Modbus Protocol Guide
EM-RS485

Senva Sensors
9290 SW Nimbus Ave
Beaverton, OR 97008

154-0023-0B

Rev.	Release Date	By	Description of Change	ECR
0A	11/22/2016	DLE	Initial Release	---
0B	4/10/2017	DLE	Updated for firmware v1.1.2	---

Table of Contents

Access Legend		
	Readable ....R	
	Writable ....W	
	Writable with 0 only (statistics reset, see System Readings) W0	
	Saved in non-volatile configuration memory ....NV	

See Also:

152-0291   *EM-RS485 Installation Instructions*

154-0022   *EM-RS485 BACnet Protocol Guide*

Configuration
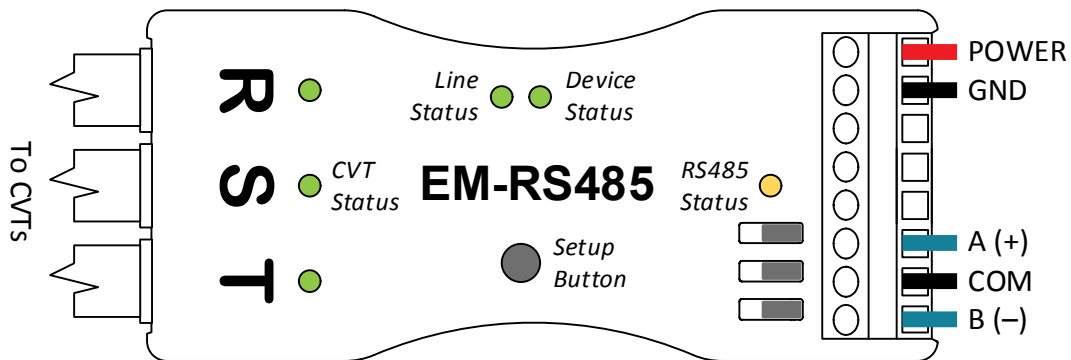
✓ Get In   ✓ Get Out   → **Get Data**

Congratulations on installing your new Senva EM-RS485 energy meter! This *Modbus Protocol Guide* assumes the first stage of installation is complete, with the meter and any CVTs connected and powered. A green *Device Status* indicates the meter is powered and ready. If not, refer to the separate *Installation Instructions* before continuing. Now, only the network configuration remains between you and the data.

Each meter ships with a default *Slave Address*. To identify this address, add "100" to the last two digits of the unique serial number printed on the label. When installing a meter on a dedicated Modbus network with no other slave devices, the global address 255 (0xFF) may also be used (see R123).
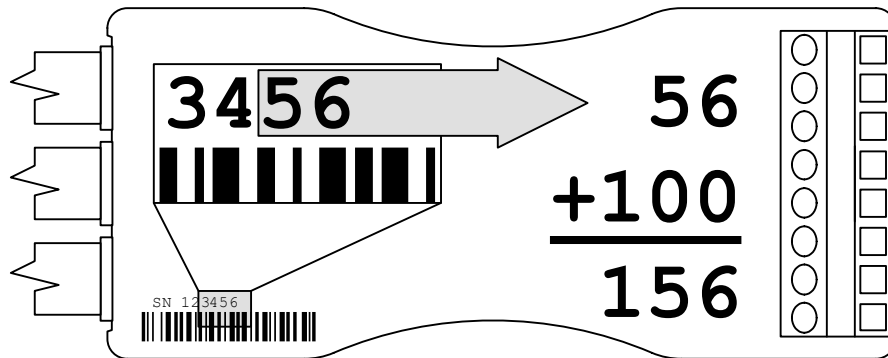
Figure 1: Example Default Address

> **WARNING:** Before connecting a meter to an existing network, ensure the default *Slave Address* will not conflict! If necessary, select an alternate seed address with the *Setup Button* interface (see *Installation Instructions*). Regardless of whether the default *Slave Address*, the global address, or an alternate seed address is used, the meter may be programmed with any supported address after an initial connection is established (see R123).

Leave the meter in the default factory mode for automatic network configuration:

- Automatic *Baud Rate* detection (see R114, R124): 9600 – 115200 baud
- Automatic *Parity* detection (see R116, R126): Even, Odd, No Parity
- Automatic *Data Bits* detection (see R117, R127): 7, 8 Bits
- Automatic *Protocol* detection (see R112, R122): Modbus RTU, ASCII

To begin automatic configuration, simply connect the RS485 terminals to an active Modbus network. An active Modbus network consists of a Modbus master device that regularly polls at least one Modbus slave (whether the slave replies or not).

> **IMPORANT:** If a Modbus network has devices communicating with multiple baud rates and/or formats, the automatic configuration result is unpredictable. Set the configuration manually with the *Setup Button* interface (see *Installation Instructions*) before connecting the meter in such an environment.

Once connected, the meter observes RS485 activity to learn baud rate, serial format, and protocol. Without activity, the meter cannot learn! The meter will not interfere with existing network traffic during the observation phase. As configuration proceeds, the *RS485 Status* LED indicates progress with a combination of color and blinking activity patterns. Diagnostic mode conditions can help identify the current auto configuration step (see Figure 2, and also the *Installation Instructions*).
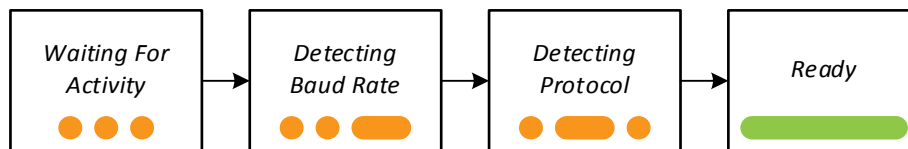
Figure 2: Automatic Configuration Conditions

The *RS485 Status* LED turns green after at least one full frame successfully passes a CRC* integrity test. Assuming no conflicts, the master can then use Modbus functions to query or configure registers.

The meter stores any discovered automatic configuration result in non-volatile memory and reloads them whenever the meter resets (e.g. after power loss). The automatic configuration can be cleared by holding down the *Setup Button* while resetting the meter (e.g. removing and reapplying power). User-configured parameters will not be affected, but the meter must redetect any missing parameters before reestablishing communication.

For permanent installations, the protocol configuration parameters (see R122 – R128) may be set to lock the baud rate, format, and protocol. However, this will prevent the meter from adapting to future changes in the network environment.

The EM-RS485 supports the following Modbus device functions:

- 0x08 *Diagnostics*
- 0x11 *Report Server ID*

---

* Cyclical Redundancy Check

Holding Registers

The EM-RS485 supports the following Modbus functions:

- 0x03 *Read Holding Registers*
- 0x06 *Write Single Register*
- 0x10 *Write Multiple Registers*

In this document, Modbus addresses (beginning with "R") represent <u>raw protocol addresses</u>. Some Modbus conventions offset protocol addresses to form a register ID (e.g. 40001, Modicon notation). Refer to the relevant controller documentation to determine any required programming offset for each installation.

Constructed registers (see Data Types) span multiple Modbus address. The notation RXX/YY specifies a pair of aligned registers. The notation RXX-YY specifies a range of consecutive registers, inclusive.

Unless otherwise specified, changes to RS485 parameters are effective after the response (i.e. a client must maintain the original parameters for the remainder of the current transaction).

System Configuration

R102   Reset Reason   UINT16   R

Returns a reason determined at the time of the last reset:

1. *Configuration Reset* (see R190)
2. (reserved)
3. *Power Loss*
4. (reserved)
5. *Hardware Watchdog*

R103   Reset Count   UINT16   R/NV

Returns a lifetime count of firmware resets for any reason. The meter maintains this count in a protected section of non-volatile memory unaffected by *Configuration Reset* (see R190).

At each reset, the meter restores accumulated energy, demand statistics, and pulse input counts from non-volatile memory. However, all the analog statistics reset, plus the *Up Time* (see R104), *Energy Timestamp* (see R174), and pulse input *Elapsed Active Time* (see R212).

R104/05   Up Time   UINT32   R

Returns the time since the last meter reset, in seconds. To determine the cause, read R102.

R111   Identify Meter   BOOL   R/W

Sets the LED status interface into a visually identifiable mode:

0. *Inactive*
1. *Active*

When set to *Active*, all status LEDs (see *Installation Guide*) begin slowly blinking green together. This pattern is distinct from any other interface pattern the meter may display during normal operation. The LEDs will remain in identify mode until the reset to *Inactive* or the *Setup Button* is pressed.

This feature may be useful if several meters are connected on a single network and the association between discovered device IDs and physical meters is uncertain.

Default: *Inactive* (normal LEDs)

R112   Auto Protocol   BOOL   R/W/NV

Sets the state of automatic protocol detection:

> 0.   *Inactive*
> 1.   *Active*

When *Active*, the RS485 receiver initially allows frames of any supported protocol. On establishing confidence in a particular protocol (about 10 consecutive frames of the same type), this becomes the preferred *RS485 Protocol* (see R122).

Generally, having a preferred protocol disallows other protocols. This reduces uncertainty in the unlikely event that a particular frame or sequence could be interpreted as more than one protocol. However, should the protocol really change (e.g. by moving the meter to a different network), the meter will eventually lose confidence in the preferred protocol. After temporarily allowing all protocols, automatic protocol detection will establish a new preference. To avoid the delays associated with changing protocol, set the *RS485 Protocol* to some option that permanently allows multiple protocols.

When changing this value, the meter keeps the current *RS485 Protocol* to avoid communication loss. Setting *Inactive* disables further automatic protocol changes and only allows the protocol(s) specifically set in *RS485 Protocol*.

Default: *Active*

R114   Auto Baud Rate   BOOL   R/W/NV

Sets the state of automatic baud rate detection:

> 0.   *Inactive*
> 1.   *Active*

When *Active*, the meter may automatically change the *Baud Rate* (see R124) in response to RS485 communication errors. When changing this value, the meter always keeps the current *Baud Rate* to avoid communication loss.

Default: *Active*

R116   Auto Parity   BOOL   R/W/NV

Sets the state of automatic parity detection:

> 0.   *Inactive*
> 1.   *Active*

When *Active*, the meter may automatically change the *Parity* (see R126) in response to RS485 communication errors. When changing this value, the meter always keeps the current *Parity* to avoid communication loss.

Default: *Active*

R117   Auto Data Bits   BOOL   R/W/NV

Sets the state of automatic data bits detection:

> 0.   *Inactive*
> 1.   *Active*

When *Active*, the meter may automatically change the *Data Bits* (see R127) in response to RS485 communication errors. When changing this value, the meter always keeps the current *Data Bits* to avoid communication loss.

Default: *Active*

R118   Auto Stop Bits   BOOL   R/W/NV

Sets the state of automatic stop bits:

    0.   *Inactive*
    1.   *Active*

Returns *Active* when *Stop Bits* is *Auto* (see R128).

Default: *Active*

R122   RS485 Protocol   UINT16   R/W/NV

Sets the communication protocol(s):

    1.   *Auto*   5.   *BACnet and Modbus RTU*
    2.   *BACnet*   6.   *BACnet and Modbus ASCII*
    3.   *Modbus RTU*   7.   *Modbus RTU and ASCII*
    4.   *Modbus ASCII*   8.   *Any Protocol*

If *Auto Protocol* is *Active* (see R112), returns the auto-detected protocol (typically *Modbus RTU* or *Modbus ASCII*). Otherwise, returns the user-configured protocol option.

Setting any value other than *Auto* also sets *Auto Protocol* to *Inactive*. Setting *Auto* copies any previously set protocol option to the automatic protocol detector, and sets *Auto Protocol* to *Active*. Setting an option with multiple protocols (5 – 8) reduces the *Auto Protocol* re-detection delay.

Default: *Auto*

R123   Slave Address   UINT16   R/W/NV

Sets the Modbus slave address, 1 – 254.

Assign unique addresses to each Modbus slave device on a network. The Modbus specification only allows slave addresses 1 – 247. Although the meter supports the assignment of reserved addresses 248 – 254, undefined network behavior may result.

In the default configuration, returns the factory default slave address (see Configuration). Otherwise, returns the user-configured slave address. Before setting the address, ensure that the new address will not conflict with any other slave devices on the Modbus network.

In addition to the assigned slave address, the meter will respond to Modbus commands addressed to the global address 255 (0xFF). Only use this address if the meter is installed on a dedicated Modbus network with no other slave devices.

Default: *Varies*

R124/25   RS485 Baud Rate   UINT32   R/W/NV

Sets the communication baud rate, 1200 – 460800.

When *Auto Baud Rate* is *Active* (see R114), returns the auto-detected baud rate (see Configuration). Otherwise, returns the user-configured baud rate.

Almost by definition, successfully reading baud rate implies a correct value, with no further action required. However, when transitioning a Modbus network to a new baud rate, it may be useful to remotely configure the new baud rate before transitioning the gateway/controller. Setting any user-configured baud rate also sets *Auto Baud Rate* to *Inactive*.

> **WARNING:** The meter provides no facility to revert the baud rate remotely. Once written, the meter will lose communication until the client baud rate matches the new configuration.

Default: *Varies*

R126   RS485 Parity   UINT16   R/W/NV

Sets the communication parity:

1. *Auto*
2. *No Parity*
3. *Odd Parity*
4. *Even Parity*

If *Auto Parity* is *Active* (see R116), returns the auto-detected parity (typically *Even Parity* for Modbus). Otherwise, returns the user-configured parity option.

Setting any value other than *Auto* sets *Auto Parity* to *Inactive*. Setting *Auto* sets *Auto Parity* to *Active*, but keeps the current parity option to avoid loss of communication.

Setting *Auto* copies any previously set parity option to the automatic parity detector and sets *Auto Parity* to *Active*.

Default: *Auto*

R127   RS485 Data Bits   UINT16   R/W/NV

Sets the communication data bits:

1. *Auto*
2. *7 Bits*
3. *8 Bits*

If *Auto Data Bits* is *Active* (see R117), returns the automatically detected number of data bits (typically *8 Bits* for *Modbus RTU*, *7 Bits* for *Modbus ASCII*). Otherwise, returns the user-configured data bits option.

Setting any value other than *Auto* sets *Auto Data Bits* to *Inactive*. Setting *Auto* sets *Auto Data Bits* to *Active*, but keeps the current data bits option to avoid loss of communication.

Default: *Auto*

R128   RS485 Stop Bits   UINT16   R/W/NV

Sets the communication stop bits:

1. *Auto*
2. *1 Bit*
3. *1.5 Bits*
4. *2 Bits*

Always returns the user-configured stop bits option. When set to *Auto*, Modbus dynamically provides the most compatible configuration:*1 Bit* for data receive and *2 Bits* for data transmit.

The *Auto Stop Bits* (see R118) value follows this value. Setting any value other than *Auto* sets *Auto Stop Bits* to *Inactive*. Setting *Auto* sets *Auto Stop Bits* to *Active*.

Default: *Auto*

R133   Temperature Units   UINT16   R/W/NV

Sets the preferred units for temperature values:

1. *Degrees Fahrenheit* (°F)
2. *Degrees Celsius* (°C)

Saved statistical values automatically convert when the selected unit changes.

Default: *Degrees Fahrenheit*

R134 **Smoothed Temperature Response Time** UINT16 R/W/NV

Sets the step response time for smoothed temperature (see R312), in seconds.

Across all groups, the various *Smoothed* values track the instantaneous measurement after the application of a first-order exponential function. This low pass filter attenuates fast changes, such as the inrush current of a large industrial motor. *Smoothed* values may provide a stable baseline measurement but will always lag the instantaneous measurement (see Figure 3A).

Formally, response time sets the time required for a *Smoothed* value to complete 90% of the transition after an ideal step between two stable values (see Figure 3B).

A: General Smoothing   B: Ideal Step Response
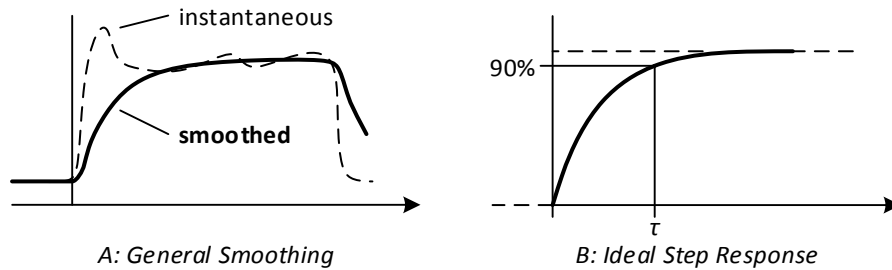
Figure 3: Smoothed Response Time

During periods of invalid measurement, *Smoothed* values return 0 (undefined). The resumption of valid measurements momentarily suppresses the smoothing function while the value stabilizes.

Default: 30 seconds

R142 **Smoothed Frequency Response Time** UINT16 R/W/NV

Sets the step response time (see R134) for smoothed *Frequency* (see R412) and *Voltage Angle* (e.g. R1442), in seconds.

Default: 60 seconds

R144 **Smoothed Voltage Response Time** UINT16 R/W/NV

Sets the step response time (see R134) for smoothed *RMS Voltage* (e.g. R1422), in seconds.

Default: 10 seconds

R152 **System Current Sensor Technology** UINT16 R

Returns the overall current sensor technology of the CVT(s) installed with a meter. This value is provided in anticipation of future CVT technology upgrades:

1. *Unknown Technology*
2. *Conflicted Technology*
3. *Multiple Technology*
4. *Rogowski Coil*
5. *Current Transformer*

This value derives from the combination of the *Current Sensor Technology* (see R1154) of each CVT. All CVTs installed with a single meter must be compatible for proper operation.

Read only. At EM-RS485 launch, all Senva CVTs are based on *Rogowski Coil* technology. If no CVTs are installed, returns *Unknown Technology*.

R153   Angle Units   **UINT16   R/W/NV**

Sets the preferred units for angle values:

1. *Degrees*
2. *Radians*

Saved statistical values automatically convert when the selected unit changes.

Default: *Degrees*

R154   Smoothed Current Response Time   **UINT16   R/W/NV**

Sets the step response time (see R134) for smoothed *RMS Current* (e.g. R1522), *Current Angle* (e.g. R1542), and *Power Factor* (e.g. R1552), in seconds.

Default: 2 seconds

R161   System Phase Selection   **UINT16   R/W/NV**

Sets the phase selection mask for system measurements:

1. *3 Phase*
2. *R Phase and S Phase*
3. *S Phase and T Phase*
4. *R Phase and T Phase*

System measurements, including phase averages (e.g. R420) and accumulations (e.g. R700), are based on the selected phases only. Set this value in case of a split system (e.g. 2 CVTs measuring a 2-phase system input with a third CVT measuring a separate branch load). There are no equivalent options for single phase, as individual phase measurements are always accessible.

For consistency, consider resetting the system statistics (see R192) after changing this setting.

Default: *3 Phase*

R162   Power Spectrum   **UINT16   R/W/NV**

Sets the bandwidth of real and reactive power and energy measurements:

1. Wideband
2. Fundamental

Generally, harmonic components are the result of non-linear distortions in the generator or the load. In *Wideband* mode, measurements include power of all harmonic components (e.g. 3rd, 5th), up to the cutoff frequency (see *Installation Instructions*). In *Fundamental* mode, measurements include only power in the fundamental *Frequency* (see R410).

> **NOTE:** Harmonic power requires matched frequency components in the spectrum of both voltage and current. For example, given a 5th harmonic of current, there must be a corresponding 5th harmonic of voltage. Otherwise, even though distortion power increases, the real and reactive components of power cancel leaving only the power in the fundamental.

For consistency, consider resetting accumulated energy (see R192) after changing this setting.

Default: *Wideband*

R163   Power Units   UINT16   R/W/NV

Sets the preferred units for power and demand power values:

1.   *Kilowatts*
2.   *Watts*
3.   *Megawatts*

Saved statistical values, included maximum demand power, automatically convert when the selected unit changes.

The options specify real power units only. Reactive and apparent power always follow the real power scale, as shown in each column:

	Relative Scale = 1.0	1,000	1,000,000
Real Power	W (Watts)	kW	MW
Reactive Power	VAR (Volt-Amps Reactive)	kVAR	MVAR
Apparent Power	VA (Volt-Amps)	kVA	MVA

Default: *Kilowatts*

R164   Smoothed Power Response Time   UINT16   R/W/NV

Sets the step response time (see R134) for smoothed *Power* (e.g. R1602), in seconds.

Default: 2 seconds

R170   Energy Data Type   BOOL   R/W/NV

Sets the data type when reading energy accumulators (e.g. R700):

0.   *Floating Point*
1.   *Unsigned Integer*

Both modes read from the same internal register, with a fixed capacity of ±1.0 TWh. Changing the mode does not affect the accumulated energy in any way. Reading a register in either mode always returns a value scaled to the system *Energy Units* (see R173).

In *Floating Point* mode, energy registers return a floating point value that does not overflow (unless the internal 1.0 TWh register itself overflows). However, the resolution will gradually degrade as energy accumulates, making it harder to observe small changes in energy over short intervals.

In *Unsigned Integer* mode, energy registers return an unsigned integer, 0 – 999999. When the energy exceeds the upper bound, the value wraps to 0 (modulo arithmetic). This view most closely corresponds to traditional analog meters, with the primary advantage that the energy resolution is fixed at 1 *Energy Unit*.

 If energy overflows, the overflow energy may still be read by setting the next larger *Energy Unit*. Negative power causes net accumulators (e.g. R1706) to run backwards; underflow causes the value to wrap from 0 backwards to 999999.
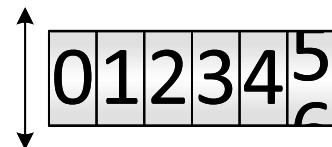
Default: *Floating Point*

R173 Energy Units   UINT16   R/W/NV

Sets the preferred units for accumulated energy values:

1. *Kilowatt Hours*
2. *Watt Hours*
3. *Megawatt Hours*

Accumulated energy automatically converts with no loss when the selected unit changes.

The options specify real energy units only. Reactive and apparent energy always follow the real energy scale, as shown in each column:

	Relative Scale = 1.0	1,000	1,000,000
Real Energy	Wh (Watt hours)	kWh	MWh
Reactive Energy	VARh (Volt-Amp Reactive hours)	kVARh	MVARh
Apparent Energy	VAh (Volt-Amp hours)	kVAh	MVAh

Default: *Kilowatt Hours*

R174/75 Energy Timestamp   FLOAT   R

Returns a high resolution timestamp, 0 – 4194304 milliseconds ($2^{22} - 1$, about 1 hour).

The timestamp value updates atomically with the various energy accumulators. If read just before or after a block of one or more energy measurements, this timestamp may be useful for calculating accurate average power from differential energy:

$$P_{AVG} = \frac{\Delta E}{\Delta t} = \frac{E_2 - E_1}{t_2 - t_1}$$

R181 Demand Synchronization Mode   UINT16   R/W/NV

Sets the synchronization mode for the demand window:

1. *No Synchronization*
2. *Setup Button*
3. *Binary Input 1 (falling)*
4. *Binary Input 1 (rising)*
5. *Binary Input 2 (falling)*
6. *Binary Input 2 (rising)*

Selecting any of the synchronization sources allows the internal window to be aligned to some external reference (Figure 4B). When a synchronization event is detected, the current window ends immediately and a new window begins. Synchronization events occur exactly once when the selected condition is detected. Synchronization cannot re-occur until the condition is removed and redetected, no matter how long it may be maintained.

In *No Synchronization* mode, the *Elapsed Demand Window* (see R184) counts time continuously, only restarting if the meter itself restarts (Figure 4A). When the counter reaches the full *Demand Window Time* (see R183), the current demand window ends and a new window begins.

In *Setup Button* (see R200) mode, synchronization occurs as soon as the button is pressed. The *Setup Button* always performs its normal function.   If there are any active diagnostic conditions, it may be necessary to exit diagnostic mode after pressing the button (see *Installation Instructions*). To avoid a second synchronization, wait for diagnostic mode to time out (about 60 seconds).

In *Binary Input* (see R201, R202) mode, *Falling Edge* synchronization occurs when an external contact pulls the pulse input to GND (active low, see Figure 5). *Rising Edge* synchronization occurs in the opposite condition, when an external contact opens. The *Debounce Time* (see R208) may delay the

synchronization up to 250 milliseconds after the transition. This mode may be useful to align demand windows with a utility meter that provides a regular synchronization pulse.

For *Full Synchronization*, relying exclusively on an external trigger, disable the internal window time by setting the *Demand Window Time* to 0 minutes (Figure 4C).

A: No Synchronization   *B: Basic Synchronization*   *C: Full Synchronization*
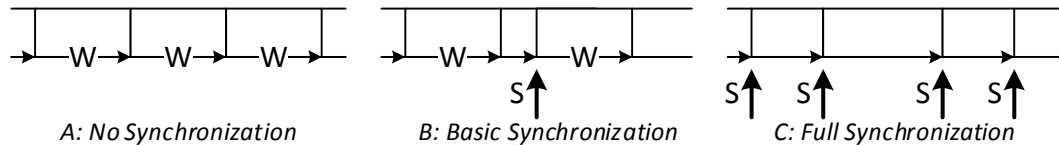
Figure 4: Synchronization Modes

> **NOTE:** Consider synchronizing when the average power is typically light. When a synchronization event is detected, it makes no difference how much or little time has elapsed in the current window. Average power may be more volatile if the window has only just started, being measured over a shorter period of time.

Default: *No Synchronization*

R183   Demand Window Time   UINT16   R/W/NV

Sets the maximum demand window time, 0 – 1440 minutes.

The demand measurements (see R1800) measure average power within a windowed period.

Every time the *Elapsed Demand Window* time (see R184) reaches this limit, the current window ends and a new window starts.

If set to 0 minutes, the window time is unlimited. In this case, new windows are only started by external synchronization (see R181) or software synchronization (see R184).

Default: 15 minutes

R184/85   Elapsed Demand Window   UINT32   R/W0

Returns the time since the beginning of the current demand window, in minutes.

The demand measurements (see R1800) measure average power within a windowed period.

This value resets to 0 at the beginning of each new demand window. Writing 0 at any time automatically starts a new window (software synchronization).

R186/87   Demand Window Count   UINT32   R/NV

Returns the number of completed demand windows. Any demand window at least 1 second long counts, regardless of whether the window was defined by external synchronization (see R181), software synchronization (see R184), or elapsed time (see R183). Resetting all or a portion of the demand statistics (see R192, R1192) does not automatically start a new demand window.

The system and all phase demand values update together (e.g. R1800), so this count can serve as a unique key to identify each new batch of demand statistics (e.g. for logging).

Resets to 0 only when the system and all phase demand statistics are reset together (see R192).

R190/91   Reset Meter Configuration   UINT32   W

Always returns 0. Write the reset key to reset the meter to factory defaults.

> **WARNING:** The entire non-volatile configuration will be permanently lost; previous configurations cannot be recovered. This includes accumulated energy, demand statistics, and pulse input counts. This also includes the current RS485 serial format and *Slave Address*. The only parameters not affected are the *Reset Count* (see R103) and the *Energy Reset Count* (see R194).

After a configuration reset, the meter itself will reset and re-learn the current baud rate, serial format, and protocol (see Configuration).

Write 9699690 to reset the meter to factory defaults.

R192/93   Reset Meter Statistics   UINT32   W

Always returns 0. Write one of the following keys to reset some or all of the phase statistics. Writing any other value results in an error response.

> **WARNING:** Selected statistics will be permanently lost; previous records cannot be recovered.

System statistics ONLY:

- Write 4765089 to reset analog statistics (R410 – R678: *Minimum, Maximum, Average*)
- Write 5338209 to reset demand statistics (R800 – R866: *Minimum, Maximum*)
- Write 6647201 to clear accumulated energy (R700 – R766: *All Registers*)
- Write 5811297 to reset all system statistics

System and all phases R/S/T:

- Write 7648701 to reset all analog statistics
- Write 7566461 to reset all demand statistics
- Write 6909373 to clear all accumulated energy
- Write 4762749 to reset all statistics

Phase R/S/T statistics may also be reset individually (see R1192). Analog statistics automatically reset whenever the meter itself resets (see R103). Individual analog and demand statistics may also be automatically reset when *Auto Reset Statistics* is *Active* (see R195).

Resetting any subset of accumulated energy increments the *Energy Reset Count* (see R194).

R194   Energy Reset Count   UINT16   R/NV

Returns the number of times accumulated energy has been reset. Counts "1" for every full or partial energy reset key written (see R192, R1192), regardless of the actual energy accumulation.

This value may be useful for auditing, since the meter maintains this count in a protected section of non-volatile memory unaffected by *Configuration Reset* (see R190)

R195   Auto Reset Statistics   BOOL   R/W/NV

Setting "1" activates *Reset After Read* mode, where reading an individual statistical measurement also resets it, as if it had been followed by a write of 0 (see System Readings).

Auto reset mode may be useful in some low-overhead remote logging installations.

> **WARNING:** When using *Auto Reset Statistics* as part of a periodic process, ensure there are no extra reads generated between logging intervals. Otherwise, the resulting records may reflect only a portion of the intended interval.

Default: *Inactive*

Binary Inputs

R200 Setup Button   BOOL   R
Returns "1" when the *Setup Button* (see *Installation Instructions*) is pressed.

This value may be useful for protocol testing. Regardless of the value returned, the *Setup Button* always performs its normal function for diagnostics and configuration.

R201 Binary Input 1   BOOL   R
R202 Binary Input 2   BOOL   R
Returns the current stable state of the corresponding pulse input (active low; see *Installation Instructions)*. The *Pulse Input Debounce Time* (see R208) sets the minimum stability requirement for each transition.

This value may be useful if the pulse input is connected to a discrete contact, such as an alarm, to trigger additional controller actions. If so, the corresponding *Pulse Input* count (see R210, R220) may be ignored.

One of the binary inputs may be selected as the source for *Demand Window Synchronization* (see R181).
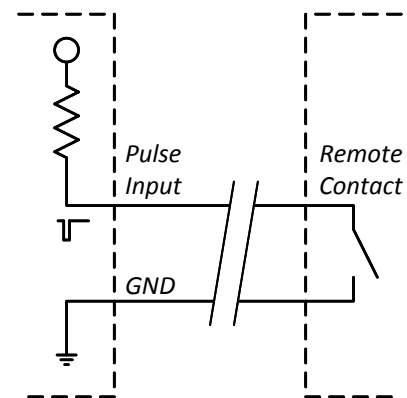
Figure 5: Binary Input Wiring

Pulse Inputs

R208 Pulse Input Debounce Time   UINT16   R/W/NV
Sets the delay time for each input transition before registering a new state, 0 – 255 milliseconds.

This suppresses glitches in the input, such as might be generated by a mechanical relay or electrical interference (see Figure 6). Affects both the *Pulse Inputs* (see R210, R220) and corresponding *Binary Inputs* (see R201, R202).
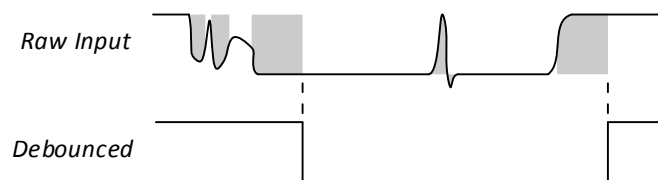
Figure 6: Debouncing Delay

If possible, set the debounce time to 50% of the expected minimum pulse time. Setting 0 disables debouncing: new input states register immediately, but the count may be noisy.

> **IMPORTANT:** Because each pulse must have both a high and low interval, the maximum pulse rate will be 1/2 the equivalent rate of a single debounce time. For example, a 1 millisecond debounce time permits a maximum pulse rate of 500 Hz. Reduce the maximum pulse rate further when the duty cycle of the input is not 50%.

Default: 10 milliseconds (50 Hz)

R210/11   Pulse Input 1 Count   UINT32   R/W/NV

Returns the count of pulses received at the respective pulse terminal (see *Installation Instructions*).

> **NOTE:** The corresponding *Binary Inputs* (R201/R202) track the instantaneous state of the terminal.

Each count represents a pair of input edges (active low), registered on the leading (falling) edge. At each transition, the input delays by the *Debounce Time* (see R208).
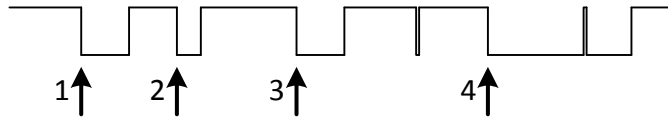
Figure 7: Pulse Input Counting

R212/13   Pulse Input 1 Active Elapsed Time   UINT32   R/W0

Returns the total time, in seconds, that the pulse input has been active (active low) since the last meter reset. Write 0 to reset the count.

R214/15   Pulse Input 1 Maximum   UINT32   R/W/NV

Sets the upper limit of the *Pulse Input Count* (see R210). After counting up to this limit, the next pulse will cause the *Count* to reset to 0. If setting the *Maximum* smaller than the *Count*, the *Count* does not update until the next pulse input event.

Default: 4294967295 ($2^{32} - 1$)

R216/17   Pulse Input 1 Preset   UINT32   R/W/NV

Write this register to initialize the pulse input counter. This may be useful for continuity when the EM-RS485 replaces an existing meter.

When written, the meter first copies the original *Pulse Input Count* (see R210) to *Count Before Preset* (see R218). Then, the meter sets both *Pulse Count* and *Preset* (this register) to the new value. These steps are performed atomically, which allows the *Pulse Count* to be modified while accurately accounting for every input pulse.

Default: 0

R218/19   Pulse Input 1 Count Before Preset   UINT32   R/NV

Returns the *Pulse Count* (see R200) saved during the last write to *Pulse Input Preset* (see R216).

Default: 0

R220/21	**Pulse Input 2 Count**	**UINT32**	**R/W/NV**
R222/23	**Pulse Input 2 Active Elapsed Time**	**UINT32**	**R/W0**
R224/25	**Pulse Input 2 Maximum**	**UINT32**	**R/W/NV**
R226/27	**Pulse Input 2 Preset**	**UINT32**	**R/W/NV**
R228/29	**Pulse Input 2 Count Before Preset**	**UINT32**	**R/NV**

Pulse Input 2 holding register functions match *Pulse Input 1*.

PowerPrint

R240   PowerPrint Alarm   BOOL   R

Returns "1" when any of the PowerPrint conditions are active:

- *Frequency Drift* (see R242, R400)
- *Phase Angle Drift* (see R1146, R400)
- *Brown Out Voltage* (see R1144, R1400)
- *Surge Voltage* (see R1144, R1400)
- *Unexpected Sensor* (see R1104, R400)

Review associated conditions and measurements to determine the source of any anomaly and appropriate actions. Once triggered, the *Alarm* remains *Active* for as long as any PowerPrint condition remains active, plus an additional 10 seconds.

R241   PowerPrint Active   BOOL   R/W/NV

Sets the overall state of the PowerPrint feature:

0.   *Inactive*
1.   *Active*

Returns *Active* if at least one of the PowerPrint reference parameters has been set.

- *Frequency* (see R242)
- *Voltage* (see R1144)
- *Voltage Angle* (see R1146)
- *Identity* (see R1104)

Setting *Inactive* clears all of the reference parameters at once. Setting *Active* while *Inactive* initializes PowerPrint (if already *Active,* setting *Active* has no effect).   When activated this way, PowerPrint initializes all of the reference parameters at once:

- Sets the expected frequency to exactly 50 Hz or 60 Hz if the measured *Frequency* (see R410) is within the *Frequency Tolerance* (see R244); otherwise leaves expected frequency undefined.
- Sets the expected voltage for each phase equal to the measured *RMS Voltage* (see R1420) if the measured voltage is not detecting the *Phase Loss* condition.
- Sets the expected voltage angle between each phase and the next equal to the measured angle (see R1440) if neither phase is detecting the *Phase Loss* condition.
- Sets the reference identity for each phase CVT if the *Status* (see R1103) is *No Fault Detected*.

May return a BACnet *Internal Error* if no PowerPrint parameters could be set (e.g. no CVTs installed).

Default: *Inactive*

R242/43   PowerPrint Frequency   FLOAT   R/W/NV

Sets the expected PowerPrint frequency. If set to any non-zero value, and the *Frequency* (see R410) differs from expected by more than the *Frequency Tolerance* (see R244), then the *Frequency Drift* condition (see R400) will be set.

Set the expected frequency by writing this value directly, or by initializing *PowerPrint* (see R241).

Default: 0 Hz (undefined)

R244/45   PowerPrint Frequency Tolerance   FLOAT   R/W/NV

Sets the tolerance of the *PowerPrint Frequency* (see R242), 0 – 10 Hz.

Default: 0.2 Hz

R246/47   PowerPrint Voltage Tolerance   FLOAT   R/W/NV

Sets the tolerance of the *PowerPrint Voltage* (see R1144) for all phases, 0 – 100% as a ratio of the target voltage. For example, given a target voltage of 240 V and a tolerance of 10%, PowerPrint expects voltages of 216 – 264 V.

Default: 10%

R248/49   PowerPrint Voltage Angle Tolerance   FLOAT   R/W/NV

Sets the tolerance of the *PowerPrint Voltage Angle* (see R1146) for all pairs of phases, 0– 180°. The default units are *Degrees* (see R153).

Default: 30°

Miscellaneous

R276-91   Location String   ASCII   R/W/NV

Null terminated ASCII string to be appended to the Server ID, 0 – 31 characters. Consecutive characters are appended to the fixed portion of the Server ID until the first null (0) is found.

Although registers after the first null won't print, they may still be used for arbitrary storage.

Default: "<location>"

R292-99   User Data   UINT16   R/W/NV

Arbitrary data storage, 0 – 65535.

Any value written may be read back later.

Default: 0

System Readings

For statistical purposes, input values are organized into groups. By convention, the primary value leading each group provides the most accurate, up-to-date reading possible. Secondary values within a group provide statistical measurements in time that may support some simple logging applications with less overhead for setup and bandwidth. Typical statistical values include:

- **Smoothed:** Returns the value after applying a first-order exponential filter (see R134).
- **Minimum:** Returns the single lowest valid reading taken since last reset.
- **Maximum:** Returns the single highest valid reading taken since last reset.
- **Average:** Returns the average of all valid readings taken since last reset.

Once recorded, there are a few methods to reset statistics records (*Minimum*, *Maximum*, *Average*):

- Manually for a single value, by writing 0 to the register (**W0** in the Access Legend).
- Manually for multiple value, by writing one of the *Statistics Reset* keys (see R192, R1192).
- Automatically for single values, by configuring *Auto Reset Statistics* (see R195).

Most statistical values reset with a value equal to the primary register value (see Figure 8).

Demand statistical values reset to 0 until the end of the current demand window (see R1800, R186).
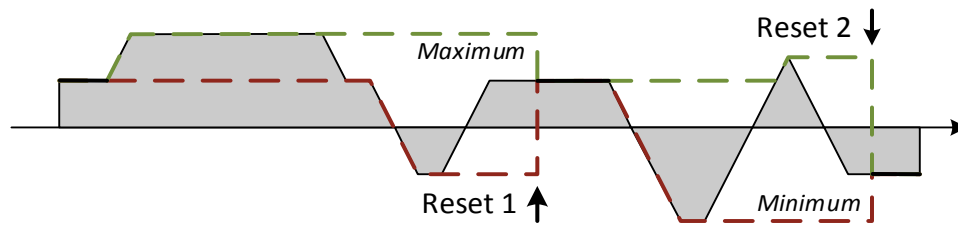
Figure 8: Reset Behavior

R310/11   Temperature   FLOAT   R/W0

Returns the approximate ambient temperature at the meter's installed location. The default units are °F (see R133). The meter compensates small drifts in CVT voltage and current measurements (the meter assumes CVT temperature is similar to meter temperature, see *Installation Instructions*).

If the temperature is beyond the product specifications, the *Device Status* LED will indicate the corresponding *Temperature Limit* warning condition (see *Installation Instructions*).

The default smoothed value response time is 30 seconds (see R134).

R312/13 Instantaneous ● R314/15 Minimum ● R316/17 Maximum ● R318/19 Average

R380/81   Power Supply Voltage   FLOAT   R/W0

Returns the approximate working voltage provided to the meter's low voltage power supply, in V. The voltage reported is an internal voltage after rectification and reverse input protection (typically 1.0 – 2.0 V less than the external voltage).

The meter requires 12.0 VDC minimum for full operation. If the measured voltage drops below this threshold, the meter anticipates a power loss and saves the configuration and accumulated energy to non-volatile memory. However, if the power loss proves incomplete, the meter may continue to operate at the reduced voltage. In this state, accumulating energy may be lost if the meter has insufficient reserve power when (if) full power loss finally occurs. The *Device Status* LED will indicate the corresponding *Low Supply Voltage* warning condition (see *Installation Instructions*).

R382/83 Instantaneous ● R384/85 Minimum ● R386/87 Maximum ● R388/89 Average

R400 Active Conditions   UINT16   R

Returns an encoded set of flags representing active system conditions:

- *Mismatched Voltage* (see R1450)   BIT [5]   32
- *Reverse RST Order* (see R1440)*   BIT [6]   64
- *Not 3-Phase* (see R1440)*   BIT [7]   128
- *Frequency Drift* (see R1420)**   BIT [12]   4096
- *Phase Drift* (see R1440)**   BIT [15]   32768

The conditions reflect the near-real-time system status observed over the previous 1 – 2 seconds. The *Line Status* LED also indicates the active conditions (see *Installation Instructions*).

If no CVTs are installed, always returns "0". To decode a set of condition flags, see Appendix B.

*Conditions only reported when the *PowerPrint Voltage* (see R1144) is undefined.
**Conditions only reported after activating the corresponding PowerPrint feature(s).

R401 Previous Conditions   UINT16   R/W0

Returns an encoded set of flags representing all active and historical system conditions. Equivalent to *Active Conditions* (see R400), except that conditions remain in the set until manually cleared.

Write "0" to clear historical flags (set in R401 but no longer set in R400). Flags are also cleared when the meter resets. Active flags (still set in R400) cannot be effectively cleared, since they will be immediately re-set.

R410/11 Line Frequency   FLOAT   R/W0

Returns the fundamental AC line frequency f, in Hz. If there are no CVTs connected, or all of the CVTs measure *Phase Loss* conditions (see R1420), returns 0 Hz.

With a *PowerPrint Frequency* target set (see R242), frequency variations may set the *Frequency Drift* condition (see R400).

The default smoothed value response time is 60 seconds (see R142).

R412/13 Instantaneous ● R414/15 Minimum ● R416/17 Maximum ● R418/19 Average

R420/21 Phase Average RMS Voltage   FLOAT   R/W0

Returns the average $\overline{V}$ of the *RMS Voltage* (see R1420) of all valid system phases. If there are no valid phases, returns 0 V.

For average calculations in general, a valid system phase must:

- Be included in the *System Phase Selection* (see R161),
- Have a *CVT Status* of *No Error* (see R1103), and
- Not be detecting the *Phase Loss* condition (see R1420).

The default smoothed value response time is 10 seconds (see R144).

R422/23 Instantaneous ● R424/25 Minimum ● R426/27 Maximum ● R428/29 Average

R450/51   Phase to Phase Average RMS Voltage   FLOAT   R/W0

Returns the average $\overline{V_{PP}}$ of the *Phase to Phase RMS Voltage* (see R1450) between valid system phases (as defined by R420). If there are exactly two valid phases, the average collapses to the single reading between them. If there are less than two valid phases, returns 0 V.

As with individual phase to phase voltages measurements, the average is valid only when CVTs share a common neutral connection and all phases have the same frequency (the meter does not check either condition).

The default smoothed value response time is 10 seconds (see R144).

R452/53 Instantaneous ● R454/55 Minimum ● R456/57 Maximum ● R458/59 Average

R520/21   Phase Average RMS Current   FLOAT   R/W0

Returns the average $\overline{I}$ of the *RMS Current* (see R1520) of valid system phases (as defined by R420). If there are no valid phases, returns 0 A.

The default smoothed value response time is 2 seconds (see R154).

R522/23 Instantaneous ● R524/25 Minimum ● R526/27 Maximum ● R528/29 Average

R540/41   Phase Average Current Angle   FLOAT   R/W0

Returns the average $\overline{\varphi}$ of the *Current Angle* (see R1540) of valid system phases. The default units are *Degrees* (see R153), normalized between -180 and $+180°$.

In addition to the standard criteria (as defined by R420), valid system phases must have sufficient load power to give a stable measurement (see R1600, *No Load* condition). Returns 0° if there are no valid phases.

The average of angles with a total sweep approaching 180° or more (see Figure 9) is indeterminate. In such cases, also returns 0°.

An indeterminate average often indicates that the CVT voltage leads or current sensor loop were installed backwards. If so, a negative multiplier (see R1142, R1152) may restore the result.

A: Sweep = 60° ✓   B: Sweep = 135° ✓   C: Sweep = 205° ✗
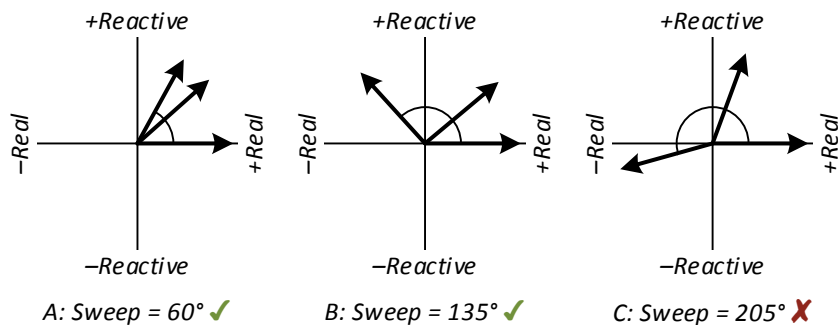
Figure 9: Swept Current Angle

The default smoothed value response time is 2 seconds (see R154).

R542/43 Instantaneous ● R544/45 Minimum ● R546/47 Maximum ● R548/49 Average

R550/51   System Power Factor   FLOAT   R/W0

Returns the true (apparent) power factor $\widehat{pf}$ of the valid system phases (as defined by R420).

Unlike an arithmetic average, the system power factor weights the *Real Power* (see R620) and *Apparent Power* (see R660) of each phase (see Figure 10). This definition keeps lightly loaded phases with relatively poor power factor from introducing excessive distortion in the result.

$$\widehat{pf} = \frac{P_{NET}}{\overline{S}}$$

If negative, the system export power exceeds the import power.

If the power in two phases flows in opposite directions, the real components cancel, reducing the overall power factor.

The default smoothed value response time is 2 seconds (see R164).

R552/53 Instantaneous ● R554/55 Minimum ● R556/57 Maximum ● R558/59 Average
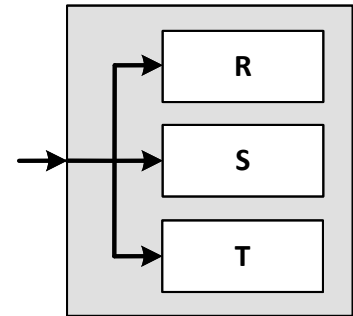
Figure 10: System Power Factor

R600/09   Total Real Power   FLOAT   R/W0

Returns the absolute sum ΣP of the *Real Power* (see R1600) of valid system phases (as defined by R420). The default units are kW (see R163).

The default smoothed value response time is 2 seconds (see R164).

R602/03 Instantaneous ● R604/05 Minimum ● R606/07 Maximum ● R608/09 Average

R610/11   Phase Average Real Power   FLOAT   R/W0

Returns the absolute average $\overline{P}$ of the *Real Power* (see R1600) of valid system phases (as defined by R420). The default units are kW (see R163).

The default smoothed value response time is 2 seconds (see R164).

R612/13 Instantaneous ● R614/15 Minimum ● R616/17 Maximum ● R618/19 Average

R620/21   Net Real Power   FLOAT   R/W0

Returns the signed sum P_{NET} of the *Real Power* (see R1600) of valid system phases (as defined by R420). The default units are kW (see R163). Negative values indicate that overall export power exceeds import power.

The default smoothed value response time is 2 seconds (see R164).

R622/23 Instantaneous ● R624/25 Minimum ● R626/27 Maximum
R628/29 Overall Average ● R630/31 Import Average ● R632/33 Export Average

R640/41   Total Reactive Power   FLOAT   R/W0

Returns the absolute sum ΣQ of the *Reactive Power* (see R1640) of valid system phases (as defined by R420). The default units are kVAR (see R163).

The default smoothed value response time is 2 seconds (see R164).

R642/43 Instantaneous ● R644/45 Minimum ● R646/47 Maximum ● R648/49 Average

R650/51 Phase Average Reactive Power FLOAT R/W0

Returns the absolute average $\overline{Q}$ of the *Reactive Power* (see R1640) of valid system phases (as defined by R420). The default units are kVAR (see R163).

The default smoothed value response time is 2 seconds (see R164).

R652/53 Instantaneous ● R654/55 Minimum ● R656/57 Maximum ● R658/59 Average

R660/61 Total Apparent Power FLOAT R/W0

Returns the absolute sum ΣS of the *Apparent Power* (see R1660) of valid system phases (as defined by R420). Always positive. The default units are kVA (see R163).

The default smoothed value response time is 2 seconds (see R164).

R662/63 Instantaneous ● R664/65 Minimum ● R666/67 Maximum ● R668/69 Average

R670/71 Phase Average Apparent Power FLOAT R/W0

Returns the absolute average $\overline{S}$ of the *Apparent Power* (see R1660) of valid system phases (as defined by R420). The default units are kVA (see R163).

The default smoothed value response time is 2 seconds (see R164).

R672/73 Instantaneous ● R 674/75 Minimum ● R676/77 Maximum ● R678/79 Average

R700/01 Total Real Energy FLOAT* R/NV

Returns the combined energy of the system phases (see R161). The default type is *Floating Point* (see R170). The default units are kWh (see R173). For a *3 Phase* installation:

$$Total = R1700 + R2700 + R3700$$

$$Import = R1702 + R2702 + R3702$$

$$Export = R1704 + R2704 + R3704$$

$$Net = R1706 + R2706 + R3706$$

R702/03 Import ● R704/05 Export ● R706/07 Net

R720/21 System Real Energy FLOAT* R/NV

Returns the combined energy of the system phases (see R161). The default type is *Floating Point* (see R170). The default units are kWh (see R173).

Unlike *Total Real Energy* (above), these accumulators derive from *Net Real Power* (see R620). For a *3 Phase* installation,

$$System = \int |P_{NET}| \cdot dt = \int |P_R + P_S + P_T| \cdot dt$$

Compare the order of the absolute value operations in this example with the *Total Real Energy* derived from the *Total Real Power* (see R600):

$$Total = \int \Sigma P \cdot dt = \int (|P_R| + |P_S| + |P_T|) \cdot dt$$

When the individual *Real Power* (see R1600) of all system phases flows in the same direction (import or export), the *System* accumulators track the corresponding *Total* accumulations exactly. However, the *System* calculation allows opposite phase powers to cancel before accumulation.
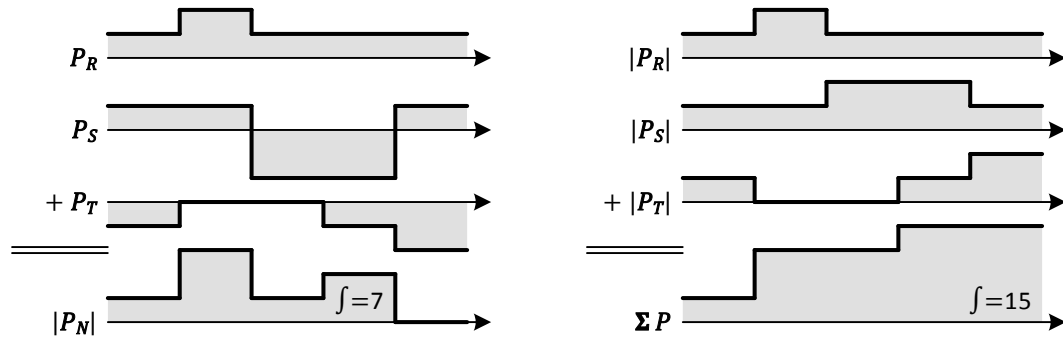
Figure 11: System vs. Total Energy

The *Import* and *Export* accumulations follow the sign of *Net Real Power*:

$$Import = \int \begin{cases} |\boldsymbol{P_{NET}}| \cdot dt & if \ \boldsymbol{P_{NET}} > 0 \\ 0 & otherwise \end{cases}$$

$$Export = \int \begin{cases} |\boldsymbol{P_{NET}}| \cdot dt & if \ \boldsymbol{P_{NET}} < 0 \\ 0 & otherwise \end{cases}$$

Net Real Energy (see R706) equals any possible *System Net* accumulator, as the calculation does not take absolute values.

R722/23 Import ● R724/25 Export

R740/41 Total Reactive Energy   FLOAT*   R/NV

Returns the combined energy of the system phases (see R161). The default type is *Floating Point* (see R170). The default units are kVARh (see R173). For a *3 Phase* installation:

$$Total = R1740 + R2740 + R3740$$

$$Import = R1742 + R2742 + R3742$$

$$Export = R1744 + R2744 + R3744$$

R742/43 Import ● R744/45 Export

R760/61 Total Apparent Energy   FLOAT*   R/NV

Returns the combined energy of the system phases (see R161). The default type is *Floating Point* (see R170). The default units are kVAh (see R173). For a *3 Phase* installation:

$$Total = R1760 + R2760 + R3760$$

$$Import = R1762 + R2762 + R3762$$

$$Export = R1764 + R2764 + R3764$$

R762/63 Import ● R764/65 Export

R800/01 Demand Real Power   FLOAT   R/W0

Returns the absolute sum $\boldsymbol{\Sigma P_D}$ of the *Demand Real Power* (see R1800) of valid system phases (as defined by R420). The default units are kW (see R163).

R802/03 Previous ● R804/05 Minimum ● R806/07 Maximum

R820/21   Demand System Real Power   FLOAT   R/W0

Returns the signed sum $\Sigma P_{D \cdot NET}$ of the *Demand Real Power* (see R1800) of valid system phases (as defined by R420). The default units are kW (see R163).

R822/23 Previous ● R824/25 Minimum ● R826/27 Maximum

R840/41   Demand Reactive Power   FLOAT   R/W0

Returns the absolute sum ΣQ_D of the *Demand Reactive Power* (see R1840) of valid system phases (as defined by R420). The default units are kVAR (see R163).

R842/43 Previous ● R844/45 Minimum ● R846/47 Maximum

R860/61   Demand Apparent Power   FLOAT   R/W0

Returns the absolute sum ΣS_D of the *Demand Apparent Power* (see R1860) of valid system phases (as defined by R420). The default units are kVA (see R163).

R862/63 Previous ● R864/65 Minimum ● R866/67 Maximum

R Phase Configuration

R1010-19   CVT Serial Number   ASCII   R

Returns the unique serial number of the CVT. With no CVT installed, returns "000000".

R1020-29   CVT Model   ASCII   R

Returns the full model of the CVT. With no CVT installed, returns "NO SENSOR".

R1102   CVT Present   BOOL   R

Returns "1" when the meter detects a CVT.

R1103   CVT Status   UINT16   R

Returns general CVT status:

1. *No CVT*
2. *No Error*
3. *Detection Error*
4. *Communication Error*
5. *Configuration Error*
6. *Version Error*
7. *Technology Error*

Any *Error* status causes the *Sensor Fault* (see R1400) condition to be set. In this case, all of the individual phase measurements (see R1420 ff.) are marked invalid. In addition, the phase carries no weight in the system average calculations (see R420 ff.). Previous phase statistics and energy accumulations are preserved.

Typically, errors result from an unreliable cable connection between the EM-RS485 and a CVT. Disconnect the CVT from the meter and inspect the cable and connector for damage. If an error persists when the CVT is reconnected, please contact technical support.

At EM-RS485 launch, all Senva CVTs are based on *Rogowski Coil* technology; *Technology Error* is provided in anticipation of future CVT technology upgrades.

R1104 PowerPrint Identity Status   UINT16   R

Sets the status of the CVT's PowerPrint identity:

1. *No Identity*
2. *Identity Saved*
3. *Identity Error*

The PowerPrint identity captures the digital identity of the installed CVT for reference. To initialize or update the PowerPrint identity, activate *PowerPrint* (see R241) or write *Identity Saved*. To clear any saved identity, write *No Identity* or disable *PowerPrint*.

Returns *Identity Saved* when the CVT identity matches the reference identity. Returns *Identity Error* when it appears that the CVT has been removed or swapped with a different one. In the latter case, PowerPrint also sets the *Unexpected Sensor* and/or the *Missing Sensor* conditions (see R1400).

Default: *No Identity*

R1140/41 Voltage Rating   FLOAT   R

Returns the CVT's maximum rated RMS voltage. This always applies to the raw input voltage, measured between the CVT voltage leads without considering the *Voltage Multiplier* (see R1142).

If the direct input voltage exceeds this rating, the *Over Voltage* condition (see R1400) will be set. In *Over Voltage* conditions voltage, power, and energy measurements may have reduced accuracy.

> **WARNING:** Exceeding the rated RMS voltage may result in hazardous operating conditions.

R1142/43 Voltage Multiplier   FLOAT   R/W/NV

Sets a multiplier to scale from raw input voltage to effective line voltage. Set equal to the ratio of any potential transformer used to step down voltages higher than the maximum rating. For example, set 35.0 when using a 4200:120 V potential transformer.

The *RMS Voltage* (see R1420) always returns the effective line voltage including the multiplier. Power and energy measurements scale by the same factor.

Negative multipliers can correct installations where CVT voltage leads are installed backwards:

- Has no effect on *RMS Voltage* (see R1420), which is always positive.
- Reverses the direction (import/export) of *Power Factor* (see R1550), *Real Power* (see R1600), and *Reactive Power* (see R1640).
- Adds 180° to *Current Angle* (see R1540), unless the *Current Multiplier* (see R1152) is also negative, in which case the signs cancel.
- Adds 180° to both *Phase to Phase Voltage Angles* (see R1440) that include this phase, unless the other phase *Voltage Multiplier* (see R2142, R3142) in the pair is also negative.

Default: 1.0

R1144/45 PowerPrint Voltage   FLOAT   R/W/NV

Sets the expected PowerPrint voltage. If set to any non-zero value, and *RMS Voltage* (see R1420) differs from expected by more than the *PowerPrint Voltage Tolerance* (see R246), then either the *Brown Out Voltage* or *Surge Voltage* conditions (see R1400) will be set.

Set the expected voltage by writing this value directly, or by initializing *PowerPrint* (see R241).

Default: 0 (undefined)

R1146/47   **PowerPrint Voltage Angle**   **FLOAT**   **R/W/NV**

Sets the expected PowerPrint relative voltage angle between this phase and the "next" (as defined for *Voltage Angle,* see R1440). If both phases have a non-zero *PowerPrint Voltage* (see R1144), and the relative *Voltage Angle* differs from the expected angle by more than the *Voltage Angle Tolerance* (see R248), then the *Phase Drift* condition (see R1400) will be set.

Set the expected angle by writing this value directly, or by initializing *PowerPrint* (see R241).

Default: 0 (undefined)

R1150/51   **Current Rating**   **FLOAT**   **R**

Returns the CVT's rated RMS current. This always applies to the raw input current measured in the Rogowski Coil loop without considering the *Current Multiplier* (see R1152). The rating applies only at 60 Hz; ratings at other frequencies are inversely proportional (see R1520).

If the raw input current exceeds this rating, the *Over Current* condition (see R1400) may be set. However, this condition reflects the technology capability of the current sensing loop, which may be higher than rating in some cases. In *Over Current* conditions the current, power, and energy measurements may have reduced accuracy.

R1152/53   **Current Multiplier**   **FLOAT**   **R/W/NV**

Sets a multiplier to scale from raw input current to effective line current. Set the inverse of the number of times the conductor passes through the current sensor loop. For example, set 0.2 when the conductor wraps 5 times.

> **WARNING:** Never deform the Rogowski Coil! Wrapping a conductor may increase accuracy when measuring very low currents, but may also reduce accuracy by deviating from the recommended installation procedure (see *Installation Instructions*). Performance specifications not guaranteed.

The *RMS Current* (see R1520) always returns the effective line current including the multiplier. Power and energy measurements scale by the same factor.

Negative multipliers can correct installations where a current transducer is installed backwards:

- Has no effect on *RMS Current* (see R1420), which is always positive.
- Reverses the direction (import/export) of *Power Factor* (see R1550), *Real Power* (see R1600), and *Reactive Power* (see R1640).
- Adds 180° to *Current Angle* (see R1540), unless the *Voltage Multiplier* (see R1142) is also negative, in which case the signs cancel.

Default: 1.0

R1154   **Current Sensor Technology**   **UINT16**   **R**

Returns the current sensor technology of the CVT:

1. *Unknown Technology*
2. *Rogowski Coil*
3. *Current Transformer*

Read only. If no CVT is installed, returns *Unknown Technology*.

At EM-RS485 launch, all Senva CVTs are based on *Rogowski Coil* technology. The combination of the technology of all installed CVTs gives the *System Current Sensor Technology* (R152).

R1161   Power Multiplier Override   BOOL   R/W

Returns the status of the phase *Power Multiplier* (see R1162). "0" indicates the default multiplier; "1" indicates an override. Setting "0" resets the *Power Multiplier* to default.

Default: *Inactive*

R1162/63   Power Multiplier   FLOAT   R/W/NV

Sets a multiplier to scale from raw input power to reported power. For example, set 3.0 to infer the other power and energy of all three phases of a balanced load while measuring just one. This way, the reported measurements have the correct magnitude and scale without any post-calculation.

> **WARNING:** The less balanced the phases, the more this technique reduces measurement accuracy, especially for reactive power. However, the equipment and installation savings may be worthwhile when the primary objective is a relative/trend type measurement.

Negative multipliers reverse the direction (import/export) of *Power Factor* (see R1550), *Real Power* (see R1600), and *Reactive Power* (see R1640).

Setting this value also sets the *Power Multiplier Override* (R1161) to *Active*. To restore the default, set the *Power Multiplier Override* to *Inactive*.

Default: 1.0

R1192/93   Statistics Reset   UINT32   R/W

Always returns 0. Write one of the following keys to reset some or all of the phase statistics. Writing any other value results in an error response.

> **WARNING:** Selected statistics will be permanently lost; previous records cannot be recovered.
>
> **NOTE:** Each phase has different keys, which are also different from the system reset keys. This guarantees that statistics cannot be accidentally reset by writing a key to the wrong register.

R Phase (R1192):

- Write 7779749 to reset analog statistics (R1420 – R1672: *Minimum, Maximum, Average*)
- Write 5207141 to reset demand statistics (R1800 – R1866: *Minimum, Maximum*)
- Write 7564709 to clear accumulated energy (R1700 – R1766: *All Registers*)
- Write 6204517 to reset all R Phase statistics

S Phase (R2192):

- Write 6600105 to reset analog statistics (R2420 – R2672: *Minimum, Maximum, Average*)
- Write 7173225 to reset demand statistics (R2800 – R2866: *Minimum, Maximum*)
- Write 4287913 to clear accumulated energy (R2700 – R2766: *All Registers*)
- Write 6073449 to reset all S Phase statistics

T Phase (R3192):

- Write 4240817 to reset analog statistics (R3420 – R3672: *Minimum, Maximum, Average*)
- Write 4813937 to reset demand statistics (R3800 – R3866: *Minimum, Maximum*)
- Write 6516145 to clear accumulated energy (R3700 – R3766: *All Registers*)
- Write 4369521 to reset all T Phase statistics

Phase statistics may also be reset by a *System Statistics Reset* (see R192). Analog statistics are automatically reset whenever the meter itself resets (see R103). Individual analog and demand statistics may also be automatically reset when *Auto Reset Statistics* is *Active* (see R195).

Resetting any subset of accumulated energy increments the *Energy Reset Count* (see R194).

R Phase Measurements

R1400   Active Conditions   UINT16   R

Returns an encoded set of flags representing active phase conditions:

• *Sensor Fault* (see R1103)	BIT [0]	1
• *No Load* (see R1600)	BIT [1]	2
• *Negative Power* (see R1600)	BIT [2]	4
• *Phase Loss* (see R1420)	BIT [3]	8
• *Bad Frequency* (see R1420)	BIT [4]	16
• *Low Power Factor* (see R1550)	BIT [5]	32
• *Over Current* (see R1150)	BIT [6]	64
• *Over Voltage* (see R1140)	BIT [7]	128
• *High Harmonics* (see R1520)	BIT [8]	256
• *Unexpected Sensor* (see R1104)*	BIT [9]	512
• *Missing Sensor* (see R1104)*	BIT [10]	1024
• *Surge Voltage* (see R1144)*	BIT [11]	2048
• *Brown Out Voltage* (see R1144)*	BIT [13]	8192

The conditions reflect the near-real-time phase status observed over the previous 1 – 2 seconds. The *CVT Status* LED also indicates the active conditions (see *Installation Instructions*).

If no CVT is installed, always returns "0". To decode a set of condition flags, see Appendix B.

*Conditions only reported after activating the corresponding PowerPrint feature(s).

R1401   Previous Conditions   UINT16   R/W0

Returns an encoded set of flags representing all active and historical phase conditions. Equivalent to *Active Conditions* (see R1400), except that conditions remain in the set until manually cleared.

Write "0" to clear historical flags (set in R1401 but no longer set in R1400). Flags are also cleared when the meter resets. Active flags (still set in R1400) cannot be effectively cleared, since they will be immediately re-set.

R1420/21   Phase RMS Voltage   FLOAT   R/W0

Returns the effective line RMS voltage V measured between the CVT voltage leads and multiplied by the *Voltage Multiplier* (see R1142), in V. Always positive, regardless of the sign of the multiplier.

When voltage exceeds the *Voltage Rating* (see R1140), the measurement may have a reduced accuracy.

When the voltage drops below approximately 15% of the *Voltage Rating* (90 V for a 600 V rated CVT), the *Phase Loss* condition (see R1400) may be set. Even at higher RMS voltages, *Phase Loss* may still occur if the frequency exceeds the system limits (see *Installation Instructions*).

In *Phase Loss* conditions, the *Real Power* (see R1600), *Reactive Power* (see R1640), and derived measurements become invalid. *Apparent Power* (see R1660) remains valid down to approximately 2% of the *Voltage Rating* (12 V for a 600 V rated CVT), although measurements may have a reduced accuracy. Below 2%, returns 0 V.
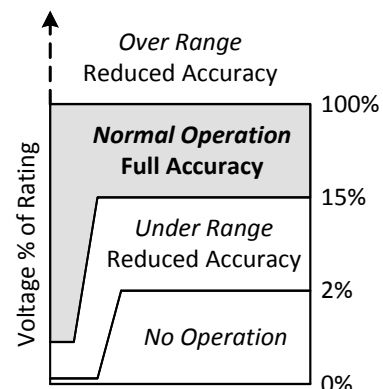
Figure 12: Voltage Range

With a *PowerPrint Voltage* target set (see R1144), voltage variations may set the *Brown Out Voltage* (too low) or *Surge Voltage* (too high) conditions (see R400). The default smoothed value response time is 10 seconds (see R144).

R1422/23 Instantaneous ● R1424/25 Minimum ● R1426/27 Maximum ● R1428/29 Average

R1440/41 Phase to Phase Voltage Angle   FLOAT   R/W0

Returns the relative angle θ between the voltage of this phase and the "next" (definition below). The default units are *Degrees* (see R153), normalized between −180 and +180°.

IMPORANT: Unlike most measurements (intra-phase and independent), the definition of phase to phase voltage depends on "next" phase. The complete progression:

- R1440   R Phase to S Phase
- R2440   S Phase to T Phase
- R3440   T Phase to R Phase

Positive angles indicate that the "next" phase lags this phase (see Figure 14). A negative *Voltage Multiplier* (see R1142) for one phase rotates the result by 180°, also normalized. (Negative multipliers on both phases cancel each other)

This measurement assumes that both phases have the same frequency (the meter does not check). If the voltage of either phase drops too low, this value returns 0 V.
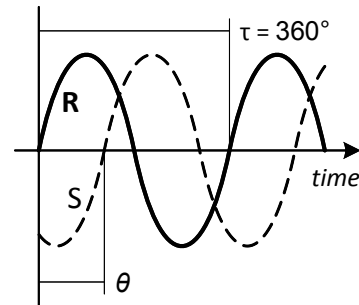
Figure 14: Phase Progression

With a *PowerPrint Voltage Angle* target set (see R1146), angle variations may set the *Phase Drift* condition (see R400).

With no *PowerPrint Voltage Angle* target, the meter substitutes 120°, a standard angle for 3-phase services. Three angles of approximately −120° will set the *Reverse RST Order* condition. Three angles not approximately equal to either −120° or +120° will set the *Not Three Phase* condition. *Phase Loss* on either phase blocks both conditions from being set.

The default smoothed value response time is 60 seconds (see R142).

R1442/43 Instantaneous ● R1444/45 Minimum ● R1446/47 Maximum ● R1448/49 Average

R1450/51 Phase to Phase RMS Voltage   FLOAT   R/W0

Returns the RMS voltage V_{PP} between the "hot" leads of this phase and the next (as defined by R1440), in V. This calculation assumes a common neutral connection (see Figure 15) between phases and that both phases have the same frequency (the meter does not check for either).
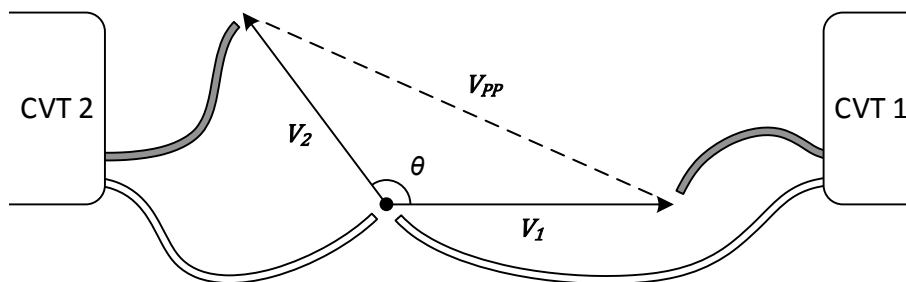
Figure 15: Phase to Phase Common Neutral

The following equation represents the basic phase to phase voltage calculation:

$$V_{PP} = \sqrt{(V_1 - V_2 \cos\theta)^2 + (V_2 \sin\theta)^2}$$

A negative *Voltage Multiplier* (see R1142) for exactly one phase rotates the result by 180°, effectively reversing the polarity of the neutral and "hot" leads.

The default smoothed value response time is 10 seconds (see R144).

R1452/53 Instantaneous ● R1454/55 Minimum ● R1456/57 Maximum ● R1458/59 Average

R1520/21   Phase RMS Current   FLOAT   R/W0

Returns the effective line RMS current I measured with the CVT current sensing loop and multiplied by the *Current Multiplier* (see R1152), in A. Always positive, regardless of the sign of the multiplier.

When the current exceeds the *Current Rating* (see R1150) the measurement may have reduced accuracy.

Fundamentally, Rogowski coils measure <u>changes in current</u>, not current itself. This is why Rogowski coils are not well-suited for DC current measurements and also why they may be sensitive to high frequency harmonics. Even though a particular RMS current may be within the CVT *Current Rating*, individual harmonic components may exceed the input range.

If the meter detects that current harmonics may lead to reduced accuracy, the *High Harmonics* condition (see R1400) will be set. However, given the wide variation in harmonics between different loads, the meter cannot detect every possible scenario leading to reduced accuracy.

The default smoothed value response time is 2 seconds (see R154).

R1522/23 Instantaneous ● R1524/25 Minimum ● R1526/27 Maximum ● R1528/29 Average

R1540/41   Phase Current Angle   FLOAT   R/W0

Returns the four quadrant current angle φ. The default units are *Degrees* (see R153), normalized between −180 and +180°. A negative *Current Multiplier* (see R1152) rotates the result by 180°, effectively reversing the orientation of the current sensor loop.

Current angle measures the angle of the phase current fundamental with respect to the voltage fundamental. Positive angles represent leading (capacitive) loads.

Internally, the meter calculates from the vector formed by *Real Power* (see R1600) and *Reactive Power* (see R1640). Note the negation required to maintain sign convention (see Figure 16):

$$\varphi = -\text{atan}\,\frac{Q}{P}$$

Displacement power factor may be easily derived from current angle:

$$pf_D = \cos(\varphi) = \frac{1}{\sqrt{1 + \left(\frac{Q}{P}\right)^2}}$$
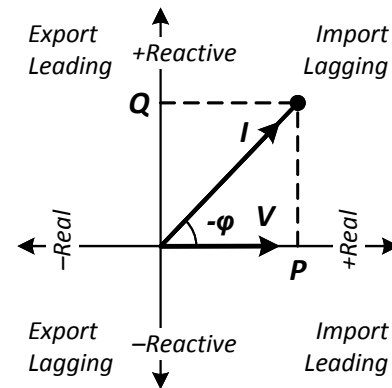
Figure 16: Current Angle Quadrants

During *No Load* conditions the *Real Power* (see R1600) becomes too small for reliable calculation. In this case, returns 0°.

The default smoothed value response time is 2 seconds (see R154).

R1542/43 Instantaneous ● R1544/55 Minimum ● R1546/47 Maximum ● R1548/49 Average

R1550/51   Phase Power Factor   FLOAT   R/W0

Returns true (a.k.a. apparent) power factor pf. A negative value indicates export power.

$$pf = {P}/{S} = {P}/{V \cdot I}$$

Like *Current Angle* (see R1450), returns 0 during *No Load* conditions (see R1600).

When power factor drops below 0.5 (absolute value), the *Low Power Factor* condition (see R1400) is set. *Low Power Factor* may indicate an installation error (see *Installation Instructions*).

The default smoothed value response time is 2 seconds (see R154).

R1552/53 Instantaneous ● R1554/55 Minimum ● R1556/57 Maximum ● R1558/59 Average

R1600/01   Phase Real Power   FLOAT   R/W0

Returns real power P, after multiplication by the *Power Multiplier* (see R1162). The default units are kW (see R163). A negative value indicates export power.

When *Real Power* drops very low, the *No Load* condition (see R1400) is set. During *No Load* conditions, *Current Angle* (see R1540) and *Power Factor* (see R1550) measurements become unreliable. The *No Load* condition is also set during *Phase Loss* conditions.

The *Import* and *Export Averages* only update during the respective intervals (see Figure 17). The *Import Average* is always positive, and the *Export Average* is always negative. When power flows exclusively in one direction, one of these will remain at 0 kW.
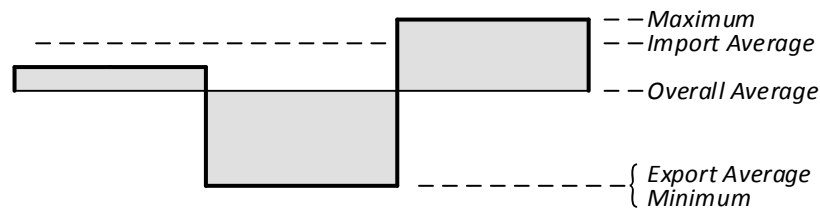
Figure 17: Real Power Averages

During *Phase Loss* conditions (see R1420), returns 0 kW and the *Averages* stop updating.

The default smoothed value response time is 2 seconds (see R164).

R1602/03 Instantaneous ● R1604/05 Minimum ● R1606/07 Maximum
R1608/09 Overall Average ● R1610/11 Import Average ● R1612/13 Export Average

R1640/41   Phase Reactive Power   FLOAT   R/W0

Returns reactive power Q, after multiplication by the *Power Multiplier* (see R1162). The default units are kVAR (see R163). A negative value indicates a capacitive load (leading power factor).

The *Import* and *Export Averages* only update during the respective *Real Power* (see R1600) intervals. When *Real Power* flows exclusively in one direction, one of these will remain at 0 kW. All three averages may be positive or negative, depending on the mix of capacitive and inductive loads.

During *Phase Loss* conditions (see R1420), returns 0 kVAR and the *Averages* stop updating.

The default smoothed value response time is 2 seconds (see R164).

R1642/43 Instantaneous ● R1644/45 Minimum ● R1646/47 Maximum
R1648/49 Overall Average ● R1650/51 Import Average ● R1652/53 Export Average

R1660/61 Phase Apparent Power   FLOAT   R/W0

Returns apparent power S, after multiplication by the *Power Multiplier* (see R1162). The default units are kVA (see R163). Apparent power is always positive:

$$S = V \cdot I$$

The *Import* and *Export Averages* only update during the respective *Real Power* (see R1600) intervals. When *Real Power* flows exclusively in one direction, one of these will remain at 0 kW.

When the *RMS Voltage* becomes invalid (see R1420), returns 0 kVA and the *Averages* stop updating.

The default smoothed value response time is 2 seconds (see R164).

R1662/63 Instantaneous ● R1664/65 Minimum ● R1666/67 Maximum
R1668/69 Overall Average ● R1670/71 Import Average ● R1672/73 Export Average

R1700/01 Total Phase Real Energy   FLOAT*   R/NV

Returns the accumulation of *Real Power* P (see R1600). The default type is *Floating Point* (see R170). The default units are kWh (see R173).

Note the absolute value operation in the accumulation of *Total* but not *Net*:

$$Total = \int |P| \cdot dt$$

$$Net = \int P \cdot dt$$
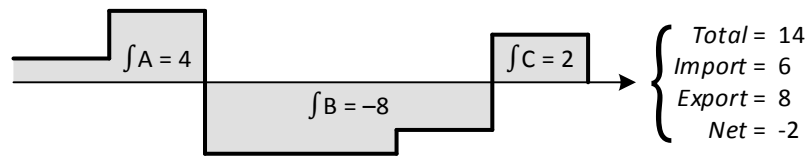
Figure 18: Real Energy

The *Import* and *Export* accumulations follow the sign of *Real Power*:

$$Import = \int \begin{cases} |P| \cdot dt & if\ P > 0 \\ 0 & otherwise \end{cases}$$

$$Export = \int \begin{cases} |P| \cdot dt & if\ P < 0 \\ 0 & otherwise \end{cases}$$

Accumulation stops during *Phase Loss* conditions (see R1420).

R1702/03 Import ● R1704/05 Export ● R1706/07 Net

R1740/41 Total Phase Reactive Energy   FLOAT*   R/NV

Returns the accumulation of *Reactive Power* Q (see R1640). The default type is *Floating Point* (see R170). The default units are kVARh (see R173).

$$Total = \int |Q| \cdot dt$$

The *Import* and *Export* accumulations follow the sign of *Real Power* P (see R1600):

$$Import = \int \begin{cases} |Q| \cdot dt & if\ P > 0 \\ 0 & otherwise \end{cases}$$

$$Export = \int \begin{cases} |Q| \cdot dt & if\ P < 0 \\ 0 & otherwise \end{cases}$$

Accumulation stops during *Phase Loss* conditions (see R1420).

Although *Reactive Power* itself is signed, the accumulators capture only the magnitude without distinguishing between capacitive and inductive modes. Consider calculating this from average power (one of R1648 – R1652) over an interval instead:

$$Net = \overline{Q} \cdot \Delta t$$

R1742/43 Import ● R1744/45 Export

R1760/61   Total Phase Apparent Energy   FLOAT*   R/NV

Returns the accumulation of *Apparent Power S* (see R1660). The default type is *Floating Point* (see R170). The default units are kVAh (see R173).

$$Total = \int S \cdot dt = \int V \cdot I \cdot dt$$

The *Import* and *Export* accumulations follow the sign of *Real Power P* (see R1600):

$$Import = \int \begin{cases} S \cdot dt & if\ P > 0 \\ 0 & otherwise \end{cases}$$

$$Export = \int \begin{cases} S \cdot dt & if\ P < 0 \\ 0 & otherwise \end{cases}$$

Accumulation stops when the *RMS Voltage* becomes invalid (see R1420).

R1762/63 Import ● R1764/65 Export

R1800/01   Demand Real Power   FLOAT   R/W0

Returns the average P_D of *Real Power* (see R1600) over a windowed interval. The default units are kW (see R163). Negative values indicate that export energy exceeded import energy over the course of the demand window.

Demand power bridges a gap between peak power and total energy accumulation. Many peak power measurements are short-lived and can be absorbed by an electrical utility with minimal side effects. However, sustained high power usage requires a fixed capacity investment regardless of the actual consumption (for example, transmission lines). Some utilities bill larger customers for both total energy consumption and peak demand power, although specific rules vary.

Internally, demand windows run for a fixed interval, with each new window marking the end of the previous window. The *Window Time* (see R183) sets the maximum window length, and periodic *Synchronization* (see R181) can help align the start of a window with an external reference. All of the demand power registers follow the same common window schedule.
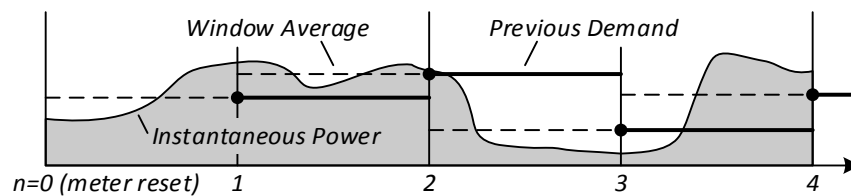
Figure 19: Fixed Demand Windows

During each window, demand continuously tracks the flow of energy in the line. When this value stops changing at the end of the window, it becomes *Previous Demand* (see Figure 19). At the same time, the *Minimum* and *Maximum Demand* statistics update with any new record(s). Finally, the demand tracker resets for the next window. The *Demand Window Count* (see R186) increments exactly once for each demand window.

Formally, demand power may be defined as measured energy divided by the measurement time:

$$P_D = \frac{\Delta E}{\Delta t} = \frac{\int_{t_n}^{t_{n+1}} P \cdot dt}{t_{n+1} - t_n}$$

Notwithstanding previous language that describes a fixed window, the primary demand power value returns a continuously smoothed representation of *Current Demand*. This value smoothly transitions between the fixed demand levels as each window develops (see Figure 20). While not a substitute for a true sliding window calculation, this provides a more timely view of changing demand without waiting for the end of an interval. In *Full Synchronization* mode (see R181), the behavior of *Current Demand* is undefined.
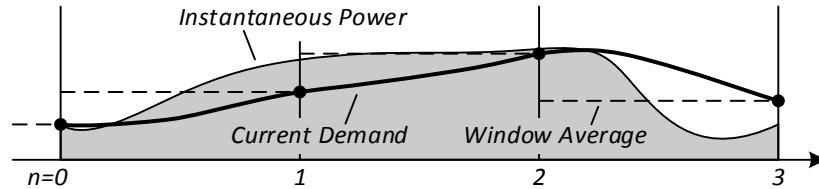
Figure 20: Current Demand Smoothing

After every reset, the meter restores the non-volatile *Minimum* and *Maximum Demand* statistics. The *Current Demand* becomes available immediately, but the *Previous Demand* requires one full window interval to fully initialize.

R1802/03 Previous ● R1804/05 Minimum ● R1806/07 Maximum

R1840/41   Demand Reactive Power   FLOAT   R/W0

Returns the average Q_D of *Reactive Power* (see R1640) over a windowed interval. The default units are kVAR (see R163). Negative values indicate a primarily capacitive load (leading power factor) over the course of the interval.

R1842/43 Previous ● R1844/45 Minimum ● R1846/47 Maximum

R1860/61   Demand Apparent Power   FLOAT   R/W0

Returns the average S_D of *Apparent Power* (see R1660) over a windowed interval. The default units are kVA (see R163).

R1862/63 Previous ● R1864/65 Minimum ● R1866/67 Maximum

S Phase

R2000 – 2999

S Phase holding registers parallel the R Phase, offset +1000.

As an example, read R2103 for *S Phase Status*

T Phase

R3000 – 3999

T Phase holding registers parallel the R Phase, offset +2000.

As an example, read R3103 for *T Phase Status*

Functions

The EM-RS485 supports the following functions of the *Modbus Application Protocol Specification*, v1.1b3. Examples are intended to be representative; refer to the full specification for questions or clarification.

Notes:

- The device address 100 (0x64) is arbitrarily selected.
- Unless otherwise specified, examples show Modbus RTU encoding only.
- Refer to the Modbus standard for CRC/LRC calculation procedures.

Data Types

Natively, Modbus holding register functions only support the UINT16 type (2 bytes). The meter constructs additional types from two or more consecutive registers. Client interface software must support the same construction for proper communication:

	# of Registers	Range (hexadecimal)
UINT16	1	0 – 65535 (0xFFFF), unless otherwise noted
BOOL	1	0 – 1
UINT32	2	0 – 4294967295 (0xFFFFFFFF), unless otherwise noted
FLOAT	2	$\pm 3.402823 \times 10^{38}$ (IEEE-754), unless otherwise noted
ASCII	–	Variable length, NULL terminated

UINT32 and FLOAT data always occupies two registers (4 bytes) in network byte order (MSB first). Read and write operations must address both registers, except *Write Single Register* (function 0x06) in expanded mode. FLOAT values are treated as a raw sequence of 4 bytes; refer to the IEEE-754 standard to interpret the contents of FLOAT values.

The following examples show UINT32 encodings in a Modbus PDU beginning at byte [n], register [r]:

Value	Decimal	[n]	[n+1]	[n+2]	[n+3]
0xAABBCCDD	2864434397	0xAA	0xBB	0xCC	0xDD
0x01234567	19088743	0x12	0x34	0x56	0x78
0x00010000	65536	0x00	0x01	0x00	0x00
REGISTER		**[r]**		**[r+1]**	

ASCII data occupies a range of registers, with each register encoding a pair of consecutive characters. Refer to Appendix C for ASCII character encodings. The MSB of each register encodes the leading ASCII character of the pair. ASCII values support random access read and write operations on any partial register range. The very last character (the LSB of the last register) must always be ASCII NULL (0). An ASCII NULL may be inserted earlier in the value to shorten the printed string. The following example shows the ASCII encoding of "TESTING" in a Modbus PDU beginning at byte [n] (register [r]):

OFFSET	[n]	[n+1]	[n+2]	[n+3]	[n+4]	[n+5]	[n+6]	[n+7]
ASCII	T	E	S	T	I	N	G	NULL
HEX	0x54	0x45	0x53	0x54	0x49	0x4E	0x47	0x00
REGISTER	**[r]**		**[r+1]**		**[r+2]**		**[r+3]**	

0x03 Read Holding Registers

Returns one or more registers in a contiguous block:

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x03
[2]	Starting Address	2	A = 0 to 65535 (0xFFFF)
[3]	Register Count	2	N = 1 to 125 registers
[4]	CRC	2	

Successful reads return the contents of the requested registers:

	Response	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x03
[2]	Byte Count	1	2 * N
[3]	Register Data	2 * N	
[4]	CRC	2	

Failed reads return an exception code:

Illegal Data	Improperly formed request or count N out of range.
Illegal Address	The last address $A + N$ exceeds 65536.
Server Failure	Alignment fault: UINT32 and FLOAT reads must address both registers.

This function supports reads from the complete Modbus address space (registers 0 – 65535) without error, including undefined addresses. This facilitates combining reads from close but non-quite-adjacent registers, which may be more efficient in some circumstances. Always discard data read from undefined addresses.

Example 1: Read the current RS485 configuration (see R122 – R128), 6 values total. However, because *Baud Rate* spans two registers, N must be 7 to get all the data.

```
Request = 0x  64   03   00 7A   00 07   2C 24
             [0]  [1]    [2]     [3]    [4]
```

```
Response = 0x  64   03   0E   00 03   00 64   00 01 2C 00   00 04   00 03   00 00   34 B5
              [0]  [1]  [2]   [3a]    [3b]       [3c]       [3d]    [3e]    [3f]     [4]
```

[3a]	*RS485 Protocol*	= 0x0003	= 3 (*Modbus RTU*)
[3b]	*Slave Address*	= 0x0064	= 100
[3c]	*Baud Rate*	= 0x00012C00	= 76800
[3d]	*RS485 Parity*	= 0x0004	= 4 (*Even Parity*),
[3e]	*RS485 Data Bits*	= 0x0003	= 3 (*8 Bits*),
[3f]	*RS485 Stop Bits*	= 0x0000	= 0 (*Auto*)

Example 2: Read the *Frequency* statistics (see R414 – R416).

```
Request = 0x  64   03   01 9E   00 06   AC 2F
             [0]  [1]    [2]     [3]    [4]
```

```
Response = 0x  64   03   0C   42 6F E7 6D   42 70 48 B4   42 70 0E 56   9F E9
              [0]  [1]  [2]     [3a]          [3b]          [3c]         [4]
```

[3a]	*Minimum Frequency*	= 0x426FE76D	= 59.976 Hz (IEEE-754)
[3b]	*Maximum Frequency*	= 0x427048B4	= 60.071 Hz (IEEE-754)
[3c]	*Average Frequency*	= 0x42700E56	= 60.014 Hz (IEEE-754)

0x06 Write Single Register

Writes a value to a single register:

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x06
[2]	Register Address	2	A = 0 to 65535 (0xFFFF)
[3]	Register Value	2	X = 0 to 65535 (0xFFFF)
[4]	CRC	2	

Successful writes echo the original request:

	Response	Size	
[0]	Device Address	1	
[1]	Function Code	1	Always 0x06
[2]	Register Address	2	A
[3]	Register Value	2	X
[4]	CRC	2	

Failed writes return an exception code:

Illegal Data	Improperly formed request.
Illegal Address	The requested address A is undefined.
Server Failure	New value X rejected (e.g. out of range).

For convenience, this function supports direct writes to the first register (low address) of UINT32 and FLOAT register pairs. Values are limited to the UINT16 range, and the meter internally expands them to the correct width before storing.

ASCII registers support arbitrary writes to any individual register within the string.

Example 1: Enable *PowerPrint* (see R241).

Request = Response = **0x** <u>64</u> <u>06</u> <u>00 F1</u> <u>00 01</u> <u>10 0C</u>
                        [0] [1] [2]   [3]   [4]

Example 2: Set *Demand Window Time* to 1 day = 1440 minutes (see R183).

Request = Response = **0x** <u>64</u> <u>06</u> <u>00 B7</u> <u>05 A0</u> <u>33 31</u>
                        [0] [1] [2]   [3]   [4]

Example 3: Software synchronization of *Elapsed Demand Window* (see R184; note UINT32 expansion).

Request = Response = **0x** <u>64</u> <u>06</u> <u>00 B8</u> <u>00 00</u> <u>00 1A</u>
                        [0] [1] [2]   [3]   [4]

Example 4: Set the *PowerPrint Frequency* to 50 Hz (see R242; note FLOAT expansion).

Request = Response = **0x** <u>64</u> <u>06</u> <u>00 F2</u> <u>00 32</u> <u>A0 19</u>
                        [0] [1] [2]   [3]   [4]

0x08 Diagnostics

Performs miscellaneous device management functions. The Modbus protocol specifications defines many diagnostic sub-functions, but the meter only supports the following sub-functions.

0x00 | Return Query Data

Returns response bytes equal to the request (echo):

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	Always 0x0000
[3]	Request Data	–	Any data
[4]	CRC	2	

Successful commands echo the original request. This sub-function supports any length of request data up to and including 250 bytes.

Example: Return 4 bytes.

Request = Response = **0x** 64 08 00 00 04 D2 00 00 10 0C
                             [0] [1]   [2]   [3]   [4]

0x01 | Restart Communications

Reinitializes the RS485 transceiver interface and clears the communications event counters.

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	Always 0x0001
[3]	Request Data	2	Always 0x0000
[4]	CRC	2	

Failed commands return an exception code:

Illegal Data   Invalid Request Data.

Successful commands echo the original request, unless the meter is in *Listen Only* Mode (see sub-function 0x04). In *Listen Only* Mode, the meter suppresses the response. After the RS485 transceiver reinitializes, the *RS485 Status* LED indicates the *Waiting For Activity* condition (see *Installation Instructions*).

The communications event counters correspond to sub-functions 0x08 - 0x0B.

Example:

Request = Response = **0x** 64 08 00 01 00 00 B8 3E
                             [0] [1]   [2]   [3]   [4]

0x03 | Change ASCII Input Delimiter

Sets a new end-of-message delimiter for future messages (replacing the default LF delimiter). This delimiter only applies to the Modbus ASCII protocol.

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	Always 0x0003
[3]	Request Data	1	Encodes the new delimiter (0 – 127)
[4]	Padding	1	Always 0x00
[5]	LRC	2	

Failed commands return an exception code:

Illegal Data Invalid Request Data.

The command may fail if the padding byte is non-zero, or if the new delimiter is out of range. (Because the Modbus ASCII only specifies 7 data bits, delimiter characters greater than 127 cannot be transmitted.) If a command fails, the previously configured delimiter remains unchanged.

Successful commands echo the original request, including the original delimiter.

> **IMPORANT:** Switch to the new delimiter only at the beginning of the *next* Modbus request.

Example 1: Switch the delimiter to 0x00 (NULL).   Encoding is Modbus ASCII.

Request = Response = **0x** **3A** **36 34** **30 38** **30 30 30 33** **30 30** **30 30** **39 31** **0D 0A**
          : [0] [1]   [2]   [3] [4] [5] CR LF

Example 2: Switch the delimiter back 0x0A (the Modbus default). NOTE: The LF 0x00 follows from *Example 1*.

Request = Response = **0x** **3A** **36 34** **30 38** **30 30 30 33** **30 3A** **30 30** **38 37** **0D 00**
          : [0] [1]   [2]   [3] [4] [5] CR LF

0x04 | Force Listen Only Mode

Disables all Modbus protocol functions except for *Restart Communications* (see sub-function 0x01). This mode isolates the meter from other devices on the network, allowing those devices to continue communicating without interruption.   In this mode, the meter monitors Modbus commands addressed to itself (including broadcast commands) but takes no actions and sends no response.

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	Always 0x0004
[3]	Request Data	2	Always 0x0000
[4]	CRC	2	

Failed commands return an exception code:

Illegal Data Request data does not equal 0x0000.

Successful commands return no response.

Example:

Request = **0x** **64** **08** **00 04** **00 00** **A8 3F**
      [0] [1] [2]   [3]   [4]

0x0A | Clear Counters and Diagnostic Register

Resets the diagnostic counters (see sub-functions 0x0B – 0x12).

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	Always 0x000A
[3]	Request Data	2	Always 0x0000
[4]	CRC	2	

Failed commands return an exception code:

Illegal Data   Request data not equal to 0x0000.

Successful commands echo the original request. NOTE: The diagnostic register is not supported.

Example:

Request = Response = **0x   64   08   00   0A   00   00   08   3C**
                          [0]   [1]   [2]   [3]   [4]

0x0B – 0x12 | Return Diagnostic Counters

Returns one of the serial port diagnostic counters. These counters may be useful for performance and error management.   Diagnostic counters reset to 0 when the meter itself resets, or manually (see sub-function 0x0A).

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x08
[2]	Sub-Function Code	2	0x000B – 0x0012 (described below)
[3]	Request Data	2	Always 0x0000
[4]	CRC	2	

Failed commands return an exception code:

Illegal Data   Request data does not equal 0x0000.

Successful commands return the current counter value in the Data field. The Modbus specification defines the following counters:

**0x0B	Bus Message Count**	Count of messages received, not including errors.
**0x0C	Bus Communication Error Count**	Count of character overrun, parity, and CRC errors.
**0x0D	Bus Exception Error Count**	Count of exception responses returned.
**0x0E	Server Message Count**	Count of messages addressed to and processed by the remote device, including broadcast messages.
**0x0F	Server No Response Count**	Count of messages addressed to the remote device for which it returned no response (e.g. broadcast messages).
**0x10	Server NAK Count**	Count of Negative Acknowledge exception responses. Always returns 0.
**0x11	Server Busy Count**	Count of Server Device Busy exception responses. Always returns 0.
**0x12	Bus Character Overrun Count**	Count of messages that the meter could not handle due to a character overrun (occurs when characters arrive at the port faster than they can be processed).

Example 1: Read the *Bus Message Count*.

Request = **0x 64 08 00 0B 00 00 98 3C**
         [0] [1] [2] [3] [4]

Response = **0x 64 08 00 0B 01 A0 99 D4**
         [0] [1] [2] [3] [4]

[3] *Bus Message Count* = 0x01A0 = 416

Example 2: Read the *Server No Response Count*.

Request = **0x 64 08 00 0F 00 00 D9 FD**
         [0] [1] [2] [3] [4]

Response = **0x 64 08 00 0F 00 02 58 3C**
         [0] [1] [2] [3] [4]

[3] *Server No Response Count* = 0x0002 = 2

0x10 Write Multiple Registers

Writes one or more registers in a contiguous block:

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x10
[2]	Starting Address	2	A = 0 to 65535 (0xFFFF)
[3]	Write Count	2	N = 1 to 123 registers
[4]	Byte Count	1	Always 2 * N
[5]	Write Registers	2 * N	X …
[6]	CRC	2	

Successful writes echo the *Starting Address* and *Write Count*:

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x10
[2]	Starting Address	2	A
[3]	Write Count	2	N
[4]	CRC	2	

Failed writes return an exception code:

Illegal Data	Improperly formed request or count N out of range.
Illegal Address	The last address $A + N$ exceeds exceeds 65536.
Server Failure	New value X rejected (e.g. out of range), or
	Write to a read-only register, or
	Write to an undefined register, or
	Alignment error: writes to UINT32 and FLOAT must address both registers.

A *Server Failure* exception indicates that the meter rejected a write to one or more registers. Unless exactly one value was written, it is not possible to determine which portion of the request caused the exception. The meter attempts to write each register in the request, regardless of failure status.

Example 1: Reset the R Phase accumulated energy (see R1192, key = 7564709 = 0x00736DA5):

Request = **0x 64 10 04 A8 00 02 04 00 73 6D A5 38 4C**
　　　　　　　[0] [1] [2] [3] [4] [5] [6]

Response = **0x 64 10 04 A8 00 02 C8 ED**
　　　　　　　　 [0] [1] [2] [3] [4]

Example 2: Change the location string to "Panel 311.5" (see R276):

Request = **0x 64 10 01 14 00 06 0C 50 61 6E 65 6C 20 33 31 31 2E 35 00 EF B5**
　　　　　　　[0] [1] [2] [3] [4] [5] [6]

Response = **0x 64 10 01 14 00 06 08 06**
　　　　　　　　 [0] [1] [2] [3] [4]

0x11 Report Server ID

Returns device information in ASCII string format:

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x11
[2]	CRC	2	

The request always returns a valid response:

	Response	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x11
[2]	Byte Count	1	Total length of fields 3 – 5
[3]	Server ID	1	Always 0x01
[4]	Run Indicator	1	Always 0xFF (run mode)
[5]	Additional Data	–	Varies, see below
[6]	CRC	2	

The *Additional Data* field returns an ASCII string with several concatenated values:

[5a]	Vendor Name	"Senva Sensors"
[5b]	Model Name	"EM-RS485"
[5c]	Serial Number	varies
[5d]	Firmware Version	varies
[5e]	Location String	varies (see R276)

Example: Read the server ID:

```
Request = 0x  64  11  EB 7C
              [0] [1]  [2]
```

```
Response = 0x  64  11  31  01  FF  53  65  6E  76  61  20  53  65  6E  73  6F  72  …
               …  73  20  45  4D  2D  52  53  34  38  35  20  …
               …  32  31  30  31  34  35  20  31  2E  31  2E  …
               …  30  20  50  61  6E  65  6C  20  33  31  31  2E  35  96 CB
              [0] [1] [2] [3] [4]                [5]                     [6]
```

[5] *Additional Data* = "Senva Sensors EM-RS485 210145 1.1.0 Panel 311.5"

0x17 Read/Write Multiple Registers

Writes one or more registers in a contiguous block, then reads one or more registers from a contiguous block. The two blocks need not specify the same starting address or count.

	Request	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x17
[2]	Read Address	2	0 to 65535 (0xFFFF)
[3]	Read Count	2	R = 1 to 125 registers
[4]	Write Address	2	0 to 65535 (0xFFFF)
[5]	Write Count	2	W = 1 to 121 registers
[6]	Write Length	1	Always 2 * W
[7]	Write Data	W * 2	
[8]	CRC	2	

The meter performs the write operation first, and then the operation read. Successful reads return the contents of the requested registers:

	Response	Size	Notes
[0]	Device Address	1	
[1]	Function Code	1	Always 0x17
[2]	Byte Count	1	Always 2 * R
[3]	Register Data	2 * R	
[4]	CRC	2	

Failed operations may return an exception code for any of the reasons of *Read Holding Registers* (function 0x03) or *Write Multiple Registers* (function 0x10). It is not possible to determine which portion of the operation caused the exception.

Example: Read system demand power (see R10250 ff.) immediately after a demand synchronization (see R184).

```
Request = 0x  64   17   28 0A   00 06   00 B8   00 02   04   00 00 00 00   51 5C
             [0]  [1]   [2]     [3]     [4]     [5]    [6]     [7]         [8]
```

```
Response = 0x  64   17   0C   3F 11 EB 85   3E B8 51 EC   3F 5E B8 52   B5 FC
              [0]  [1]  [2]     [3a]          [3b]          [3c]        [4]
```

[3a]	*Demand Real Power*	0x3F11EB85	= 0.57 kW (IEEE-754)
[3b]	*Demand Reactive Power*	0x3EB851EC	= 0.36 kW (IEEE-754)
[3c]	*Demand Apparent Power*	0x3F5EB852	= 0.87 kW (IEEE-754)

Appendix A: Common Registers

This subset of holding registers facilitates efficient bulk transfers between a meter and a logger. Each alternate address directly maps the value of the base address, with full read and write support.

This subset is organized in 4 planes, each with a unique offset "X":

- System $X = 10000$
- R Phase $X = 11000$
- S Phase $X = 12000$
- T Phase $X = 13000$

To calculate the final address of a mapped value, add "X" for the desired plane to the listed address offset. For example, the *R Phase RMS Voltage* maps to 11222/23 (11000+222/23). For convenience, the table lists register equivalents for the System and R Phase planes. S and T Phase registers follow the same pattern.

Address	Description	Units	Type	Access	System	R Phase
X + 200/01	Real Power	kW*	FLOAT	R/W0	R600/01	R1600/01
X + 202/03	Total Real Energy	kWh*	FLOAT*	R/NV	R700/01	R1700/01
X + 204/05	Reactive Power	kVAR*	FLOAT	R/W0	R640/41	R1640/41
X + 206/07	Total Reactive Energy	kVARh*	FLOAT*	R/NV	R740/41	R1740/41
X + 208/09	Apparent Power	kVA*	FLOAT	R/W0	R660/61	R1660/61
X + 210/11	Total Apparent Energy	kVAh*	FLOAT*	R/NV	R760/61	R1760/61
X + 212/13	(Reserved)					
X + 214/15	(Reserved)					
X + 216/17	Line Frequency	Hertz	FLOAT	R/W0	R410/11	N/A
X + 218/19	Phase to Phase Voltage Angle	Degree*	FLOAT	R/W0	N/A	R1440/41
X + 220/21	Phase to Phase RMS Voltage	Volts	FLOAT	R/W0	R450/51	R1450/51
X + 222/23	RMS Voltage	Volts	FLOAT	R/W0	R420/21	R1420/21
X + 224/25	RMS Current	Amps	FLOAT	R/W0	R520/21	R1520/21
X + 226/27	Current Angle	Degree*	FLOAT	R/W0	R540/41	R1540/41
X + 228/29	Power Factor	W/VA	FLOAT	R/W0	R550/51	R1550/51
X + 230/31	(Reserved)					
X + 232/33	(Reserved)					
X + 234/35	Import Real Energy	kWh*	FLOAT*	R/NV	R702/03	R1702/03
X + 236/37	Export Real Energy	kWh*	FLOAT*	R/NV	R704/05	R1704/05
X + 238/39	Import Reactive Energy	kVARh*	FLOAT*	R/NV	R742/43	R1742/43
X + 240/41	Export Reactive Energy	kVARh*	FLOAT*	R/NV	R744/45	R1744/45
X + 242/43	Import Apparent Energy	kVAh*	FLOAT*	R/NV	R762/63	R1762/63
X + 244/45	Export Apparent Energy	kVAh*	FLOAT*	R/NV	R764/65	R1764/65
X + 246/47	(Reserved)					
X + 248/49	(Reserved)					

(continued on the next page)

Address	Description	Units	Type	Access	System	Phase
X + 250/51	Demand Real Power	kW*	FLOAT	R/W0	R800/01	R1800/01
X + 252/53	Demand Reactive Power	kVAR*	FLOAT	R/W0	R840/41	R1840/41
X + 254/55	Demand Apparent Power	kVA*	FLOAT	R/W0	R860/61	R1860/61
X + 256/57	(Reserved)					
X + 258/59	(Reserved)					
X + 260/61	Min. Phase to Phase Voltage	Volts	FLOAT	R/W0	R454/55	R1454/55
X + 262/63	Max. Phase to Phase Voltage	Volts	FLOAT	R/W0	R456/57	R1456/57
X + 264/65	Minimum RMS Voltage	Volts	FLOAT	R/W0	R424/25	R1424/25
X + 266/67	Maximum RMS Voltage	Volts	FLOAT	R/W0	R426/27	R1426/27
X + 268/69	(Reserved)					
X + 270/71	(Reserved)					
X + 272/73	Minimum Power Factor	W/VA	FLOAT	R/W0	R554/55	R1554/55
X + 274/75	Maximum Power Factor	W/VA	FLOAT	R/W0	R556/57	R1556/57
X + 276/77	Minimum Real Power	kW*	FLOAT	R/W0	R604/05	R1604/05
X + 278/79	Maximum Real Power	kW*	FLOAT	R/W0	R606/07	R1606/07

* Default factory configuration. Alternate configuration possible.

Appendix B: Condition Flags Decoding

Reading the condition flag registers (see R400, R1400) always returns some positive integer R encoding a set C of one or more conditions. Conditions are encoded in binary form, with the interpretation of bits varying between registers. Undefined bits are reserved.

Follow this iterative procedure to find C given any value R:

1. Initialize $C = \{\ \}$ (the empty set)
2. Initialize $X = 2^{15} = 32768$
3. If $(R < X)$, skip to step 6
4. Subtract X from R
5. If the register defines condition X, add that to C. Otherwise, skip.
6. Divide X by 2 (move to the next smaller bit)
7. If $(X > 1)$, repeat steps 3

For example, if R1400 $R = 3108$, then $C = \{$ *Negative Power, Low Power Factor, Surge Voltage* $\}$:

Repetition			Step 3	Step 4	Step 5
1.	$R = 3108$	$X = 32768$	TRUE		
2.	$R = 3108$	$X = 16384$	TRUE		
3.	$R = 3108$	$X = 8192$	TRUE		
4.	$R = 3108$	$X = 4096$	TRUE		
5.	$R = 3108$	$X = 2048$	FALSE	$R = 1060$	$C = C \cup \{$ *Surge Voltage* $\}$
6.	$R = 1060$	$X = 1024$	FALSE	$R = 36$	skip $\{$ *Reserved Condition* $\}$
7.	$R = 36$	$X = 512$	TRUE		
8.	$R = 36$	$X = 256$	TRUE		
9.	$R = 36$	$X = 128$	TRUE		
10.	$R = 36$	$X = 64$	TRUE		
11.	$R = 36$	$X = 32$	FALSE	$R = 4$	$C = C \cup \{$ *Low Power Factor* $\}$
12.	$R = 4$	$X = 16$	TRUE		
13.	$R = 4$	$X = 8$	TRUE		
14.	$R = 4$	$X = 4$	FALSE	$R = 0$	$C = C \cup \{$ *Negative Power* $\}$
15.	$R = 0$	$X = 2$	TRUE		
16.	$R = 0$	$X = 1$	TRUE		

An uncompensated PV array may explain this particular set of conditions:

- The *Negative Power* condition may indicate that real power generation exceeds consumption, at least momentarily.
- The *Low Power Factor* condition may indicate a large reactive power, at least when compared to the net real power (assuming that the PV array does not generate reactive power).
- The *Surge Voltage* condition may indicate a too-small *PowerPrint Voltage Tolerance* (see R246), not accounting for the voltage boost required to return power back to the grid.

Appendix C: Hex Conversions

HEX	DEC	ASCII		HEX	DEC	ASCII		HEX	DEC	LATIN-1		HEX	DEC	LATIN-1
0x00	0	NULL		0x40	64	@		0x80	128	€		0xC0	192	À
0x01	1			0x41	65	A		0x81	129			0xC1	193	Á
0x02	2			0x42	66	B		0x82	130	‚		0xC2	194	Â
0x03	3			0x43	67	C		0x83	131	ƒ		0xC3	195	Ã
0x04	4			0x44	68	D		0x84	132	„		0xC4	196	Ä
0x05	5			0x45	69	E		0x85	133	…		0xC5	197	Å
0x06	6			0x46	70	F		0x86	134	†		0xC6	198	Æ
0x07	7			0x47	71	G		0x87	135	‡		0xC7	199	Ç
0x08	8			0x48	72	H		0x88	136	ˆ		0xC8	200	È
0x09	9			0x49	73	I		0x89	137	‰		0xC9	201	É
0x0A	10			0x4A	74	J		0x8A	138	Š		0xCA	202	Ê
0x0B	11			0x4B	75	K		0x8B	139	‹		0xCB	203	Ë
0x0C	12			0x4C	76	L		0x8C	140	Œ		0xCC	204	Ì
0x0D	13			0x4D	77	M		0x8D	141			0xCD	205	Í
0x0E	14			0x4E	78	N		0x8E	142	Ž		0xCE	206	Î
0x0F	15			0x4F	79	O		0x8F	143			0xCF	207	Ï
0x10	16			0x50	80	P		0x90	144			0xD0	208	Ð
0x11	17			0x51	81	Q		0x91	145	'		0xD1	209	Ñ
0x12	18			0x52	82	R		0x92	146	'		0xD2	210	Ò
0x13	19			0x53	83	S		0x93	147	"		0xD3	211	Ó
0x14	20			0x54	84	T		0x94	148	"		0xD4	212	Ô
0x15	21			0x55	85	U		0x95	149	•		0xD5	213	Õ
0x16	22			0x56	86	V		0x96	150	–		0xD6	214	Ö
0x17	23			0x57	87	W		0x97	151	—		0xD7	215	×
0x18	24			0x58	88	X		0x98	152	˜		0xD8	216	Ø
0x19	25			0x59	89	Y		0x99	153	™		0xD9	217	Ù
0x1A	26			0x5A	90	Z		0x9A	154	š		0xDA	218	Ú
0x1B	27			0x5B	91	[		0x9B	155	›		0xDB	219	Û
0x1C	28			0x5C	92	\		0x9C	156	œ		0xDC	220	Ü
0x1D	29			0x5D	93	]		0x9D	157			0xDD	221	Ý
0x1E	30			0x5E	94	^		0x9E	158	ž		0xDE	222	Þ
0x1F	31			0x5F	95	_		0x9F	159	Ÿ		0xDF	223	ß
0x20	32			0x60	96	`		0xA0	160			0xE0	224	à
0x21	33	!		0x61	97	a		0xA1	161	¡		0xE1	225	á
0x22	34	"		0x62	98	b		0xA2	162	¢		0xE2	226	â
0x23	35	#		0x63	99	c		0xA3	163	£		0xE3	227	ã
0x24	36	$		0x64	100	d		0xA4	164	¤		0xE4	228	ä
0x25	37	%		0x65	101	e		0xA5	165	¥		0xE5	229	å
0x26	38	&		0x66	102	f		0xA6	166	¦		0xE6	230	æ
0x27	39	'		0x67	103	g		0xA7	167	§		0xE7	231	ç
0x28	40	(		0x68	104	h		0xA8	168	¨		0xE8	232	è
0x29	41	)		0x69	105	i		0xA9	169	©		0xE9	233	é
0x2A	42	*		0x6A	106	j		0xAA	170	ª		0xEA	234	ê
0x2B	43	+		0x6B	107	k		0xAB	171	«		0xEB	235	ë
0x2C	44	,		0x6C	108	l		0xAC	172	¬		0xEC	236	ì
0x2D	45	-		0x6D	109	m		0xAD	173			0xED	237	í
0x2E	46	.		0x6E	110	n		0xAE	174	®		0xEE	238	î
0x2F	47	/		0x6F	111	o		0xAF	175	¯		0xEF	239	ï
0x30	48	0		0x70	112	p		0xB0	176	°		0xF0	240	ð
0x31	49	1		0x71	113	q		0xB1	177	±		0xF1	241	ñ
0x32	50	2		0x72	114	r		0xB2	178	²		0xF2	242	ò
0x33	51	3		0x73	115	s		0xB3	179	³		0xF3	243	ó
0x34	52	4		0x74	116	t		0xB4	180	´		0xF4	244	ô
0x35	53	5		0x75	117	u		0xB5	181	µ		0xF5	245	õ
0x36	54	6		0x76	118	v		0xB6	182	¶		0xF6	246	ö
0x37	55	7		0x77	119	w		0xB7	183	·		0xF7	247	÷
0x38	56	8		0x78	120	x		0xB8	184	¸		0xF8	248	ø
0x39	57	9		0x79	121	y		0xB9	185	¹		0xF9	249	ù
0x3A	58	:		0x7A	122	z		0xBA	186	º		0xFA	250	ú
0x3B	59	;		0x7B	123	{		0xBB	187	»		0xFB	251	û
0x3C	60	<		0x7C	124				0xBC	188	¼		0xFC	252	ü
0x3D	61	=		0x7D	125	}		0xBD	189	½		0xFD	253	ý
0x3E	62	>		0x7E	126	~		0xBE	190	¾		0xFE	254	þ
0x3F	63	?		0x7F	127			0xBF	191	¿		0xFF	255	ÿ