RW	False	If enabled, 32-bit registers are sent least significant word first. See p. 23.
Current LED Threshold	0x51B	41308	16	S	RW	1 (0.1%)	Expressed in 10ths of a percent of the full scale (varies by model). See p. 24.
Voltage LED Threshold	0x51C	41309	16	S	RW	5 (5%)	Expressed as a percentage of 400V. See p. 24.
Serial Number	0x51D	41310	32	U	RW	-	Factory programmed serial number of the unit.
Hardware Version	0x51F	41312	16	U	R	-	Version numbers of different hardware and software components of this device. Divide by 100 to get the version number; for example, a value of "100" indicates version 1.00.
Firmware Version	0x520	41313	16	U	R	-	
Bootloader Version	0x521	41314	16	U	R	-	
Model Number	0x522	41315	16	U	RW	-	The model number of the device. This is expressed as a two-byte ASCII string. 19761 indicates the "M1" model.
Input Configuration	0x523	41316	16	U	RW	-	"1" for milliamp CTs, "2" for mV CTs, "3" for 5A CTs, "0" for a custom setup.
Energy Reset	0x524	41317	16	U	RW	-	Writing 0xA5A5 (42405) resets the accumulated energy to 0. See p. 24.
Compatibility Mode	0x525	41318	16	B	RW	False	Enables limited emulation of the WattsOn-1100's register map. See p. 24.
Power Factor Sign Mode	0x526	41319	16	U	RW	3 (Quad)	Indicates how the sign of the power factor is calculated. See page 24.
Passcode	0x527	41320	32	U	RW	-	Used for entering a passcode when locking or unlocking the device. See p. 25.
Lock	0x529	41322	16	U	RW	0	"0" indicates unlocked, "1" indicates locked. With a passcode entered above, write "0" to unlock, "1" to lock, or "2" to change the passcode. See p. 25.
Phase Compensation (All)	0x52A	41323	16	S	RW	0	Compensates for the inherent phase shift in current transformers for more accurate power measurements. Represented in units of 0.01 degrees. Writing to the "All" register sets the phase compensation values for all phases simultaneously. If the values are not identical in all three channels, the "All" register reads as "0". See p. 26.
Phase Compensation A	0x52B	41324	16	S	RW	0	
Phase Compensation B	0x52C	41325	16	S	RW	0	
Phase Compensation C	0x52D	41326	16	S	RW	0	
Energy Integer Divider	0x52E	41327	16	U	RW	100	Divisor for integer energy values to allow fitting into 32 bits. See p. 26.
SW Sub-Interval Length	0x52F	41328	16	U	RW	60	The length in seconds of a sub-interval for sliding window power. See p. 26.
SW Sub-Interval Count	0x530	41329	16	U	RW	15	The number of sub-intervals for sliding window power. See p. 26.
SW Synchronize	0x531	41330	16	U	RW	-	Resets the timer of the sliding window power calculation. See p. 26.
Auto Frequency Channel	0x532	41331	16	B	RW	True	Auto-select a valid voltage channel for frequency measurement. See p. 27.
Frequency Active Channel	0x533	41332	16	U	RW	0 (A)	Voltage channel used to measure frequency. 0, 1, 2 for A, B, C. See p. 27.
Reserved	0x534	41333	16	-	R	0	Reserved for future use. These registers output "0" when read. To ensure compatibility with future versions, these registers should not be written to.
…							
Reserved	0x53F	41344	16	-	R	0	
Scratch Pad Register 1	0x540	41345	16	-	RW	0	32 registers available for user storage. Values written here are stored in non-volatile memory. They can be used to store room numbers, customer IDs, etc. They can be used as 32 16-bit registers, or 16 32-bit registers.
…							
Scratch Pad Register 32	0x54F	41376	16	-	RW	0	

* Default values depend on the input type of the device. Milliamp units default to "1", 333 mV units default to "333", and 5A units default to "5". Because the primary and secondary values are equal for all models, the ratios all reduce to 1:1 regardless of the input type, by default.

5.6.2. *Setting PT Ratios*

Potential Transformer (PT) ratios allow the device to scale the data to report the real-world voltage values on the input of the potential transformers.

Because the WattsOn can accept up to 600V line-to-line voltage directly, potential transformers are often not required. In this case, PT ratios may be left at their default values of 1:1. If potential transformers are being used for higher voltages, and the same type of transformer is used on all three voltage channels, write the PT ratio primary into the *Primary PT Ratio (All)* register, at address **0x508** and the PT ratio secondary into the *Secondary PT Ratio (All)* register, at address **0x509**.

> **Example:** If a 600:120V PT is being used (that is, a PT that outputs 120V when the input voltage is 600V), write the value "600" to register 0x508, and the value "120" to register 0x509.

It is also permissible to use different PTs in each channel. In this case, it is necessary to enter the PT ratio primary into three separate registers, one for each channel. Write the value for channels A, B, and C into registers **0x50A**, **0x50C**, and **0x50E**, respectively. Enter the PT ratio secondary for channels A, B, and C into registers **0x50B, 0x50D**, and **0x50F**, respectively.

5.6.3. *Uptime*

The uptime register reports the number of seconds that the device has been running. This counter is reset when the device is powered off, reset, or the bootloader is started. Writes to this register are permitted if desired to represent a date, time, or elapsed time counter.

5.6.4. *Masking*

Modbus Masking is a feature used to change the Modbus map of the device. It can be enabled or disabled by writing a "1" or "0", respectively, to the *Modbus Enabled* register, **0x517**. Custom Modbus blocks may be configured to exist in the same register address space as the native WattsOn registers; this functionality can be enabled by writing a "1" to the *Masking Override* register, **0x518**. Otherwise, the WattsOn native registers will always override custom register blocks. See **6, Customizing the Register Map** (p. 33) for details on this feature.

5.6.5. *Low Current Noise Filtering*

When reading very low current values (such as below 1% of the unit's full scale), noise may become noticeable. Due to the design of the analog-to-digital converters in the device, there are slight oscillations at low input values, which may appear as reading instability. A proprietary noise filtering algorithm is employed by default to filter out noise when reading low current values, improving accuracy and increasing the dynamic range of the device. However, this will result in slower response times for low fluctuating signals. The settling time for slowly changing signals is approximately 5 seconds, however the settling time is much lower (i.e., under 500 ms) for signals that change magnitude quickly.

> **Note:** Energy accumulation accuracy is not affected by this setting.

Filtering may be disabled by writing a "0" to register **0x519** (41306).

5.6.6. *Setting 32-bit Endianness*

By default, the higher-order 16-bit word of a 32-bit register is the register with the lower Modbus address, and the lower-order word is at the higher address. Most Modbus software and devices will interpret 32-bit registers this way. Writing a "1" to the *32-bit Little Endian* register at address **0x51A** (41307) configures the WattsOn to reverse the 16-bit word ordering, so that the higher-order word is at the higher address, and the lower-order word is at the lower address. See the following table for an example.

For an total active power of 100,000 kW (hexadecimal 0x186A0)

32-bit Little Endian Mode register **0x51A** = 0 (default)

Register	Decimal	Hexadecimal
Active Power Total register **0x100**	1	0x0001
Active Power Total register **0x101**	34,464	0x86A0

32-bit Little Endian Mode register **0x51A** = 1

Register	Decimal	Hexadecimal
Active Power Total register **0x100**	34,464	0x86A0
Active Power Total register **0x101**	1	0x0001

5.6.7. Setting LED Thresholds

The WattsOn features an LED for each of the three current channels and each of the three voltage channels on the device. These LEDs are off when there is low current or voltage on the corresponding input channel. By default, these thresholds are less than 0.1% of the unit's maximum measurement current (200 mA, 333 mV, or 10A, depending on the meter type), or less than 5% of the unit's maximum voltage (400 V).

These percentages can be changed via Modbus. To change the threshold at which the current LED turns on, write to the *Current LED Threshold* register at address **0x51B** (41308). Valid values are between 0 and 1000, representing 0.0% to 100.0%, respectively. To change the threshold at which the voltage LED turns on, write to the *Voltage LED Threshold* register at address **0x51C** (41309). Valid values are between 0 and 100, representing 0% and 100%, respectively. These settings apply to all channels.

The current LEDs also indicate direction of power flow and poor power factor; see **2.1.2, Current &** Power Indicators (p. 7) for details.

5.6.8. Resetting Accumulated Energy

To reset the resettable accumulated data registers to 0, write the hexadecimal value 0xA5A5 (decimal value 42405) into the *Energy Reset* register, **0x524**. Note that this will not affect that data in the revenue accumulated data registers; they will continue to hold their former values despite any resets.

5.6.9. WattsOn-1100 Compatibility Mode

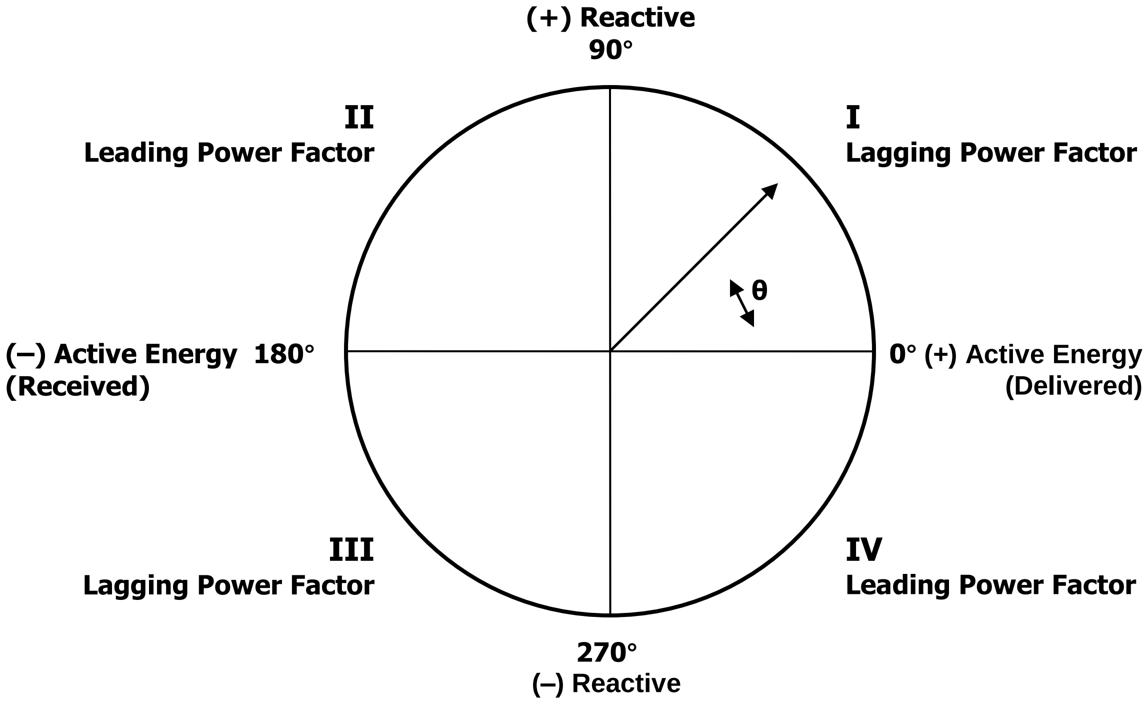
By writing a "1" to the *Compatibility Mode* register, **0x525**, the WattsOn-Mark II will emulate a partial register map of the legacy WattsOn-1100. The 32-bit floating-point registers from **0x300** to **0x376**, as well as the configuration registers from **0x080** to **0x09E** are emulated while in this mode. The 16-bit integer registers are not emulated. See the WattsOn-1100 manual for details on these registers. With the exception of the CT ratios, PT ratios, and scratch pad registers, the registers in the WattsOn-1100 configuration block are read-only; other settings must be configured using the WattsOn-Mark II configuration registers instead.

5.6.10. Power Factor Sign Mode

The sign of the power factor registers can be determined in several different ways. This is summarized in the table to the right.

Power quadrants (relevant in sign mode 3) are illustrated in the diagram below.

Sign Mode	Description
0	Absolute value Always positive.
1	Follows real power The power factor has the same sign as the real power.
2	Follows reactive power The power factor has the same sign as the reactive power.
3 (default)	Quadrant Positive when the power is in quadrants 1 or 3 Negative when the power is in quadrants 2 or 4



5.6.11. Password Protection

The WattsOn-Mark II features a password protection system. The device can be locked to prevent writes to ***ALL*** of its registers, preventing any settings from being changed or operations (resets, reboots, etc.) to be performed.

Lock Register Operation	Value
Unlock	0
Lock/Confirm Passcode	1
Change Passcode	2

(i) Setting a Password

1. Write any 32-bit number except 0 into the *Passcode* register, **0x527**. This number is the password. Whenever a password has been entered, this register will read "1".
2. Write "2" to the *Lock* register, **0x529.**
3. Write the same password into the *Passcode* register, **0x527**, a second time.
4. Write "1" to the *Lock* register. A password has now been set, and the device is now locked.
5. Read the *Lock* register to confirm that it now read "1", indicating that the device is now locked.

(ii) Unlocking the Device

1. Write the password into the *Passcode* register, **0x527**. This register will read "1".
2. Write "0" to the *Lock* register. If the password was correct, the device is now unlocked (the *Lock* register will read as 0) and the device can be written to normally. If the password was incorrect, the *Lock* register will continue to read "1", and the device will reject all password attempts for the next 5 seconds.

   Once the device has been unlocked, it will remain unlocked for 10 minutes, or until the device is either manually locked again or rebooted, whichever comes first. To permanently unlock the device, see *(v) Removing Password Protection*.

(iii) Locking the Device (if a password has previously been set)

1. Write the password into the *Passcode* register, **0x527**. This register will read "1".
2. Write "1" to the *Lock* register. If the password was correct, the device is now locked (the *Lock* register will read as 1) and the device cannot be written to until unlocked again. If the password was incorrect, the *Lock* register will continue to read "0", and the device will remain unlocked.
3. Read the *Lock* register to confirm that it reads "1", indicating that the device is now locked.

(iv) Changing the Password

1. If the device is locked (the *Lock* register, **0x527** reads "1"), unlock the device; see *(ii) Unlocking the Device*.
2. Write a new password (any 32-bit number except 0) into the *Passcode* register, **0x527**. This register will now read "1".
3. Write "2" to the *Lock* register, **0x529.**
4. Write the same password into the *Passcode* register, **0x527**, a second time.
5. Write "1" to the *Lock* register. The password has now been changed, and the device is now locked.
6. Read the *Lock* register to confirm that it now reads "1", indicating that the device is now locked.

(v) Removing Password Protection

1. If the device is locked (the *Lock* register, **0x527** reads "1"), unlock the device; see *(ii) Unlocking the Device*.
2. Write "0" into the *Passcode* register, **0x527**. This register will now read "1".
3. Write "2" to the *Lock* register, **0x529**. The password protection has now been removed.

5.6.12. Phase Compensation

Most current transformers have an inherent phase shift. This causes inaccuracies in power measurements as the power factor decreases. If the phase shift of a particular type of CT is known, the WattsOn can compensate for this phase shift either globally or per-phase.

Phase compensation values are entered in hundreds of a degree, so a value of 1 represents a 0.01° compensation for lag. Some current transformers have the phase shift value printed on the label.

5.6.13. Energy Integer Divider

It is recommended to read the device using floating-point registers if possible, as floating-point registers can represent arbitrarily large energy values regardless of the scaling applied.

When using integer accumulated data registers, as described in section **5.5, Accumulated Data Registers** (p. 15), only values between -2,147,483,648 and +2,147,483,647 can be read. In order to permit reading larger energy values, they are first divided by the divider programmed into the *Energy Integer Divider* register, **0x52E** (by default, 100) before they are returned in these registers. With the default setting, the base resolution of the integer registers is 100 Wh/VAh/VARh.

Depending on the size of the system being monitored, it may be desirable to use a higher divider (if reaching values in excess of 2 billion is anticipated soon), or a lower divider (for greater resolution). Set this register to 1 to read individual Watt-hours (or VAh/VARh), or 1000 to read kWh (or kVAh/kVARh). Only multiples of 10 from 1 to 10000 may be used. Floating-point registers do not make use of this register.

Example 1: Suppose the system is consuming 10,000 kW. After 1 hour, the WattsOn will accumulate 10,000,000 Wh of energy. With a default divider of 100, the energy register would read "100,000" at this time. Dividing the maximum value (2,147,483,647) by 100,000 yields about 21,475 hours (2.5 years) before the energy will no longer fit into a 32-bit register. The divider should be set to a higher value, such as 1,000 to extend to use of these registers, or floating-point may be read instead.

Example 2: Suppose the system is consuming 100 kW. After 1 hour, the WattsOn will accumulate 100,000 Wh of energy. With a default divider of 100, the energy register would read "1,000" at this time. Dividing the maximum value (2,147,483,647) by 1,000 yields about 2,147,484 hours (250 years) before the energy will no longer fit into a 32-bit register. The divider may be set to a lower value, such as 10 to increase the resolution of the energy registers from 100 Wh/VAh/VARh to 10 Wh/VAh/VARh.

5.6.14. Sliding Window Demand Power Measurement

The WattsOn can measure the average power over an arbitrary interval of time, called demand power. The interval length can be programmed in seconds to any value between 1 and 65,535 seconds. Typical values are 1 minute (60 seconds), 5 minutes (300 seconds), 10 minutes (600 seconds), 15 minutes (900 seconds), 30 minutes (1800 seconds), 1 hour (3600 seconds), or any arbitrary value expressed in seconds.

In addition, the WattsOn can be configured to measure sliding window (also called rolling demand) power. In this case, the time interval is divided into several sub-intervals. The average power over the full interval is updated each sub-interval. This device can be configured for up to 60 sub-intervals. The interval length is equal to the sub-interval length times the number of sub-intervals. If sub-intervals are not needed, set the sub-interval count to 1.

> **Example 1:** To configure the device to record the average power over 15 minute intervals, set the *SW Sub-Interval Length* register, **0x52F**, to 900 (15 minutes × 60 seconds) and the *SW Sub-Interval Count* register, **0x530**, to 1. Every 15 minutes, the *Sliding Window Power* registers will update with the average power over the previous 15 minutes.

> **Example 2:** To configure the device to record the average power over 15 minute intervals, updating every 5 minutes, set the *SW Sub-Interval Length* register, **0x52F**, to 300 (5 minutes × 60 seconds) and the *SW Sub-Interval Count* register, **0x530**, to 3 (15 minute intervals ÷ 5 minute sub-intervals). Every five minutes, the *Sliding Window Power* registers will update with the average power over the previous 15 minutes.

Writing any value to the *SW Sub-Interval Length* register, the *SW Sub-Interval Count* register, or writing a 1 to the *SW Synchronize* register restarts the demand interval.

5.6.15. Frequency Measurement Channel

Frequency is measured using one of the three voltage channels. By default, the device will automatically select a voltage channel with an RMS voltage greater than 5V on which to perform the frequency measurement. If the voltage in this channel falls to below 5V, a new channel will be automatically selected. If no channel contains a voltage above this threshold, the frequency will read "0". The channel currently being used is displayed in the *Frequency Active Channel* register, **0x533** (0, 1, and 2 represent channels A, B, and C, respectively).

The meter may instead be forced to use a specific voltage channel for frequency measurement. To do so, first disable automatic channel selection by writing "0" into the *Auto Frequency Channel* register, **0x532**. Then, write a value into the *Frequency Active Channel* register corresponding to the desired channel to be used for frequency measurement, with "0" representing channel A (the first channel from the left), "1" representing channel B, and "2" representing channel C.

5.6.16. Scratch Pad Registers

There are 32 scratch pad registers available, starting at register **0x540** and ending at **0x55F**. Any values can be written to these registers. Values written to these registers will be stored in non-volatile memory so that they are retained after the device has been powered off or rebooted. These can be used for room numbers, customer IDs, or any other purpose as desired. These registers are not used for any measurement purposes.

> **Note:** Consideration should be given to the fact that these registers are written to flash memory, which has limited write cycle endurance. Writes should be limited to fewer than 10,000 operations. Writes in excess of 10,000 may cause the device to become permanently read-only in order to protect itself from a flash failure.

5.7. System Registers

These registers are used to configure the serial communication parameters, to reset the device, or to enter the device's bootloader mode for firmware updates.

Name	Offset	Address	Size	Type	R/W	Default	Description
Modbus Address	0x600	41537	16	U	RW	15	If the hardware address switch is in the "F" position, the value set here is used instead of the switch's address. This allows addressing more than 15 Modbus devices on the same line.
Serial Baud Rate	0x601	41538	16	U	RW	9600	Sets the device's serial parameters. These settings are not applied until a "1" is written to the Serial Commit register, and are not permanent until a valid Modbus query message is received using the new settings.
Serial Parity Mode	0x602	41539	16	U	RW	0	
Serial Stop Bits	0x603	41540	16	U	RW	1	
Serial Response Delay	0x604	41541	16	U	RW	0	
Serial Commit	0x605	41542	16	U	RW	0	
Reserved	0x606	41543	16	-	R	0	Reserved for future use. These registers output "0" when read. To ensure compatibility with future versions, these registers should not be written to.
Reserved	0x607	41544	16	-	R	0	
Device Mode	0x608	41545	16	U	R	1	"1" indicates the device firmware is running normally, "2" indicates the device is in bootloader mode.
Reset to Firmware	0x609	41546	16	U	W	0	Write the value 0xAA55 (43605) to reboot the unit. This register always reads as "0".
Reset to Bootloader	0x60A	41547	16	U	W	0	Write the value 0xB001 (45057) to reboot the unit. When reset in this way, the device will enter bootloader mode. This register always reads as "0".

5.7.1. Modbus Addresses above 15

Using the rotary switch, addresses from 1-15 can be set. The switch indicates numbers as hexadecimal values, with 1-9 being shown as normal, A representing 10, B representing 11, and so on. When the rotary switch is set to F (15), the device will instead use an address entered into the *Modbus Address* register, **0x600**, which defaults to 15. This allows addresses of 16 or greater to be assigned, or allows the address to be configurable conveniently over Modbus. Addresses up to 247 can be programmed into this register; higher addresses are not allowed under the Modbus specification.

Changes are not applied until a "1" is written to the *Serial Commit* register. Once the change is applied, a read of any register must be performed using the new Modbus address to confirm the change. See **5.7.3, Confirming Serial Settings Change** (p. 29) for details.

5.7.2. Configuring Serial Parameters

By default, the WattsOn ships pre-configured with the most common serial settings — 9600 baud, no parity, 8 data bits, 1 stop bit. In addition to the default settings, the WattsOn supports a variety of other baud rates, parity modes, and stop bit modes.

Supported serial settings are listed in the table below.

Parameter	Default Setting	Supported Values
Baud rate	9600	9600, 19200, 28800, 38400, 48000, 57600, 115200, 230400
Parity	No Parity (0)	No Parity (0), Odd Parity (1), Event Parity (2)
Stop bits	1	1, 2

Settings are changed by writing to the corresponding Modbus registers. To change the baud rate, write the new value to the *Serial Baud Rate* register **0x601**. For baud rates below 115200, write the value as-is into the register. For instance, to change the baud rate to 57600, write "57600" to register **0x601**. For baud rates equal to or greater than 115200, write only the first three digits into the register; this is done because such values are too large to fit into 16-bit registers. For instance, to change the baud rate to 115200, write "115" to register **0x601**. To change the parity mode, write a "0" for no parity, "1" for odd parity, or "2" for even parity into the *Serial Parity Mode* register **0x602.** To change the number of stop bits, enter "1" for 1 stop bit or "2" for 2 stop bits into the *Serial Stop Bits* register **0x603**.

In cases where legacy Modbus master devices cannot process responses fast enough, it may be necessary to enable a response delay within the WattsOn. If such problems exist, a delay may be introduced by using the Serial Response Delay register **0x604**. The WattsOn will wait at least as long as specified by this register (in milliseconds) before responding. Generally, small values between 0 to 100 milliseconds are sufficient. The default value is "0", meaning that the WattsOn will respond as soon as its data is ready to reply to the query.

Changes are not applied until a "1" is written to the *Serial Commit* register. This is to ensure that all serial settings are applied at once, in case that more than one serial parameter was changed. Once the changes are applied, the new settings must be confirmed by reading any register using the new settings, as described in the section below.

5.7.3. Confirming Serial Settings Change

In order to guard against accidental changes to the device's serial settings and to protect against incorrect or unknown values, there is a 3-minute period in which the Modbus master device must successfully communicate with the WattsOn before the new settings become permanent. This is to ensure that the Modbus master software or device is capable of correctly communicating at the new settings. Reading or writing any register, or using any other Modbus function, is sufficient for this purpose. If a successful query is not received within the 3-minute waiting period, or the WattsOn was rebooted before a successful communication, the previous settings will be restored.

As an additional failsafe, when the WattsOn's Modbus address is set to address 0 via the rotary switch on the unit, it will always communicate using default serial settings (9600 baud, no parity, 1 stop bit). While set to address 0, the device responds to Modbus queries addressed to **any** Modbus address. The device may then be reconfigured to the appropriate serial settings. Note that once the WattsOn's serial settings are changed, the Modbus address must be set to a non-zero value before it will begin using the new settings, so that the new settings can be confirmed as described in the paragraph above. New serial settings **cannot** be confirmed while in address 0.

5.7.4. Changing Settings from a Known Configuration

A step-by-step procedure for changing the serial configuration from a known configuration is described below. Use this procedure if communications with the device is established, but changes to the Modbus settings are required. *This procedure does not require physical access to the device (it can be done from a remote location).*

1. Change the desired serial parameters by writing to the corresponding Modbus registers.
2. Write a "1" to the *Serial Commit* register **0x605**
3. Change the Modbus master device's serial settings to match the settings applied to the WattsOn.
4. Read any register from the WattsOn using the new serial settings within 3 minutes to make the change permanent. Note that the WattsOn should remain powered during this time, or its settings will revert to their previous values.

> **Note:** If the settings do not work with the Modbus master device, or if a mistake was made, wait 3 minutes or power cycle the device, and the previous settings will be restored.

5.7.5. Changing Settings from an Unknown Configuration

A step-by-step procedure for changing the serial settings from an unknown configuration is described below. Use this procedure if the device settings are not known, and communication is not possible. *This procedure requires physical access to the device.*

1. Set the device's Modbus address to 0 using the hardware rotary switch on the device. This sets the device's serial settings to their factory defaults.

> **Note 1:** In address 0, the WattsOn responds to queries sent from any address. This may include queries intended for other devices on the Modbus line. It is therefore recommended that any other devices be removed from the Modbus line when performing this procedure.

> **Note 2:** If the device is powered on while its address is already set to 0, it will enter bootloader mode. The serial settings can be changed in either mode, but the device must be rebooted with a non-zero address once the procedure is complete in order to read the data registers.

2. Set the Modbus master device's serial settings to 9600 baud, no parity, 8 data bits, and 1 stop bit.

3. Set the serial parameters to the desired values by writing to the corresponding Modbus registers.
4. Write a “1” to the *Serial Commit* register **0x605**
5. Set the device’s Modbus address to 1 (or any non-zero value).
6. Set the Modbus master device to communicate with the WattsOn at the address and serial settings from step 3.
7. Read any register from the WattsOn using the new settings within 3 minutes to make the change permanent. Note that the WattsOn should remain powered during this time, or its settings will revert to their previous values.

5.8. Relay Output Configuration Registers

The WattsOn has two highly configurable relay outputs. These relays can be configured for pulse output, alarm output, or status output. They are configured using the following Modbus register block.

Name	Offset	Address	Size	Type	R/W	Default	Description
Relay K1 Register Offset	0x900	42305	16	U	RW	0x1000	Offset of an integer data register to control the output. Floating-point registers cannot be used.
Relay K1 Trigger Type	0x901	42306	16	U	RW	0 (Relative)	Indicates whether the output is based on the relative value of the register (i.e., for pulses), or the absolute value of the register (i.e., for alarming).
Relay K1 Upper Bound	0x902	42307	32	S	RW	1	Trigger the output when the value (either relative or absolute) goes above this value.
Relay K1 Lower Bound	0x904	42309	32	S	RW	0	Trigger the output when the value (either relative or absolute) goes below this value.
Relay K1 Min Duration	0x906	42311	16	U	RW	100	Minimum duration that the output is triggered, in milliseconds. If the Trigger Type is set to "0" (Relative), this is the duration of the pulse. If it is set to "1" (Absolute), the relay will remain triggered for at least this long, even if the threshold is crossed for a shorter period of time. To hold indefinitely, enter the maximum value "65535" (hexadecimal 0xFFFF) – this will hold the event until any register in this block is written.
Relay K1 Active Mode	0x907	42312	16	U	RW	0 (N.O.)	"0" indicates that the output is normally open, "1" indicates that it is normally closed, and "2" indicates that the output toggles each time it is triggered.
Reserved	0x908	42313	16	-	R	0	Reserved for future use. These registers output "0" when read. To ensure compatibility with future versions, these registers should not be written to.
Reserved	0x909	42314	16	-	R	0	
Relay K2 Register Offset	0x90A	42315	16	U	RW	0x1002	Offset of an integer data register to control the output. Floating-point registers cannot be used.
Relay K2 Trigger Type	0x90B	42316	16	U	RW	0 (Relative)	Indicates whether the output is based on the relative value of the register (i.e., for pulses), or the absolute value of the register (i.e., for alarming).
Relay K2 Upper Bound	0x90C	42317	32	S	RW	1	Trigger the output when the value (either relative or absolute) goes above this value.
Relay K2 Lower Bound	0x90E	42319	32	S	RW	0	Trigger the output when the value (either relative or absolute) goes below this value.
Relay K2 Min Duration	0x910	42321	16	U	RW	100	Minimum duration that the output is triggered, in milliseconds. If the Trigger Type is set to "0" (Relative), this is the duration of the pulse. If it is set to "1" (Absolute), the relay will remain triggered for at least this long, even if the threshold is crossed for a shorter period of time. To hold indefinitely, enter the maximum value "65535" (hexadecimal 0xFFFF) – this will hold the event until any register in this block is written.
Relay K2 Active Mode	0x911	42322	16	U	RW	0 (N.O.)	"0" indicates that the output is normally open, "1" indicates that it is normally closed, and "2" indicates that the output toggles each time it is triggered.

Common configurations of the relay outputs are described below.

5.8.1. Configuring a Pulse Output

The relay outputs may be configured to pulse upon accumulation of a specified quantity of energy. To do so, follow the steps below.

1. Select which energy register to use for pulses, such as the *Net Total Energy* register, at address **0x1000**, or another register from the list of **Resettable Integer Accumulated Data Registers** (p. 17) or **Revenue (Non-Resettable) Integer Accumulated Data Registers** (p. 19). Enter the register offset into the *Relay K1 Register Offset* register, **0x900**, to pulse on the relay output labelled K1 on the device, or into the *Relay K2 Register Offset* register, **0x90A**, to pulse on the relay output labelled K2 on the device.
2. Write "0" into the *Relay K1/K2 Register Offset* register, **0x901/0x902** to indicate relative mode. This causes the pulses to trigger when the register value changes, rather than on a set value.
3. To pulse on positive energy accumulation (consumption), enter a value into the *Relay K1/K2* ***Upper*** *Bound* register, **0x902/0x90C**. By default, with the *Energy Integer Divider* register set to 100, the energy accumulation registers increase by 1 for each 100 Wh/VAh/VARh of energy. Therefore, enter "1" to pulse on every 100

Wh/VAh/VARh of energy accumulated, "10" for every 1.0 kWh/kVAh/kVARh, etc. To only pulse on negative energy accumulation (generation), write a "0" into this register.

4. To pulse on negative energy accumulation (generation), enter a value into the *Relay K1/K2* ***Lower*** *Bound* register, **0x904/0x90E**. As above, by default, a value of "1" represents 0.1 Wh/VAh/VARh. Write "0" to ignore negative energy accumulation.
5. Enter the desired duration of the pulse in milliseconds into the *Relay K1/K2 Min Duration* register, **0x906/0x910**. For example, enter "100" for 100 millisecond pulses, or 1000 for 1 second pulses.
6. To have the relay close when a pulse is generated (normally open), enter a "0" into the *Relay K1/K2 Active Mode* register, **0x907/0x911**. To have the relay open when a pulse is generated (normally closed), enter a "1" into that register. To have the relay toggle between being opened and closed with each pulse, enter a "2" into that register.

5.8.2. Configuring a Threshold/Alarm Output

The relay outputs may be configured to open or close when a register raises above or falls below a certain threshold. To do so, follow the steps below. Instantaneous data registers, accumulated data registers, or configuration registers may be used.

1. Select which register to use for alarming from the list of *Integer Instantaneous Data Registers* (p. 14). Enter the register offset into the *Relay K1 Register Offset* register, **0x900**, to trigger on the relay output labelled K1 on the device, or into the *Relay K2 Register Offset* register, **0x90A**, to trigger on the relay output labelled K2 on the device. Note the scaling factor of that register from the register table.
2. Write a "1" into the *Relay K1/K2 Register Offset* register, **0x901/0x902** to indicate absolute mode. This causes the relay to trigger above or below set values, rather than on relative changes.
3. To trigger the output when the parameter rises *above* a threshold value, enter a threshold value into the *Relay K1/K2 Upper Bound* register, **0x902/0x90C**. The threshold value should be scaled to match the scaling factor of the register selected in step 1. To only trigger the output when the value falls *below* a certain threshold, write "2,147,483,647" (hexadecimal 0x7FFFFFFF) into this register to disable the high threshold.

Example: To activate the relay whenever the *Voltage A* value rises above 130V, enter the value 13000 (the *Voltage A* register has a scaling factor of 100).

4. To trigger the output when the parameter falls *below* a threshold value, enter a threshold value into the *Relay K1/K2 Lower Bound* register, **0x904/0x90E**. The threshold value should be scaled to match the scaling factor of the register selected in step 1. To only trigger the output when the value rises *above* a certain threshold, write "-2,147,483,648" (hexadecimal 0x80000000) into this register to disable the low threshold.

Example: To activate the relay whenever *Voltage A* value falls below 90V, enter the value 9000 (the *Voltage A* register has a scaling factor of 100).

5. Enter the desired minimum duration of trigger in milliseconds into the *Relay K1/K2 Min Duration* register, **0x906/0x910**. For example, to ensure that the output is triggered for at least 1 second, enter "1000" into that register. "0" can be used if no minimum duration is required; in that case, the alarm output will follow the duration of the event. Note that most registers are updated once every 500 milliseconds. To hold the alarm indefinitely, enter the maximum value of 65535 (hexadecimal 0xFFFF); in this case, the alarm can be manually cleared by writing to any register in this register block, such as writing 65535 to this register again.
6. To have the relay close when the parameter is over/under the specified thresholds (normally open), enter a "0" into the *Relay K1/K2 Active Mode* register, **0x907/0x911**. To have the relay open when the parameter is over/under the specified thresholds (normally closed), enter a "1" into the register. To have the relay alternate between being opened and closed each time the parameter crosses a threshold, enter a "2" into the register.

6. CUSTOMIZING THE REGISTER MAP

The addresses of each register in the WattsOn may be customized to obtain compatibility with other devices. This is done using up to 4 customizable register blocks which can contain any register and may be placed at any address.

Each customizable register block may contain up to 126 registers. The first register in each block is placed at a customizable address, and each subsequent register follows it at consecutive addresses.

This feature is disabled by default. To enable this feature, write "1" to the *Masking Enabled* register, **0x517**, in the Configuration and Status Registers (p. 21); By default, custom register blocks cannot be placed in the same locations as existing registers, as doing so complicates troubleshooting. To allow placing custom register blocks in the same locations as existing registers, write "1" to the *Masking Override* register, **0x518**.

To create a custom block, write the block's starting address to Address register, **0x1500** (for the first block, or **0x1600, 0x1700,** or **0x1800**, for the second, third, and fourth blocks, respectively). Next, write the number of registers that the block will contain to the Size register, **0x1501** (or **0x1601, 0x1701,** or **0x1801** for the second, third, and fourth blocks, respectively). Finally, write the Modbus address of each register that will be included in the block at addresses from **0x1502** to **0x157F** (or from **0x1602, 0x1702,** or **0x1802** for the second, third, and fourth blocks, respectively).

> **Note**: To include 32-bit registers, the two consecutive offsets will need to be written (for the higher and lower order register).

> **Example:** To place the *Net Total Energy* and *Firmware Version* registers in a custom block starting at offset **0x400**, enter "0x400" into start address register **0x1500**. *Total Energy Consumption* is 32-bits long, so it occupies 2 registers, while *Firmware Version* is 16-bit, occupying 1 register, for a total of 3 registers occupied in total. Enter "3" into block size register **0x1501**.
>
> Enter the values "0x1100", "0x1101", and "0x520" into the registers **0x1502** to **0x1504**. Because *Net Total Energy* is 32-bit, both "0x1100" and "0x1101" must be entered.

Setting the Size register to 0 will remove a custom Modbus block. In the event that a custom Modbus block is in the same location as the Masking Enabled or Masking Override registers, custom Modbus blocks can be removed by writing a "0" to each of the size registers, **0x1501, 0x1601, 0x1701,** and **0x1801**.

Custom Register Map Block 1

Name	Offset	Address	Size	Type	R/W	Default	Description
Custom Block 1 Address	0x1500	45377	16	U	RW	0	Modbus offset at which the 1st custom Modbus block will be placed.
Custom Block 1 Size	0x1501	45378	16	U	RW	0	Number of registers in the 1st custom Modbus block.
Custom Block 1 Register 1	0x1502	45379	16	U	RW	0	List of register offsets of the registers that will be included in the 1st custom Modbus block. Register addresses beyond the count specified in the Size register will be ignored.
Custom Block 1 Register 2	0x1503	45380	16	U	RW	0	
⋮							
Custom Block 1 Register 126	0x157F	45504	16	U	RW	0	

Custom Register Map Block 2

Name	Offset	Address	Size	Type	R/W	Default	Description
Custom Block 2 Address	0x1600	45633	16	U	RW	0	Modbus offset at which the 2nd custom Modbus block will be placed.
Custom Block 2 Size	0x1601	45634	16	U	RW	0	Number of registers in the 2nd custom Modbus block.
Custom Block 2 Register 1	0x1602	45635	16	U	RW	0	List of register offsets of the registers that will be included in the 2nd custom Modbus block. Register addresses beyond the count specified in the Size register will be ignored.
Custom Block 2 Register 2	0x1603	45636	16	U	RW	0	
⋮							
Custom Block 2 Register 126	0x167F	45760	16	U	RW	0	

Custom Register Map Block 3

Name	Offset	Address	Size	Type	R/W	Default	Description
Custom Block 3 Address	0x1700	45889	16	U	RW	0	Modbus offset at which the 3rd custom Modbus block will be placed.
Custom Block 3 Size	0x1701	45890	16	U	RW	0	Number of registers in the 3rd custom Modbus block.
Custom Block 3 Register 1	0x1702	45891	16	U	RW	0	List of register offsets of the registers that will be included in the 3rd custom Modbus block. Register addresses beyond the count specified in the Size register will be ignored.
Custom Block 3 Register 2	0x1703	45892	16	U	RW	0	
⋮							
Custom Block 3 Register 126	0x177F	46016	16	U	RW	0	

Custom Register Map Block 4

Name	Offset	Address	Size	Type	R/W	Default	Description
Custom Block 4 Address	0x1800	46145	16	U	RW	0	Modbus offset at which the 4th custom Modbus block will be placed.
Custom Block 4 Size	0x1801	46146	16	U	RW	0	Number of registers in the 4th custom Modbus block.
Custom Block 4 Register 1	0x1802	46147	16	U	RW	0	List of register offsets of the registers that will be included in the 4th custom Modbus block. Register addresses beyond the count specified in the Size register will be ignored.
Custom Block 4 Register 2	0x1803	46148	16	U	RW	0	
⋮							
Custom Block 4 Register 126	0x187F	46272	16	U	RW	0	

7. FIRMWARE UPDATES AND THE BOOTLOADER

The WattsOn device contains a bootloader, a small program used to update the device's firmware. While running in bootloader mode, the device supports only the System registers listed in section **5.7** for adjusting Modbus settings and rebooting the device.

The device enters bootloader mode under three conditions:

- The value "0xB001" is written to the *Reset to Bootloader* register at address **0x60A**.
- The device is restarted with its Modbus address DIP switch set to 0.
- The device's firmware is corrupt, possibly due to a failed attempt to update the firmware.

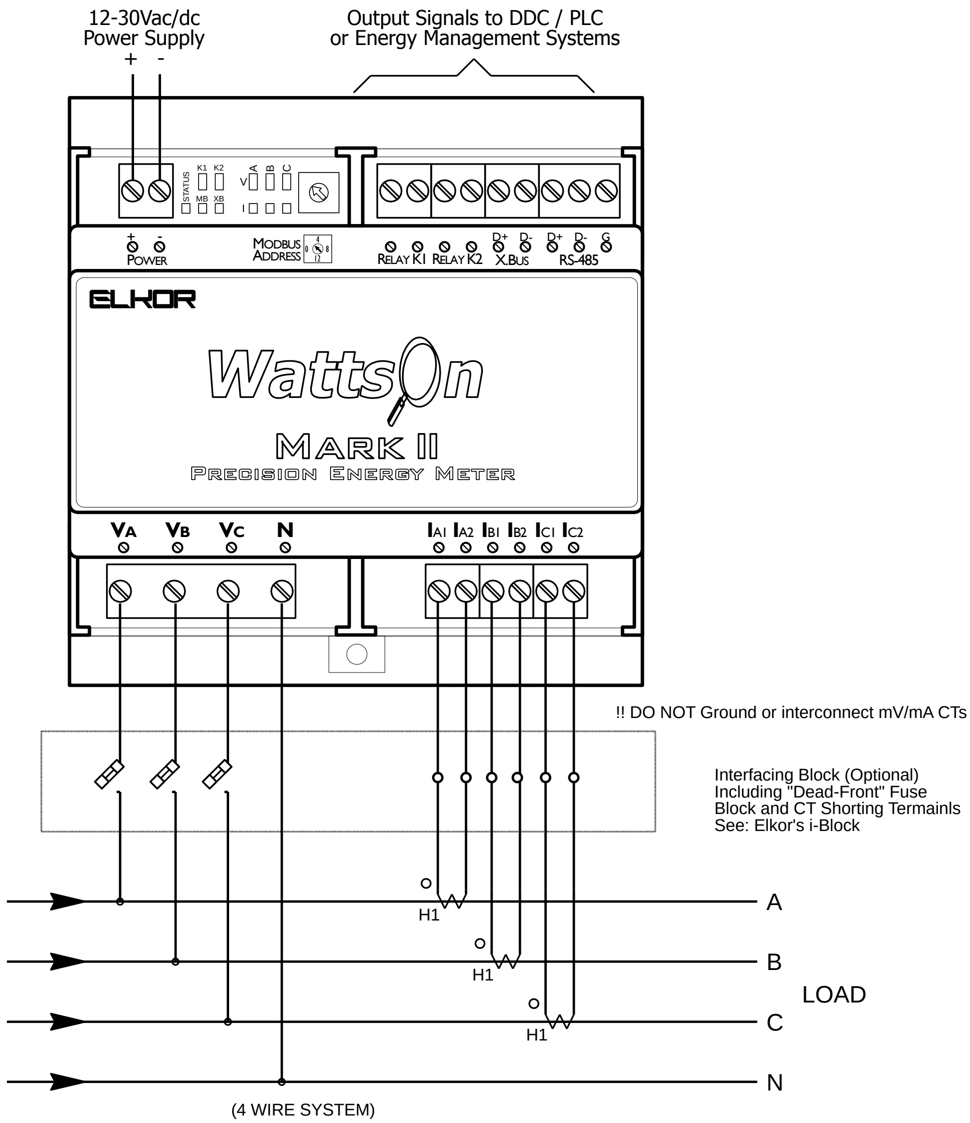
While in bootloader mode, the device's status LED periodically flashes twice. If the device's firmware is corrupt, the LED flashes red, otherwise it flashes green. See section **2.1.1, Status Indicator Codes** (p. 7) for details.

To exit bootloader mode, ensure the Modbus address DIP switch is not set to 0, and either power cycle the unit, or write the value "0xAA55" to the *Reset to Firmware* register at address **0x609.** If the device's firmware is corrupt, new firmware must be uploaded to the device before it can leave bootloader mode.

If communications is done via a PC, Elkor's software may be used to update the device firmware. Please contact Elkor for details on the firmware update protocol if required.

8. APPENDIX A, WIRING DIAGRAMS

8.1. Four-Wire (Wye) Wiring Diagram



The wiring shown is applicable for all CT types.

In the case of 5A CTs, additional grounding may be required as per local electrical codes.

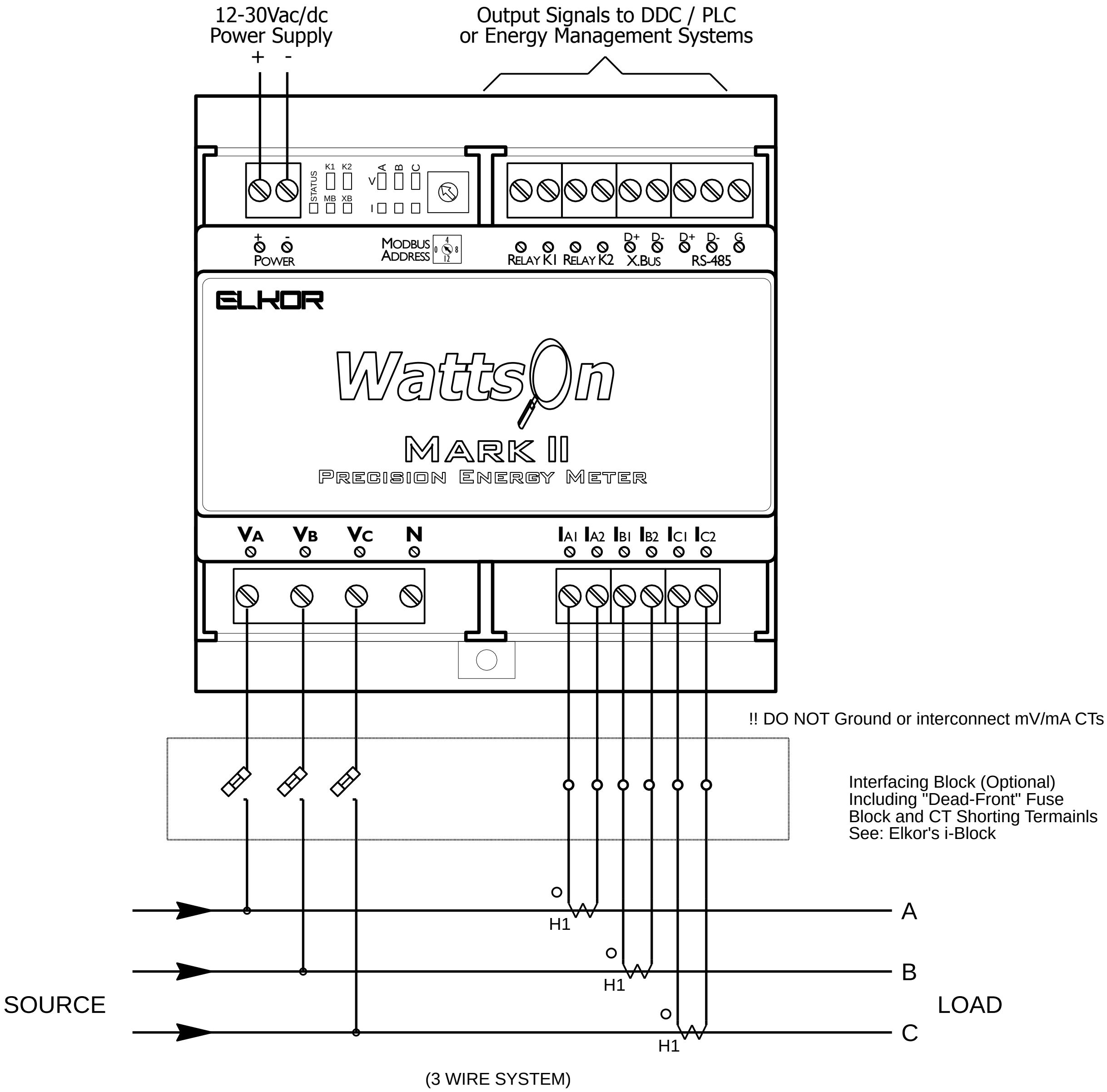
mV and mA CTs **must NOT** be grounded or interconnected in any way.
Each CT wire pair, must be terminated at the corresponding input terminals.
mV and mA CTs must not be used to feed multiple equipment.

mV and Elkor's mA CTs do not require the use of a shorting mechanism. Their outputs are low energy, voltage limited.

CT Orientation (on the conductor), CT Polarity (into the meter) and CT phasing (relationship to voltage phase) MUST be observed for correct meter operation.

System voltage and CT insulation class (typically 600V) must be observed.

8.2. Three-Wire (Delta) Wiring Diagram (Three CTs)



The wiring shown is applicable for all CT types.

In the case of 5A CTs, additional grounding may be required as per local electrical codes.

mV and mA CTs **must NOT** be grounded or interconnected in any way.
Each CT wire pair, must be terminated at the corresponding input terminals.
mV and mA CTs must not be used to feed multiple equipment.

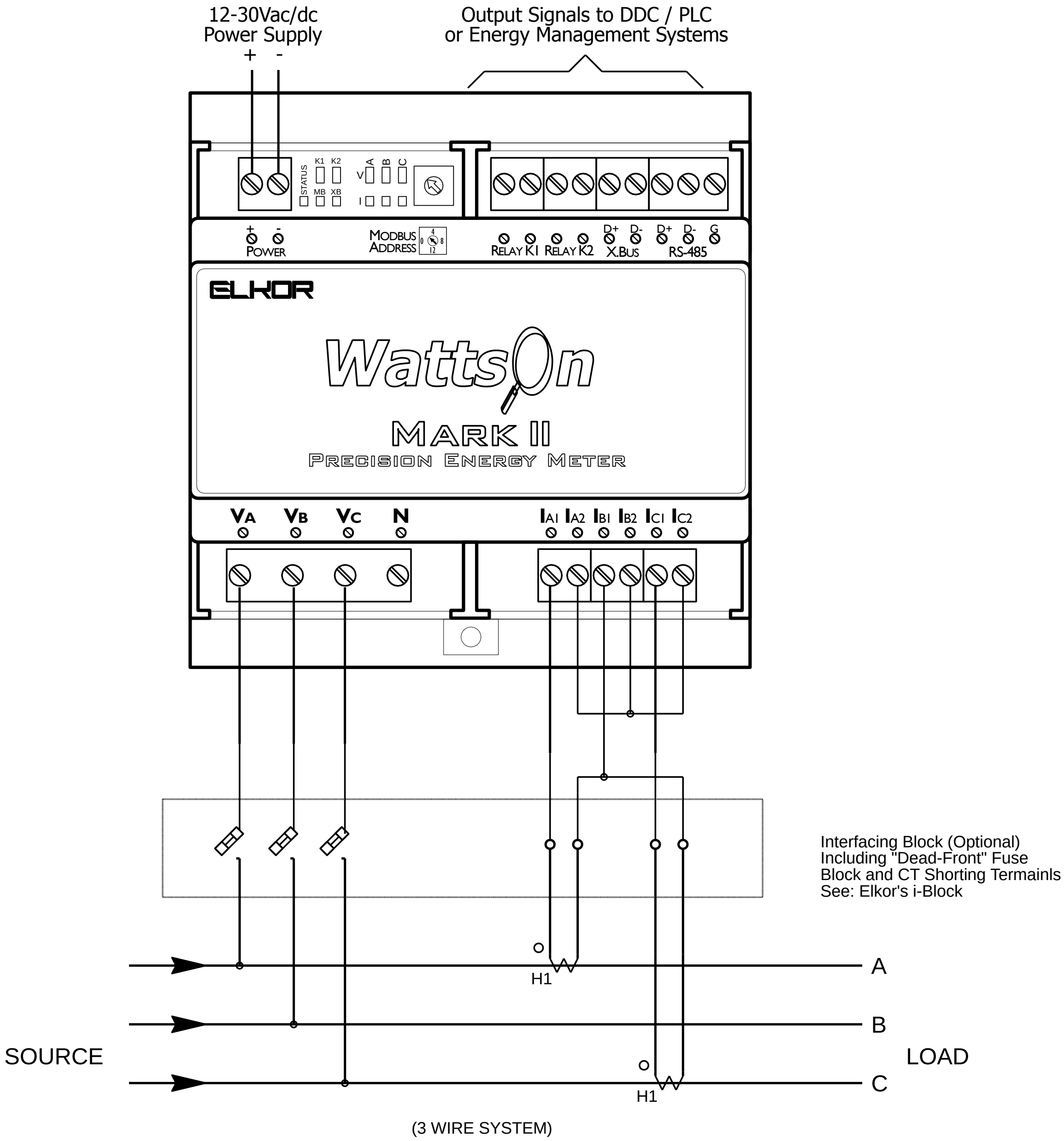
mV and Elkor's mA CTs do not require the use of a shorting mechanism. Their outputs are low energy, voltage limited.

CT Orientation (on the conductor), CT Polarity (into the meter) and CT phasing (relationship to voltage phase) MUST be observed for correct meter operation.

System voltage and CT insulation class (typically 600V) must be observed.

8.3. Three-Wire (Delta) Wiring Diagram (Two CTs)

NOTE: This wiring method may only be used with the 5A input versions



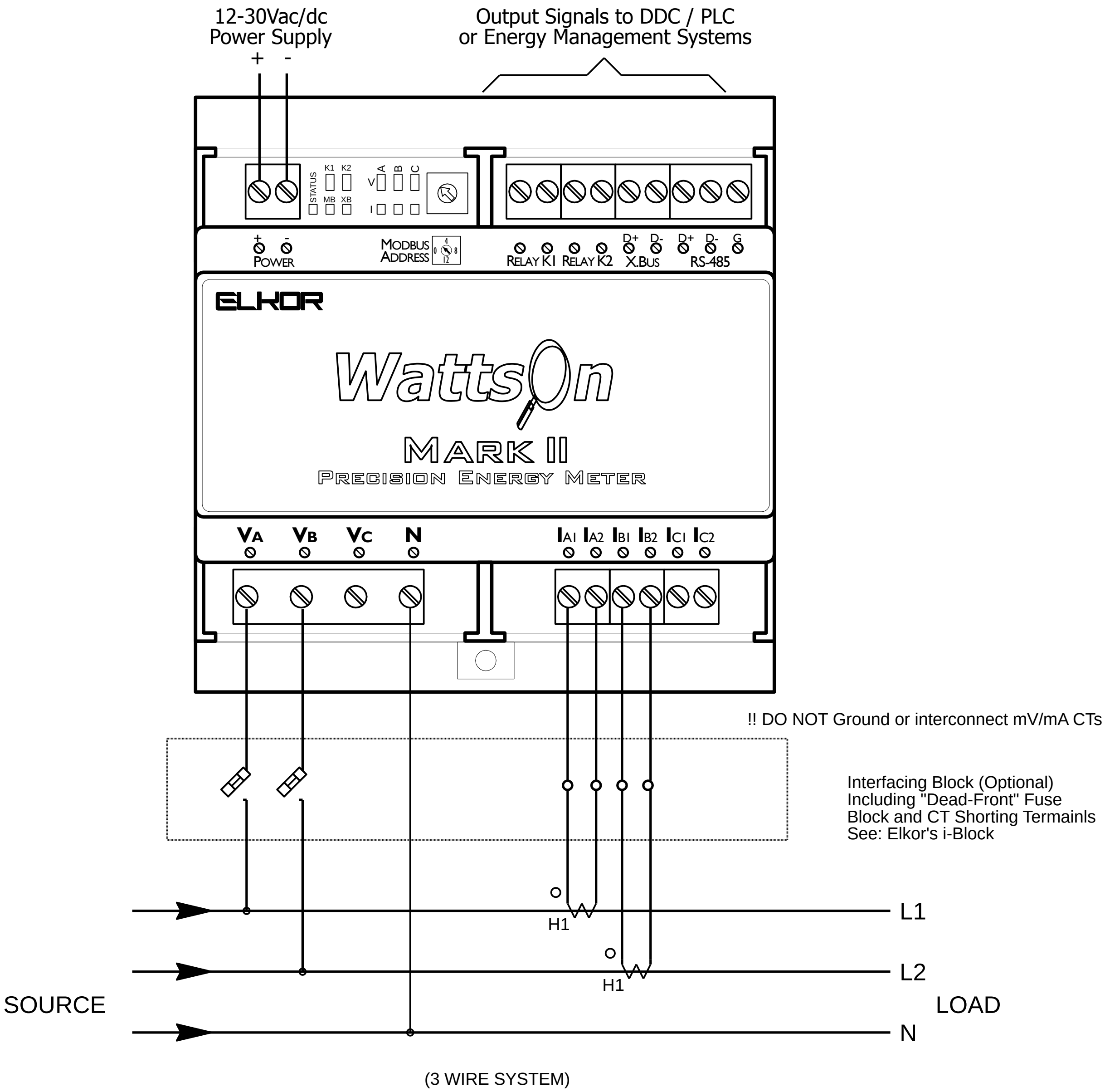
WARNING: This wiring method works only with 5A meters/CTs. When using mV or mA CTs, the 3 wire, 3 CT method must be used (see section 3.9)

In this configuration, additional grounding may be required as per local electrical codes.

CT Orientation (on the conductor), CT Polarity (into the meter) and CT phasing (relationship to voltage phase) MUST be observed for correct meter operation.

System voltage and CT insulation class (typically 600V) must be observed.

8.4. Split-Phase Wiring Diagram



The wiring shown is applicable for all CT types.

In the case of 5A CTs, additional grounding may be required as per local electrical codes.

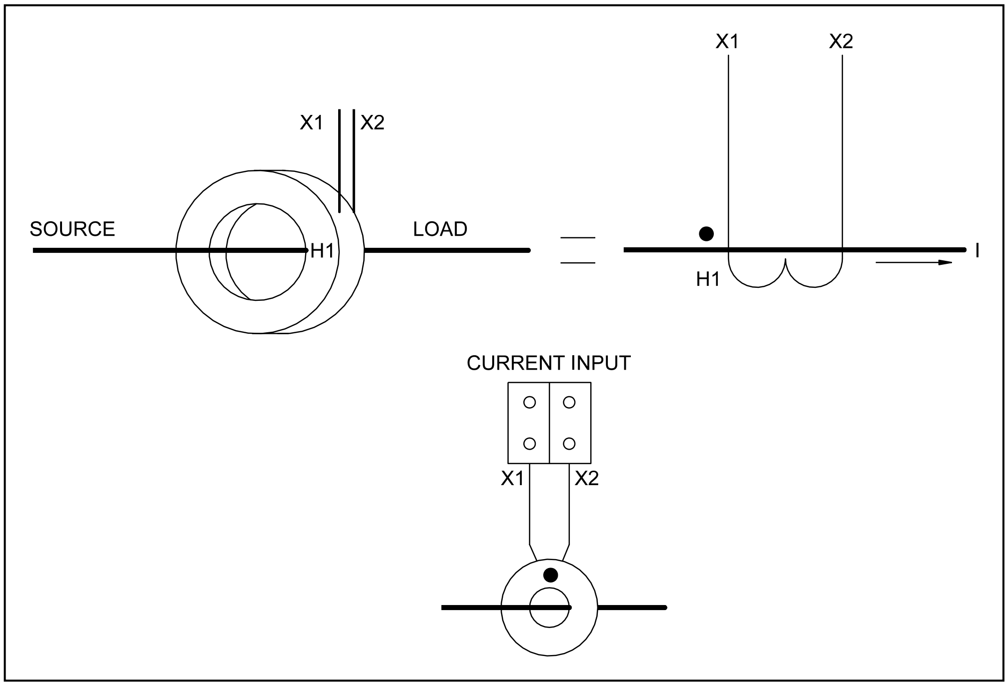
mV and mA CTs **must NOT** be grounded or interconnected in any way.
Each CT wire pair, must be terminated at the corresponding input terminals.
mV and mA CTs must not be used to feed multiple equipment.

mV and Elkor's mA CTs do not require the use of a shorting mechanism. Their outputs are low energy, voltage limited.

CT Orientation (on the conductor), CT Polarity (into the meter) and CT phasing (relationship to voltage phase) MUST be observed for correct meter operation.

System voltage and CT insulation class (typically 600V) must be observed.

8.5. CT Wiring Notes



Note: Usually, CTs are marked as shown above, where the 'H1' indicates the primary current input and 'X1' the corresponding secondary current terminal (or lead).

- While specifying CTs, one should consider both the electrical and mechanical parameters such as primary wire size, mounting arrangement, insulation level, the expected load current and accuracy requirements.

- If the load is unknown, the bus rating, or better still, the transformer size may be used for the maximum current calculations. CTs can tolerate large over-correct conditions without damage and the WattsOn can accept a 20% continuous input overload.

- 5A CTs are designed to operate with their secondary winding in permanent short, or very close to the short condition. The 5A WattsOn models provide 0.05Ω burden. If the secondary winding is open while a primary current is present, high voltage will be generated on the output. **This voltage may create a hazard to the personnel and in some situations it may damage the CT insulation.** Provisions should be made to short the secondary winding before any re-wiring is performed. We recommend using a metering Test Switch or CT Shunting Blocks to be wired between 5A CTs/PTs and WattsOn meter (ie: Elkor i-Block™).

- mV and Elkor's mA CTs feature voltage limited outputs, and shorting mechanisms may be omitted.

- Grounding may be required for 5A CTs *only*. 5A WattsOn models have isolated current inputs and 5A CT grounding is permissible. For two element systems (3 wires), grounding of CTs and PTs should be carefully observed.

- For mV and mA meter models, CTs must *not* be grounded, or interconnected with each other or any device. Each CT wire pair must be terminated at the corresponding meter current inputs.

CT Orientation (on the conductor), CT Polarity (into the meter) and CT phasing (relationship to voltage phase) MUST be observed for correct meter operation.

9. APPENDIX B, MODBUS PROTOCOL DETAILS

Modbus RTU is a protocol used to read and write information from a variety of devices such as the WattsOn. Generally, the details of the protocol are handled by the Modbus master software or device, so that the user need not be familiar with their implementation. For full details regarding the Modbus protocol, see the official Modbus specification available for free from http://www.modbus.org/specs.php. This section summaries the Modbus RTU protocol as it pertains to the WattsOn device.

9.1. Modbus Frames

Modbus messages are represented as frames of no more than 256 bytes each. The start of a frame is defined as no transmissions for at least 3.5 character periods, followed by the Modbus address (a one-byte number between 1 and 247) and the Modbus function code (a one-byte number). The contents of the frame vary between different function codes. At the end of the frame, comes a 2-byte checksum value used to verify that the frame was not corrupted during reception. Fields of 2 bytes or more, including the checksum, are transmitted with the most-significant byte first (big-endian order).

The Modbus master device sends "request" messages to a slave device, which responds with a "response" message. Both request and response messages share the same basic format:

Start	Modbus Address	Function Code	Frame Contents	CRC
3.5 character times	(1 byte)	(1 byte)	(up to 252 bytes)	(2 bytes)

Start: No transmission for 3.5 character times. This is about 3.65 milliseconds with default serial settings.

> **Example:** At a baud rate of 9600 bits per second, with one stop bit, one character requires 10 bits to transmit (one start bit, eight data bits, and one stop bit). Each bit takes 1/9600 seconds to transmit. Transmitting 3.5 characters of 10 bits each, therefore, takes 35/9600 seconds, or about 3.65 milliseconds.

Modbus Address: This should match the address indicated on the hardware address switch, or match the software-configured value if the switch is set to "F".
Function Code: Available function codes are described in subsequent sections.
Frame Contents: Varies with the function code, as described in subsequent sections.
CRC: Modbus 16-bit cyclic redundancy checksum. This value is described in the following section.

9.2. Cyclic Redundancy Checksum

Each Modbus frame ends in a cyclic redundancy checksum. This is computed from the other bytes in the message when transmitting the message. When the message is received, the checksum is computed again, and checked against the checksum found in the message. If the results differ, the message was corrupted during transmission. Below is a simple algorithm for calculating the CRC value, shown in pseudo-code. The variable *d[i]* is defined as the i^{th} byte of the message, and the variable *size* denotes the number of bytes in the message. The result of each bit of a *XOR* (exclusive or) operation is 0 if the corresponding bits of each input are the same, or 1 if the corresponding bits of each input are different.

```
crc ← 0xFFFF

loop i from 0 to size - 1
   crc ← crc XOR d[i]

   loop j from 0 to 7
      lsb ← crc AND 0x0001
      crc ← crc LEFT-SHIFT 1

      if lsb = 1 then
         crc ← crc XOR 0xA001
```

9.3. Read Holding Registers

This is the basic command used to read information from the device. The structure of its frames is as follows.

Request:

Modbus Address	Function Code	Starting Address	Register Count	CRC
1-63	3	0-65535	1-125	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)	(2 bytes)

Response:

Modbus Address	Function Code	Byte Count	First Value		...	CRC
1-63	3	2-250	Hi-byte	Lo-byte		(CRC)
(1 byte)	(1 byte)	(1 byte)	(2 bytes)			(2 bytes)

9.4. Read Input Registers

On this device, this command is identical to Read Holding Registers, above, but uses function code 4 instead of 3.

9.5. Write Single Register

This is the basic command used to write data to a single configuration register. The structure of its frames is as follows:

Request:

Modbus Address	Function Code	Address	Value		CRC
1-63	6	0-65535	Hi-byte	Lo-byte	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)		(2 bytes)

Response (identical to the response):

Modbus Address	Function Code	Address	Value		CRC
1-63	6	0-65535	Hi-byte	Lo-byte	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)		(2 bytes)

9.6. Write Multiple Registers

This command writes data to multiple configuration registers. The structure of its frames is as follows:

Request:

Modbus Address	Function Code	Starting Address	Register Count	Byte Count	First Value		...	CRC
1-63	16	0-65535	1-123	2-246	Hi-byte	Lo-byte		(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)	(1 byte)	(2 bytes)			(2 bytes)

Response:

Modbus Address	Function Code	Starting Address	Register Count	CRC
1-63	16	0-65535	1-123	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)	(2 bytes)

9.7. Mask Write Register

This command is used to modify bits in an individual register, based on an AND mask and an OR mask. The register is written to based on the result of the following expression:

Result = (Current Contents AND AndMask) OR (OrMask AND (NOT AndMask))

Example 1: To clear the 1st bit of a register to 0, use an AND mask of 0xFFFE and an OR mask of 0x0000.
Example 2: To set the 1st bit of a register to 1, use an AND mask of 0xFFFE and an OR mask of 0x0001.
Example 3: To AND the value of a register with 0x5555, use an AND mask of 0x5555 and an OR mask of 0.

The structure of its frames is as follows:

Request:

Modbus Address	Function Code	Address	And Mask		Or Mask		CRC
1-63	22	0-65535	Hi-byte	Lo-byte	Hi-byte	Lo-byte	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)		(2 bytes)		(2 bytes)

Response (identical to the request):

Modbus Address	Function Code	Address	And Mask		Or Mask		CRC
1-63	22	0-65535	Hi-byte	Lo-byte	Hi-byte	Lo-byte	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)		(2 bytes)		(2 bytes)

9.8. Read/Write Multiple Registers

This function performs reads and writes in a single command. The writes occur before the reads. The structure of its frames is as follows:

Request:

Modbus Address	Function Code	Read Starting Address	Read Count	Write Starting Address	Write Count	Write Byte Count	First Value		…	CRC
1-63	23	0-65535	1-125	0-65535	1-121	2-246	Hi-byte	Lo-byte		(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)	(2 bytes)	(2 bytes)	(1 byte)	(2 bytes)			(2 bytes)

Response:

Modbus Address	Function Code	Byte Count	First Value		…	CRC
1-63	23	2-250	Hi-byte	Lo-byte		(CRC)
(1 byte)	(1 byte)	(1 byte)	(2 bytes)			(2 bytes)

Note: The response format for Read/Write Multiple Registers is identical to that of Read Holding Registers, aside from the function code.

9.9. Diagnostic Functions

This function contains a series of sub-functions used to perform diagnostic operations on the device and the communication line. The sub-functions are described below.

9.9.1. *Echo Query Data*

This function simply returns the data sent to it, for testing purposes.

Request:

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	0	Any value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response (identical to the request):

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	0	The sent value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.9.2. *Clear Counters*

This function clears the device's count of all messages, slave messages, communication errors, and exceptions since power-up.

Request:

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	10	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response (identical to the request):

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	10	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.9.3. *Return Bus Message Count*

This function returns a count of all Modbus message this device has seen on the bus since power-up, regardless of whether they were addressed to this device or another device on the line.

Request:

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	11	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response:

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	11	Counter value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.9.4. Return Slave Message Count

This function returns a count of all Modbus messages addressed to this device that it has received since power-up.

Request:

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	14	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response:

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	14	Counter value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.9.5. Return Communication Error Count

This function returns a count of all Modbus messages that failed the CRC check upon reception.

Request:

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	12	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response:

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	12	Counter value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.9.6. Return Exception Count

This function returns a count of all Modbus messages that this device responded with an exception response.

Modbus Address	Function Code	Sub-function Code	Data (always 0)	CRC
1-63	8	13	0	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

Response:

Modbus Address	Function Code	Sub-function Code	Data	CRC
1-63	8	13	Counter value	(CRC)
(1 byte)	(1 byte)	(1 bytes)	(2 bytes)	(2 bytes)

9.10. Get Comm Event Counter

This function returns a count of all Modbus messages that were successfully completed without error or exception. The structure of its frames is as follows:

Request:

Modbus Address	Function Code	CRC
1-63	11	(CRC)
(1 byte)	(1 byte)	(2 bytes)

Response:

Modbus Address	Function Code	Status (always 0)	Event Count	CRC
1-63	8	0	Counter value	(CRC)
(1 byte)	(1 byte)	(2 bytes)	(2 bytes)	(2 bytes)

9.11. Report Slave ID

This function returns an ID number, a status code, and a text string identifying the device. The status code is 0x00 when the device is in bootloader mode, and 0xFF otherwise. The text string is an ASCII text string containing the name of the product, its input configuration (mA, mV, or 5A), and its hardware and software version. The string is null-terminated, meaning a 0 is transmitted after the last character.

Example String: "Elkor Technologies W2-M1-mA Hardware 1.00 Firmware 1.00".

While in bootloader mode, the string returned contains the bootloader version, for example, "Elkor Technologies Bootloader 1.00".

The structure of its frames is as follows:

Request:

Modbus Address	Function Code	CRC
1-63	17	(CRC)
(1 byte)	(1 byte)	(2 bytes)

Response:

Modbus Address	Function Code	Byte Count	Slave ID	Status	String identifier	CRC
1-63	17	3-249	130	0x00 or 0xFF	A null-terminated string identifying the device.	(CRC)
(1 byte)	(1 byte)	(1 byte)	(1 byte)	(1 byte)	(Up to 250 bytes)	(2 bytes)

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