WattNode® Modbus

Installation and Operation Manual

- WNC-3Y-208-MB
- WNC-3Y-400-MB
- WNC-3Y-480-MB
- WNC-3Y-600-MB
- WNC-3D-240-MB
- WNC-3D-400-MB
- WNC-3D-480-MB

Continental Control Systems LLC
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FCC Information

This equipment has been tested and complies with the limits for a Class B digital device, pursuant to part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

The FCC limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and receiver.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician to help.

Contents

Overview

Congratulations on your purchase of the WattNode® MODBUS watt/watt-hour transducer. The WattNode offers precision energy and power measurements in a compact package. The WattNode enables you to make power and energy measurements within existing electric service panels avoiding the costly installation of subpanels and associated wiring. It is designed for use in demand side management (DSM), sub-metering, and energy monitoring applications. The WattNode communicates on an EIA RS-485 two-wire bus using the MODBUS protocol. Models are available for single-phase, three-phase wye, and three-phase delta configurations for voltages from 120 VAC to 600 VAC at 50 and 60 Hz.

Measurements

The WattNode MODBUS measures the following:

- True RMS Power - Watts (Phase A, Phase B, Phase C, Sum)
- Reactive Power - VARs (Phase A, Phase B, Phase C, Sum)
- Power Factor (Phase A, Phase B, Phase C, Average)
- True RMS Energy - Watthours (Phase A, Phase B, Phase C, Sum)
- Reactive Energy - VAR-hours (Sum)
- AC Frequency
- RMS Voltage (Phase A, Phase B, Phase C)
- RMS Current (Phase A, Phase B, Phase C)
- Demand and Peak Demand

Communication

The WattNode uses a half-duplex EIA RS-485 interface for communication. The standard baud rates are 9,600 and 19,200 baud, and 38,400 can be configured. The WattNode uses the industry standard MODBUS RTU (binary) communication protocol, allowing up to 127 WattNodes per RS-485 subnet. The WattNode can auto-detect RS-485 polarity on properly biased networks, simplifying installation.

There are numerous low-cost RS-485 interfaces to PCs, using both USB and serial ports. There are many PC programs and standalone devices for collecting and recording MODBUS data.

Diagnostic LEDs

The WattNode includes three power diagnostic LEDs—one per phase. During normal operation, these LEDs flash on and off, with the speed of flashing roughly proportional to the power on each phase. The LEDs flash green for positive power, red for negative power, and yellow for low power factor. Other conditions are signaled with different LED patterns. See **Installation LED Diagnostics** for details.

The MODBUS WattNode also includes a communication LED that lights green, yellow, or red to help diagnose the RS-485 network. See **MODBUS Communication Diagnostics** for details.

Current Transformers

The WattNode works with 0.333 VAC solid-core (toroidal), split-core (opening), and bus-bar current transformers (CTs). Split-core and bus-car CTs offer greater ease of installation, because they can be installed without disconnecting the circuit being measured. Solid-core CTs are more compact, generally more accurate, and less expensive, but installation requires that the measured circuit be disconnected.

Additional Literature

- WattNode MODBUS - Quick Install Guide
- http://www.modbus.org/specs.php
  - MODBUS Application Protocol Specification - V1.1b
  - MODBUS over Serial Line - Specification & Implementation Guide - V1.0

Front Label

This section describes all the connections, information, and symbols that appear on the WattNode front label.

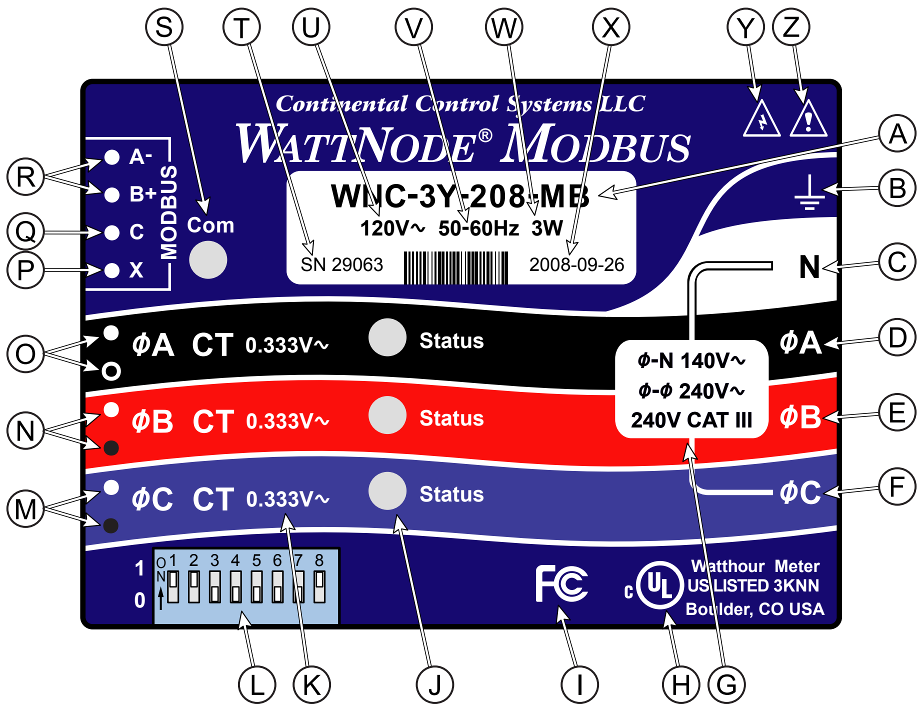


Figure 1 Front Label Diagram

A: WattNode model number. The "**WNC**" indicates a third generation WattNode. The "**3**" indicates a three phase model. The "**Y**" or "**D**" indicates wye (four-wire) or delta (three-wire) models, although delta WattNodes can measure wye circuits (the difference is in the power supply). The "**208**" (or other value) indicates the nominal phase-to-phase voltage. Finally, the "**MB**" indicates MODBUS output.

B: Functional ground. This terminal should be connected to earth ground. It is not required for safety grounding, but the accuracy of the WattNode will be reduced if this terminal is not connected.

C: Neutral. This terminal should be connected to neutral when available.

D, E, F: Mains line inputs. One or more of these terminals are connected to the mains lines. For three phase measurement, the **ØA** (phase A), **ØB** (phase B), and **ØC** (phase C) terminals are used for the three phases. On delta WattNode models, the WattNode gets power from the **ØA** and **ØB** terminals.

G: Line voltage measurement ratings. This block lists the nominal phase-to-neutral "**Ø-N 120V~**" voltage, phase-to-phase "**Ø-Ø 240V~**" voltage, and the rated measurement voltage and category "**240V CAT III**" for this WattNode model. See the **Specifications** for more information about the measurement voltage and category.

H: UL Listing mark. This shows the UL and cUL (Canadian) listing mark and number "**3KNN**".

I: FCC Mark. This logo indicates that the WattNode complied with part 15 of the FCC rules.

J: Status LEDs. These are status LEDs used to verify and diagnose WattNode operation. See **Installation LED Diagnostics** for details.

K: Current transformer (CT) voltage rating. These markings "**0.333V~**" indicate that the current transformers must generate a full-scale output of 0.333 VAC (333 millivolts AC).

L: DIP switch. This DIP switch block is used to set the MODBUS address and baud rate. See **Setting the MODBUS Address**.

M, N, O: Current transformer (CT) inputs. These indicate the positions of the screw terminals for the current transformers. The white and black circles at the left edge of the label indicate the color of the CT wire that should be inserted into the corresponding screw terminal.

P: Auxiliary output terminal. This screw terminal is reserved for future options.

Q: MODBUS common terminal. This is the common or ground terminal for MODBUS EIA RS-485 communication wiring.

R: MODBUS signal terminals. These are the RS-485 A- and B+ signal terminals (half-duplex or two-wire).

S: Communication status. This LED indicates communication status. See **MODBUS Communication Diagnostics** for details.

T: Serial number. This small label shows the WattNode serial number and will show options if any are selected.

U: Mains supply rated voltage. This marking indicates the rated supply voltage for this WattNode. The **V~** indicates AC voltage. For wye WattNode models, this voltage should appear between the **N** and **ϕA** terminals. For delta WattNode models, this voltage should appear between the **ϕA** and **ϕB** terminals.

V: Mains frequencies. This indicates the rated mains frequencies for the WattNode.

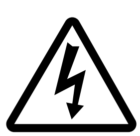
W: Maximum rated power. This indicates the maximum rated power in watts (active power) for this WattNode model.

X: Manufacture date. This is the date of manufacture for the WattNode.

Y: Caution, risk of electrical shock. There is a risk of electric shock when installing and operating the WattNode if the installation instructions are not followed correctly.

Z: Attention - consult Installation and Operation Manual. There can be danger when installing and operating the WattNode if the installation instructions are not followed correctly.

Symbols

	Attention - Consult Installation and Operation Manual	Read, understand, and follow all instructions in this Installation and Operation Manual including all warnings, cautions, and precautions before installing and using the product.
	Caution – Risk of Electrical Shock	Potential Shock Hazard from Dangerous High Voltage.

Installation

Precautions

DANGER — HIGH VOLTAGE HAZARD
WARNING - These installation/servicing instructions are for use by qualified personnel only. To avoid electrical shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

Only qualified personnel or electricians should install the WattNode. Different models of the WattNode measure circuits with voltages from 120 VAC single-phase to 600 VAC three-phase. These voltages are lethal! Always adhere to the following checklist:

1) CCS recommends that a **licensed electrician** install the WattNode.
2) CCS recommends that the WattNode be installed either in an electrical enclosure (panel or junction box) or in a limited access electrical room.
3) Verify that circuit voltages and currents are within the proper range for the WattNode model.
4) Use only UL recognized current transformers (CTs) with built-in burden resistors, that generate 0.333 VAC (333 millivolts AC) at rated current. **Do not** use current output CTs such as 1 amp or 5 amp output models! See **Specifications** - **Current Transformers** for CT maximum input current ratings.
5) Ensure that the line voltage inputs to the WattNode have either fuses or circuit breakers on each voltage phase (not needed for the neutral wire). See **Circuit Protection** below for details.
6) Equipment must be disconnected from the HAZARDOUS LIVE voltage before access.
7) The terminal block screws are **not** insulated. Do not contact metal tools to the screw terminals if the circuit is live!
8) Do not place more than one line voltage wire in a screw terminal; use wire nuts instead. You may use more than one CT wire per screw terminal.
9) Before turning on power to the WattNode, ensure that all the wires are securely installed by tugging on each wire.
10) Do not install the WattNode where it may be exposed to temperatures below -30°C or above 55°C, excessive moisture, dust, salt spray, or other contamination. The WattNode requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected).
11) Do not drill mounting holes using the WattNode as a guide; the drill chuck can damage the WattNode screw terminals and metal shavings can fall into the connectors, causing an arc risk.
12) If the WattNode is installed incorrectly, the safety protections may be impaired.

Electrical Service Types

Below is a list of service types, with connections and recommended WattNode models. Note: the WattNode ground connection improves accuracy, but is not required for safety.

Model	Type	Phase to Neutral	Phase to Phase	Electrical Service Types
WNC-3Y-208-MB	Wye	120 VAC	208–240 VAC	1 Phase 2 Wire 120V with neutral 1 Phase 3 Wire 120V/240V with neutral 3 Phase 4 Wire Wye 120V/208V with neutral
WNC-3Y-400-MB	Wye	230 VAC	400 VAC	1 Phase 2 Wire 230V with neutral 3 Phase 4 Wire Wye 230V/400V with neutral
WNC-3Y-480-MB	Wye	277 VAC	480 VAC	3 Phase 4 Wire Wye 277V/480V with neutral
WNC-3Y-600-MB	Wye	347 VAC	600 VAC	3 Phase 4 Wire Wye 347V/600V with neutral
WNC-3D-240-MB	Delta or Wye	120–140 VAC	208–240 VAC	1 Phase 2 Wire 208V (No neutral) 1 Phase 2 Wire 240V (No neutral) 1 Phase 3 Wire 120V/240V with neutral 3 Phase 3 Wire Delta 208V (No neutral) 3 Phase 4 Wire Wye 120V/208V with neutral 3 Phase 4 Wire Delta 120/208/240V with neutral
WNC-3D-400-MB	Delta or Wye	230 VAC	400 VAC	3 Phase 3 Wire Delta 400V (No neutral) 3 Phase 4 Wire Wye 230V/400V with neutral
WNC-3D-480-MB	Delta or Wye	277 VAC	480 VAC	3 Phase 3 Wire Delta 480V (No neutral) 3 Phase 4 Wire Wye 277V/480V with neutral 3 Phase 4 Wire Delta 240/415/480V with neutral

**The wire count does NOT include ground. It only includes neutral (if present) and phase wires.*

Table 1: WattNode Models

Single-Phase Two-Wire with Neutral

This configuration is most often seen in homes and offices. The two wires are neutral and line. For these models, the WattNode is powered from the **N** and **ØA** terminals.

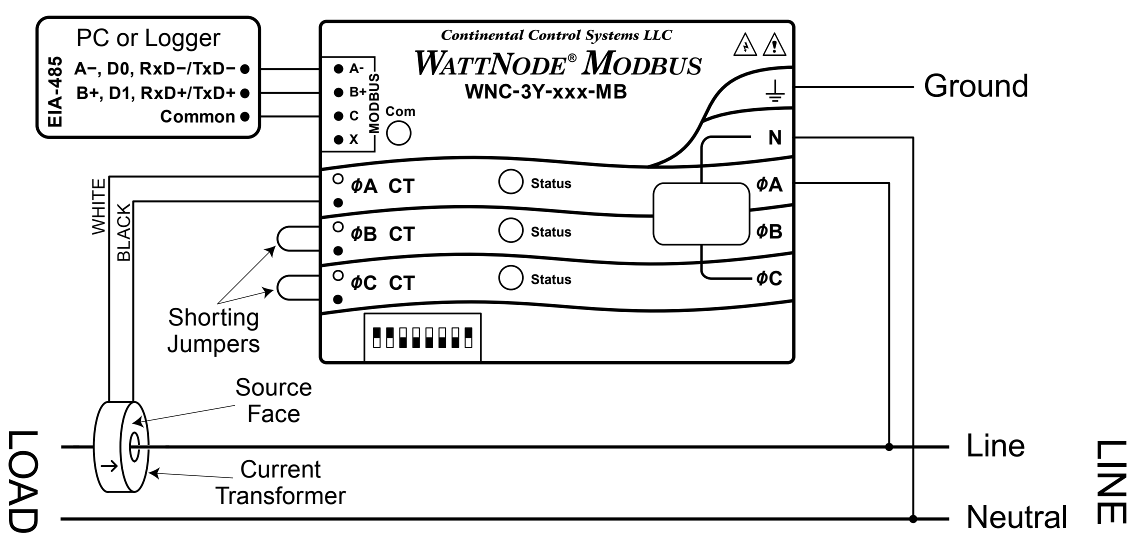


Figure 2: Single-Phase Two-Wire Connection

Recommended WattNode Models

The following table shows the WattNode models that should be used, depending on the line to neutral voltage.

Line to Neutral Voltage	WattNode Model
120 VAC	WNC-3Y-208-MB
230 VAC	WNC-3Y-400-MB

Single-Phase Three-Wire

This configuration is seen in North American residential and commercial service with 240 VAC for large appliances. The three wires are neutral and two line voltage wires with AC waveforms 180° out of phase; this results in 120 VAC between either line wire (phase) and neutral, and 240 VAC (or sometimes 208 VAC) between the two line wires (phases).

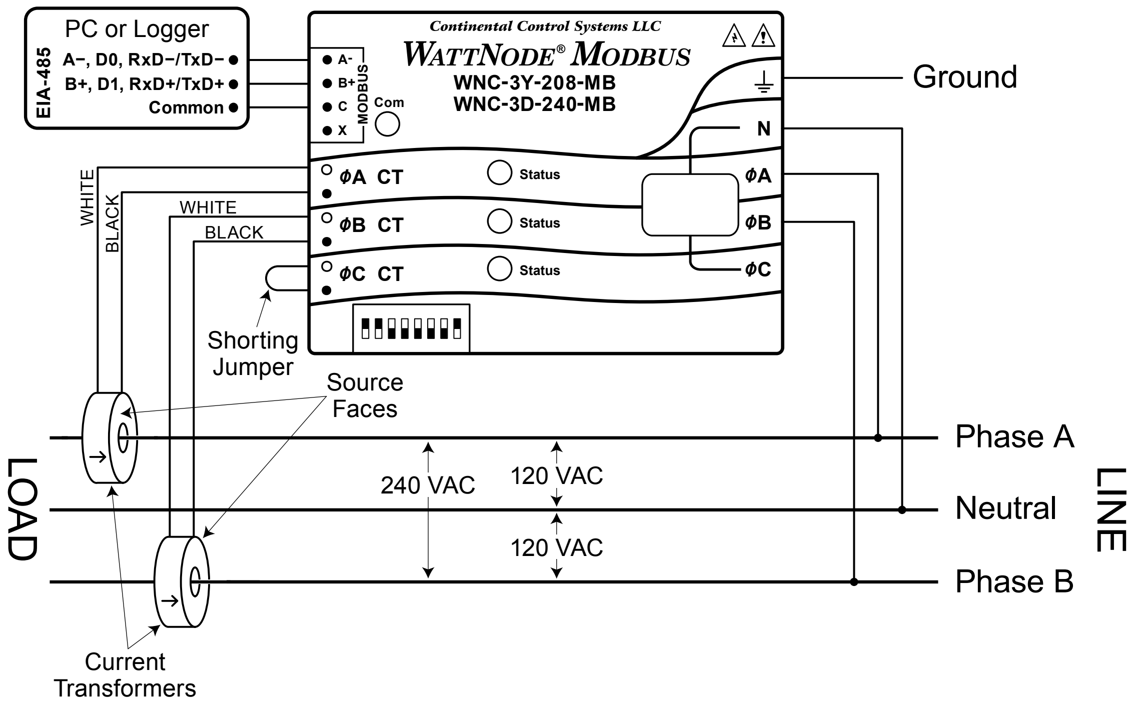


Figure 3: Single-Phase Three-Wire Connection

Recommended WattNode Models

The following table shows the WattNode models that can be used. If neutral may or may not be present, you should use the WNB-3D-240-P (see **Single-Phase Two-Wire without Neutral** below). If neutral is present, it must be connected for accurate measurements. If phase B may not be present, you should use the WNC-3Y-208-MB (see **Single-Phase Two-Wire with Neutral** above).

WattNode Power Source	WattNode Model
N and **ϕA** (Neutral and Phase A)	WNC-3Y-208-MB
ϕA and **ϕB** (Phase A and Phase B)	WNC-3D-240-MB

Single-Phase Two-Wire without Neutral

This is seen in residential and commercial service with 208 to 240 VAC for large appliances. The two wires are two line voltage wires with AC waveforms 120° or 180° out of phase. Neutral is not used. This results in 240 VAC (or 208 VAC) between the two line wires (phases). For this configuration, the WattNode is powered from the **ϕA** and **ϕB** (phase A and phase B) terminals.

For best accuracy, we recommend connecting the WattNode **N** (neutral) terminal to earth ground. This will not cause ground current to flow because the neutral terminal is not used to power the WattNode.

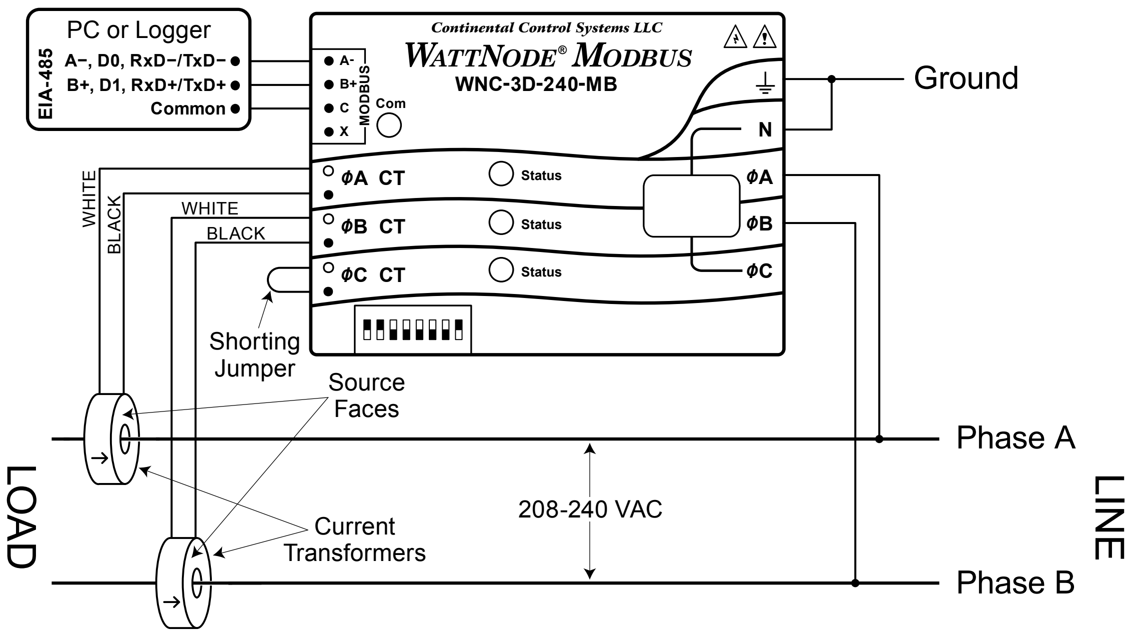


Figure 4: Single-Phase Two-Wire without Neutral Connection

Recommended WattNode Model

This configuration is normally measured with one WattNode model.

Phase-to-Phase Voltage	WattNode Model
208 - 240 VAC	WNC-3D-240-MB

However, if neutral is available, then you may also use the WNC-3Y-208-MB model. If you use the WNC-3Y-208-MB, you will need to hook up the WattNode as shown in section **Single-Phase Three-Wire** and connect neutral. You will need two CTs.

Grounded Leg

In rare cases (non-residential), one of the lines (phase A or phase B) may be grounded. You can check for this by using a multimeter (DMM) to measure the voltage between each phase and ground. If you see a reading between 0 and 5 VAC, that leg (phase) is probably grounded.

The WattNode will correctly measure circuits with a grounded leg, but the measured voltage and power for the phase will be zero and the status LED will not light for whichever phase is grounded, because the voltage is near zero. If you have a grounded leg configuration, you can save money by removing the CT for the grounded phase, since all the power will be measured on the non-grounded phase. We recommend putting the grounded leg (phase) on the **ϕB** input and attaching a note to the WattNode indicating this configuration for future reference.

Three-Phase Four-Wire Wye

This is typically seen in commercial and industrial environments. The wires are neutral and three power lines with AC waveforms shifted 120° between the successive phases. With this configuration, the line voltage wires may be connected to the **ϕA**, **ϕB**, and **ϕC** terminals in any order, **so long as the CTs are connected to matching phases**. It is important that you connect **N** (neutral). For these models, the WattNode is powered from the **N** and **ϕA** terminals.

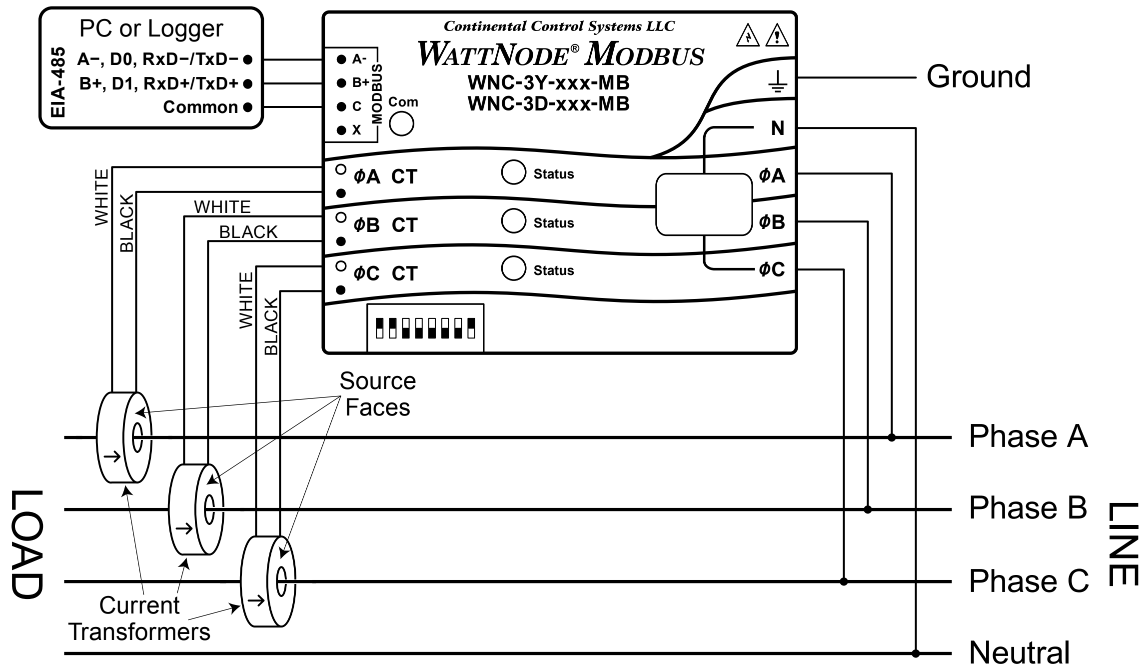


Figure 5: Three-Phase Four-Wire Wye Connection

Recommended WattNode Models

The following table shows the WattNode models that should be used, depending on the line to neutral voltage and line to line voltage (also called phase to phase voltage).

Line to Neutral Voltage	Line to Line Voltage	WattNode Model
120 VAC	208 VAC	WNC-3Y-208-MB
230 VAC	400 VAC	WNC-3Y-400-MB
277 VAC	480 VAC	WNC-3Y-480-MB
347 VAC	600 VAC	WNC-3Y-600-MB

Note: you may also use the following delta WattNode models to measure three-phase four-wire wye circuits. The only difference is that delta WattNode models are powered from **ϕA** and **ϕB**, rather than **N** and **ϕA**. If neutral is present, it must be connected for accurate measurements.

Line to Neutral Voltage	Line to Line Voltage	WattNode Model
120 - 140 VAC	208 - 240 VAC	WNC-3D-240-MB
230 VAC	400 VAC	WNC-3D-400-MB
277 VAC	480 VAC	WNC-3D-480-MB

Three-Phase Three-Wire Delta (No Neutral)

This is typically seen in manufacturing and industrial environments. There is no neutral wire, just three power lines with AC waveforms shifted 120° between the successive phases. With this configuration, the line voltage wires may be connected to the **ϕA**, **ϕB**, and **ϕC** terminals in any order, so long as the CTs are connected to matching phases. For these models, the WattNode is powered from the **ϕA** and **ϕB** (phase A and phase B) terminals. Note: all delta WattNode models provide a neutral connection **N**, which allows delta WattNode models to measure both wye and delta configurations.

For best accuracy, we recommend connecting the **N** (neutral) terminal to earth ground. This is not necessary on balanced three-phase circuits, where the ground-to-phase A, ground-to-phase B, and ground-to-phase C voltages are all roughly the same. This will not cause ground current to flow because the neutral terminal is not used to power the WattNode.

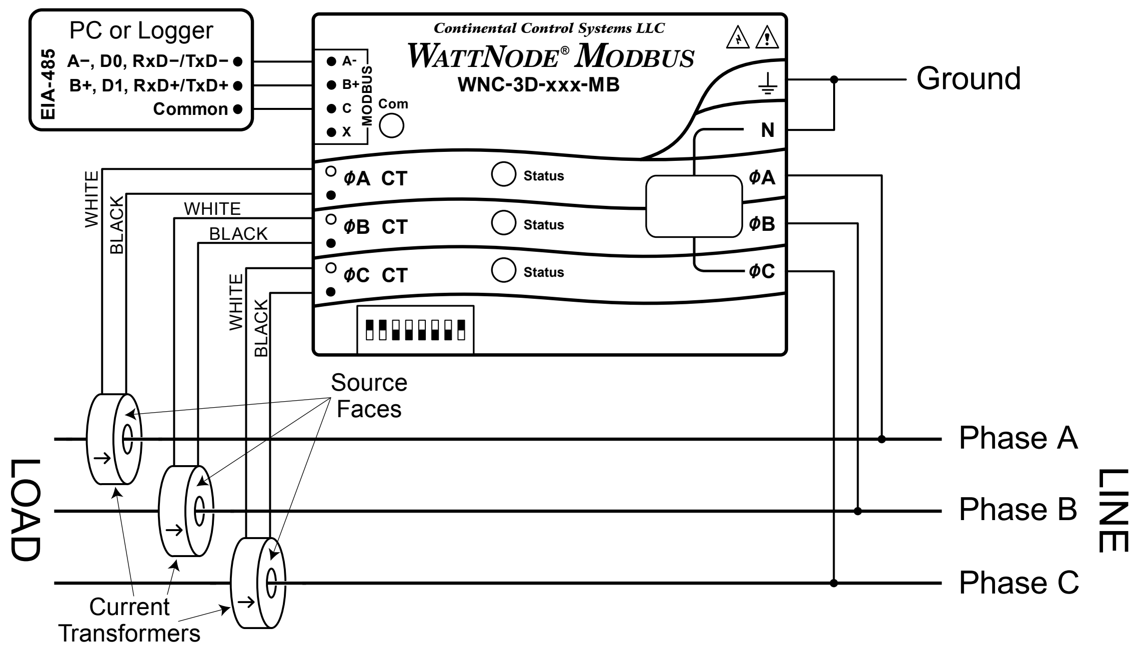


Figure 6: Three-Phase Three-Wire Delta Connection

Recommended WattNode Models

The following table shows the WattNode models that should be used, depending on the line to line voltage (also called phase to phase voltage).

Line to Line Voltage	WattNode Model
208 - 240 VAC	WNC-3D-240-MB
400 VAC	WNC-3D-400-MB
480 VAC	WNC-3D-480-MB

Grounded Leg

In rare cases, one of the phases may be grounded. You can check for this by using a multimeter (DMM) to measure the voltage between each phase and ground. If you see a reading between 0 and 5 VAC, that leg is probably grounded.

The WattNode will correctly measure circuits with a grounded leg, but the measured voltage and power for the phase will be zero and the status LED will not light for whichever phase is grounded, because the voltage is near zero. Also, one or both of the active (non-grounded) phases may show yellow or red/yellow LED flashing because the grounded leg configuration results in unusual power factors.

For optimum accuracy with a grounded leg, you should also connect the **N** (neutral) terminal on the WattNode to the ground terminal; this will not cause any ground current to flow because the neutral terminal is not used to power the WattNode. If you have a grounded leg configuration, you can save money by removing the CT for the grounded phase, since all the power will be measured on the non-grounded phases. We recommend putting the grounded leg on the ***ϕ*C** (Phase C) input and attaching a note to the WattNode indicating this configuration for future reference.

Mounting

Protect the WattNode from moisture, direct sunlight, high temperatures, and conductive pollution (salt spray, metal dust, etc.) If moisture or conductive pollution may be present, use an IP 66 or NEMA 4 rated enclosure to protect the WattNode. Due to its exposed screw terminals, the WattNode must be installed in an electrical service panel, a junction box, or an electrical room. The WattNode may be installed in any orientation, directly to a wall of an electrical panel or junction box.

The WattNode has two mounting holes spaced 127 mm (5.0 in) apart (center to center). These mounting holes are normally obscured by the detachable screw terminals. Remove the screw terminals by pulling outward while rocking from end to end. The WattNode or **Figure 7** may be used as a template to mark mounting hole positions, but **do not drill the holes with the WattNode in the mounting position** because the drill may damage the WattNode connectors and leave drill shavings in the connectors.

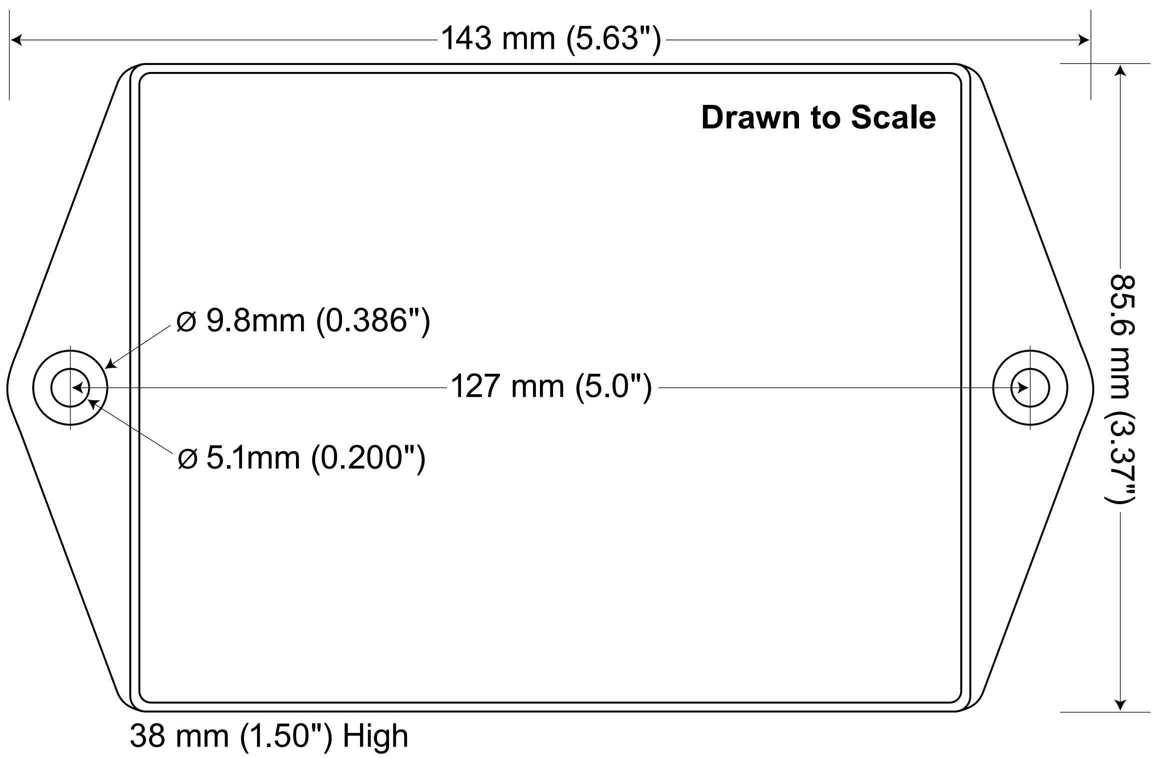


Figure 7: WattNode Dimensions

We recommend self tapping or self drilling sheet metal screws in the following sizes (**bold** are preferred).

Screw Style	U.S.A. UTS Sizes	Metric Sizes
Pan Head	#6, **#8**, #10	M3.5, **M4**, M5
Round Head	#6, **#8**, #10	M3.5, **M4**, M5
Truss Head	**#6**, #8	**M3.5**, M4
Hex Washer Head (integrated washer)	#6, **#8**	M3.5, **M4**
Hex Head (add washer)	#6, **#8**, #10	M3.5, **M4**, M5

Table 2: WattNode Mounting Screws

To protect the WattNode's case, use washers if the screws could pull through the mounting holes. Don't over-tighten the screws, because long term stress on the case can cause cracking.

Selecting Current Transformers

The rated current of the CTs should normally be chosen somewhat above the maximum current of the circuit being measured (see **Current Crest Factor** below for more details). In some cases, you might select CTs with a lower rated current to optimize accuracy at lower current readings. Take care that the maximum allowable current for the CT can not be exceeded without tripping a circuit breaker or fuse (see **Specifications - Current Transformers**).

We only offer AC current transformers. These cannot measure DC currents. Furthermore, significant DC currents can saturate the magnetic core, interfering with accurate AC current measurements. The vast majority of loads will only have AC current, but occasionally you may encounter devices that draw DC current and may not be measured correctly. The most common sources of DC are devices that only use half cycles of AC current, resulting in large effective DC currents. Examples of devices that may cause DC currents include heat guns, hair dryers, and electric instant hot water heaters.

CTs can measure lower currents than they were designed for by passing the wire through the CT more than once. For example, to measure currents up to 1 amp with a 5 amp CT, loop the wire through the CT five times. The CT is now effectively a 1 amp CT instead of a 5 amp CT. The effective current rating of the CT is the labeled rating divided by the number of times that the wire passes through the CT.

If you are using the measurement phases of the WattNode (**ϕA**, **ϕB**, and **ϕC**) to measure different circuits, you can use CTs with different rated current on the different phases. Instead of setting one ***CtAmps*** value for all phases, you can use different values for each phase: ***CtAmpsA***, ***CtAmpsB***, and ***CtAmpsC***.

Current Crest Factor

The term "current crest factor" is used to describe the ratio of the peak current to the RMS current. Resistive loads like heaters and incandescent lights have nearly sinusoidal current waveforms with a crest factor near 1.4. Power factor corrected loads like PC power supplies typically have a crest factor of 1.4 to 1.5. Many common loads can have current crest factors ranging from 2.0 to 3.0, and higher values are possible.

The WattNode current transformer inputs will saturate and become inaccurate if the peak current is too high. This means you may want to be conservative in selecting the CT rated current. For example, if your load draws 10 amps RMS, but has a crest factor of 3.0, then the peak current is 30 amps. If you use a 15 amp CT, the WattNode will not be able to accurately measure the 30 amp peak current. **Note:** this is a limitation of the WattNode measurement circuitry, not the CT.

The following graph shows the maximum RMS current for accurate WattNode measurements as a function of the current waveform crest factor. The current is shown as a percentage of CT rated current. For example, if you have a 10 amp load with a crest factor of 2.0, the maximum CT current is approximately 85%. 85% of 15 amps is 12.75, which is higher than 10 amps, so your measurements should be accurate. On the other hand, if you have a 40 amp load with a crest factor of 4.0, the maximum CT current is 42%. 42% of a 100 amp CT is 42 amps, so you would need a 100 amp CT to accurately measure this 40 amp load.

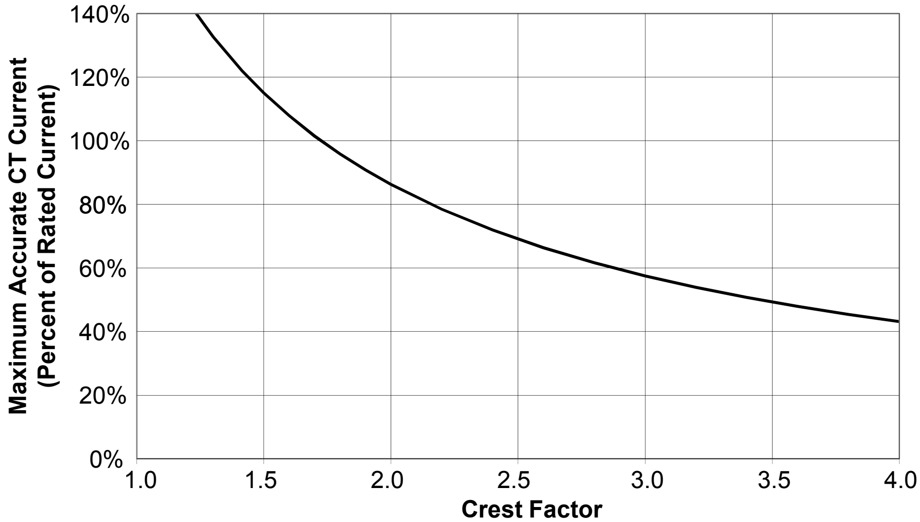


Figure 8: Maximum CT Current vs. Crest Factor

You frequently won't know the crest factor for your load. In this case, it's generally safe to assume the crest factor will fall in the 1.4 to 2.5 range and select CTs with a rated current roughly 150% of the expected RMS current. So if you expect to be measuring currents up to 30 amps, select a 50 amp CT.

Connecting Current Transformers

- Use only UL recognized current transformers (CTs) with built-in burden resistors that generate 0.333 VAC (333 millivolts AC) at rated current. See **Specifications - Current Transformers** for the maximum input current ratings.
- **Do not** use current output CTs such as 1 amp or 5 amp output models: they will destroy the WattNode and present a shock hazard!
- Find the arrow or label "THIS SIDE TOWARD SOURCE" on the CT and face toward the current source: generally the utility meter or the circuit breaker for branch circuits. If CTs are mounted backwards or with their white and black wires reversed the measured power will be negative. The WattNode indicates negative phase power with flashing red LEDs.
- Be careful to match up the current transformers to the voltage phases being measured. Make sure the ***ϕ*A CT** is measuring the line voltage connected to ***ϕ*A**, and the same for phases B and C. It may help to use colored tape or labels to identify the wires.
- To prevent magnetic interference, the CTs on different phases should be separated by 1 inch (25 mm). The line voltage conductors for each phase should be separated by at least 1 inch (25 mm) from each other and from neutral.
- For best accuracy, the CT opening shouldn't be more than 50% larger than the conductor. If the CT opening is much bigger than the conductor, position the conductor to stay centered in the opening.
- We recommend keeping CT wires short if possible because the CT signals are low-voltage and are susceptible to interference. It is generally better to install the WattNode near the conductors being measured instead of extending the CT wires. However, it is possible to extend the CT wires by 300 feet (100 m) or more by using shielded twisted-pair cable and by not running the CT wires close to high current or high voltage line conductors.
- OPTIONAL: if you see spurious readings on unused phases, jumper the unused CT inputs.

To connect CTs, pass the wire to be measured through the CT and connect the CT to the WattNode. **Always remove power before disconnecting any live wires.** Put the line wires through the CTs as shown in the section **Electrical Service Types**. You may measure generated power by treating the generator as the source.

Solid-core CTs require that the wire be disconnected before passing it through the opening in the CT.

Split-core and bus-bar CTs can be opened for installation around a wire by puling the removable section straight away from the rest of the CT; it may require a strong pull. Some CT models include thumb-screws to secure the opening. The removable section generally only fits one way, so match up the steel core pieces when closing the CT. If the CT seems to jam and will not close, the steel core pieces are probably not aligned correctly; DO NOT FORCE together. Instead, reposition or rock the removable portion until the CT closes without excessive force. A nylon cable tie can be secured around the CT to prevent inadvertent opening.

Next, connect the CTs to the WattNode terminals labeled ***ϕ*A CT**, ***ϕ*B CT**, and ***ϕ*C CT**. Route the twisted black and white wires from the CT to the WattNode. We recommend trimming excess length from the wires to reduce the risk of interference. Strip or trim the wires to expose 1/4" (6 mm) of bare wire. The current transformers connect to the six position black screw terminal block. Connect each CT with the white wire aligned with the white dot on the label, and the black wire aligned with the black dot. Note the order in which the phases are connected, as the voltage phases **must** match the current phases for accurate power measurement.

Finally record the CT rated current as part of the installation record for each WattNode. If the wires being measured are passed through the CTs more than once, then the recorded rated CT current is divided by the number of times that the wire passes through the CT.

Circuit Protection

The WattNode is considered permanently connected equipment, because it does not use a conventional power cord that can be easily unplugged. **Permanently connected equipment must have overcurrent protection and be installed with a means to disconnect the equipment.** A switch, disconnect, or circuit breaker may be used to disconnect the WattNode. If a switch or disconnect is used, then there must also be a fuse or circuit breaker of appropriate rating protecting the WattNode.

The WattNode only draws 10-30 milliamps, so the rating of any switches, disconnects, fuses, and/or circuit breakers is determined primarily by the wire gauge used, the mains voltage, and the current interrupting rating required.

- The switch, disconnect, or circuit breaker used to disconnect the WattNode must be as close as practical to the WattNode.
- CCS recommends using circuit breakers or fuses rated for between 0.5 amps and 20 amps and rated for the mains voltages being measured.
- The overcurrent protection device (circuit breakers or fuses) must protect the ungrounded supply conductors (the mains terminals labeled ***ϕ*A**, ***ϕ*B**, and ***ϕ*C**). If neutral is protected by the overcurrent protection device, then the overcurrent protection device must interrupt both neutral and the ungrounded conductors simultaneously.
- Any switches or disconnects should have at least a 1 amp rating and must be rated for the mains voltages being measured.
- The circuit protection / disconnect system must meet IEC 60947-1 and IEC 60947-3, as well as all national and local electrical codes.
- The line voltage connections should be made with wire rated for use in a service panel or junction box with a voltage rating sufficient for the highest voltage present. CCS recommends 14 or 12 AWG (1.5 mm^2 or 2.5 mm^2) stranded wire, rated for 300V or 600V. Solid wire may be used, but must be routed carefully to avoid putting excessive stress on the pluggable screw terminal.

- The WattNode has an earth connection, which should be connected for maximum accuracy. However, this earth connection is not used for safety (protective) earthing.

Connecting Voltage Terminals

Always disconnect power—by shutting off circuit breakers or removing fuses—before connecting the voltage lines to the WattNode. Connect each WattNode voltage input (green terminal block) to the appropriate phase; also connect ground and neutral (if applicable).

So long as the phase voltages are the same, the WattNode voltage inputs do not need to be connected to the same branch circuit as the load being monitored. In other words, if you have a three-phase panel with a 100A three-phase breaker powering a motor that you wish to monitor, you can power the WattNode (or several WattNodes) from a separate low current (20A) three-phase breaker in the same panel.

When connecting the WattNode, do not place more than one voltage wire in a screw terminal; use separate wire nuts or terminal blocks if needed. The screw terminals handle wire up to 12 AWG (2.5 mm^2). Prepare the voltage wires by stripping the wires to expose 1/4” (6 mm) of bare wire. Connect each voltage line to the green terminal block as shown in the section **Electrical Service Types**. ***Verify that the voltage line phases match the CT phases.*** After the voltage lines have been connected, make sure both terminal blocks are securely installed on the WattNode.

If there is any doubt that the voltage rating of the WattNode is correct for the circuit being measured, then before applying power to the WattNode, disconnect the green screw terminal from the WattNode and then turn on the power. Use a voltmeter to measure the voltages (touch the screw heads) and verify that they match the values in the white box on the label.

When power is first applied to the WattNode, check that the LEDs behave normally: if you see the LEDs flashing red-green-red-green, then disconnect the power immediately! This indicates the line voltage is too high for the WattNode.

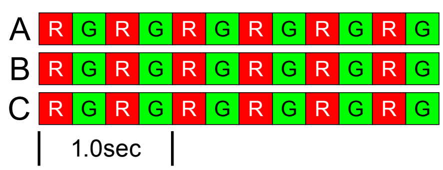


Figure 9: WattNode LED Overvoltage Warning

The WattNode is powered from the voltage inputs: ***Φ*A** (phase A) to **N** (neutral) , or ***Φ*A** to ***Φ*B** for delta models. If the WattNode is not receiving at least 85% of the nominal line voltage, it may stop operating. Since the WattNode consumes a small amount of power itself, you may wish to power the WattNode from a separate circuit or place the current transformers downstream of the WattNode, so that the power from the WattNode is not measured.

Setting the MODBUS Address

Each WattNode on a MODBUS network must have a unique address and must be configured with the correct baud rate. The WattNode uses an eight position DIP switch to specify the address and baud rate.

The WattNode supports MODBUS addresses from 1 to 127. Address 0 is used for broadcast messages and is not a valid WattNode address. As shipped from the factory, the WattNode will be configured with an address of 0, which is invalid and will prevent any communication and cause the “**Com**” LED to light solid red.

Set the MODBUS address by switching DIP switch positions 1-7, each of which adds a different value to the address. The change will take effect immediately.

DIP Switch	1	2	3	4	5	6	7
Up (1) Value	1	2	4	8	16	32	64
Address	**Examples**						
1	**Up**	Down	Down	Down	Down	Down	Down
1+2+4 = 7	**Up**	**Up**	**Up**	Down	Down	Down	Down
4+16 = 20	Down	Down	**Up**	Down	**Up**	Down	Down
1+2+16+32+64 = 115	**Up**	**Up**	Down	Down	**Up**	**Up**	**Up**

Table 3MODBUS Address Selection

For example, if DIP switch positions 3 and 5 are in the 1 (up) position and the rest are 0 (down), the resulting MODBUS address is 4 + 16 = 20.

Baud Rate

Select the baud rate by setting DIP switch position 8 as shown below. The change will take effect immediately.

Baud Rate	DIP Switch Position 8
9,600 (default)	0 (down)
19,200	1 (up)

Table 4Baud Rate Selection

Connecting MODBUS Outputs

The MODBUS WattNode communicates using a serial EIA RS-485 interface. The WattNode uses half-duplex two-wire (plus common) communication, so the same pair of wires is used for sending AND receiving. Up to 127 WattNodes can be connected together on the same RS-485 bus.

Planning the MODBUS Network

EIA RS-485 networks should always be wired in a bus (or daisy-chain) configuration. In other words, the bus should start at the PC or logger and then run to each WattNode in turn. Try to avoid branches, and avoid home-run wiring (where each WattNode has its own wire back to the PC or logger). For best results, especially for longer distances, use wire intended for RS-485 communication.

Manufacturer	Part Number	AWG	Pairs	Shielded?	Impedance	Insulation
Belden	9841	24	1	Yes	120 ohms	300V
Belden	9842	24	2	Yes	120 ohms	300V
	CAT 5, 5e	24	4	Optional	100 ohms	300V
	CAT 6	23 or 24	4	Optional	100 ohms	300V

Table 5Recommended RS-485 Cabling

- Since the MODBUS / RS-485 wiring may be located near line voltage wiring, use wires or cables rated for the highest voltage present, generally 300V or 600V rated wire.
- If this cable will be in the presence of bare conductors, such as bus-bars, it should be double insulated or jacketed.
- Use twisted-pair cable (unshielded or shielded) to prevent interference.

Because the WattNode uses half-duplex communication, it only needs a single twisted-pair, but it also **needs a conductor for common**, which may be the shield or a spare conductor.

Length Limits

Under ideal conditions, using cable with a 120 ohm impedance and proper termination, it should be possible to run RS-485 signals 1200m (4000ft) at up to 19,200 baud. However, a number of factors can reduce this range, including electrical and magnetic interference (EMI), bus loading, poor termination, etc. Repeaters are available to extend the range if necessary.

If it isn't convenient to daisy-chain the main RS-485 bus to each WattNode, you may use stubs or branches. Long stubs or branches—greater than 30m (100ft)—may cause signal reflections and should be avoided.

Termination

Networks shorter than 500m (1650ft) should not need termination. Longer networks and networks in electrically noisy environments may need termination at both ends of the bus with 120 ohm resistors between the "**A-**" and "**B+**" terminals. Generally, you will put one termination resistor at the PC or monitoring device and one at the WattNode farthest from the monitoring device.

Some EIA RS-485 PC interfaces include jumpers or switches to provide internal termination at one end of the bus.

In some cases, termination can cause problems. It dramatically increases the load on the bus, so that some RS-485 PC interfaces cannot handle the load (particularly port powered ones). Also, adding 120 ohm termination resistors may require the addition of bias resistors (see next section).

Biasing

EIA RS-485 networks frequently use bias resistors to hold the bus in a "high" or logic 1 state when no devices are transmitting. In this state, the MODBUS "**A-**" terminal is more negative than the "**B+**" terminal. Without bias resistors, the bus can float and noise can appear as bogus data.

The WattNode uses an RS-485 failsafe transceiver that eliminates the need for bias resistors except in noisy environments. Furthermore, many RS-485 PC interfaces include internal bias resistors.

If you determine that your network is experiencing noise problems, then you may want to add termination and possibly bias resistors.

Wiring

Once you've planned the network and strung the cable, you can connect the WattNodes.

- The MODBUS outputs are completely isolated from all dangerous voltages, so you can connect them with the WattNode powered.
- When connecting WattNodes to a PC or logger, connect all "**A-**" terminals together, all "**B+**" terminals together, and all "**C**" (common) terminals together. In most cases, if you swap "**A-**" and "**B+**", the WattNode will auto-detect the reversed polarity and will communicate correctly. **Note:** if your RS-485 network isn't properly biased (one terminal more positive than the other), then the auto-detect feature will not work.
- You may put two sets of wires in each screw terminal to make it easier to daisy-chain the network from one WattNode to the next. If you do this, we recommend that you twist the wires tightly together before putting them into the screw terminal to ensure that one wire doesn't pull free, causing communication problems.
- If you are using shielded cable, you may use the shield to provide the MODBUS common "**C**" connection between all devices on the network.
- If you are using a shielded cable and the shield **is not** being used for the MODBUS common signal, then connect the shield to earth ground or MODBUS common at the PC interface or data logger, and at the far end of the cable, connect the shield to earth ground. If the shield is being used for the MODBUS common, to prevent ground loops, only ground one end at the PC or logger.

Installation Summary

1) Mount the WattNode.
2) Turn off power before installing solid-core CTs or making voltage connections.
3) Mount the CTs around the line wires being measured. Take care to orient the CTs facing the source of power.
4) Connect the twisted white and black wires from the CT to the black terminal block on the WattNode, matching the wire colors to the white and black dots on the label of the WattNode.
5) Connect the voltage wires including ground and neutral (if present) to the green terminal block of the WattNode, and double check that the current measurement phases match the voltage measurement phases.
6) Set the MODBUS network address and baud rate with the DIP switches.
7) Connect the output terminals of the WattNode to the monitoring equipment.
8) Apply power to the WattNode.
9) Verify that the LEDs light correctly and don't indicate an error condition.

Installation LED Diagnostics

The WattNode includes three multi-color power diagnostic LEDs (one for each phase) to help verify correct operation and diagnose incorrect installation. The LEDs are marked "Status" on the label. The following diagrams and descriptions explain the various LED patterns and their meanings. The A, B, and C on the left side indicate the phase of the LEDs. Values like "1.0sec" and "3.0sec" indicate the time the LEDs are lit in seconds. In the diagrams, sometimes the colors are abbreviated: R = red, G or Grn = green, Y = yellow.

Normal Startup

On initial power-up, the LEDs will all light up in a red, yellow, green sequence. After this startup sequence, the LEDs will show the status, such as **Normal Operation** below.

A	Red	Yellow	Green
B	Red	Yellow	Green
C	Red	Yellow	Green
	1.0sec	1.0sec	1.0sec

Normal Operation

During normal operation, when positive power is measured on a phase, the LED for that phase will flash green. Typical flash rates are shown below.

Green	Off	Green	Off	Green	Off

Percent of Full-Scale Power	LED Flash Rate	Flashes in 10 Seconds
100%	5.0 Hz	50
50%	3.6 Hz	36
25%	2.5 Hz	25
10%	1.6 Hz	16
5%	1.1 Hz	11
1% (and lower)	0.5 Hz	5

Table 6: LED Flash Rates vs. Power

Zero Power

Below the minimum power that the WattNode can measure (see **Specifications - Measurement - Creep Limit**) as long as line VAC is present, the WattNode will display solid green for that phase.

Green

Inactive Phase

If the WattNode detects no power and line voltage below 20% of nominal, it will turn off the LED for the phase.

Off

Negative Power

If one or more of the phase LEDs are flashing red, it indicates negative power (power flowing into the grid) on those phases. The rate of flashing indicates magnitude of negative power (see **Table 6** above). This can happen for the following reasons:

A	Red	Off	Red	Off	Red	Off	
B	Off	Red	Off	Red	Off	Red	
C		Red	Off	Red	Off	Red	Off

- This is a bidirectional power measurement application, such as a photovoltaic system, where negative power occurs whenever you generate more power than you consume.
- The current transformer (CT) for this phase was installed backwards on the wire or the white and black wires for the CT were reversed where they connect to the WattNode. This can be solved by flipping the CT on the wire or swapping the white and black wires at the WattNode. Alternatively, you can use the configuration register ***CtDirections (1607)*** to reverse the polarity of one or more of the CTs.
- In some cases, this can also occur if the CT wires are connected to the wrong inputs on the WattNode, such as if the CT wires for phases B and C are swapped.

Note: if all three LEDs are flashing red and they always turn on and off together, like the diagram for **Low Line Voltage** below, then the WattNode is experiencing an error or low line voltage, not negative power.

Low Power Factor

The WattNode will display yellow flashing or red/yellow flashing on any phase with low power factor. This may be normal for your load, or it may indicate that the CTs are not installed correctly.

Yellow	Off	Yellow	Off	Yellow	Off
Yellow	Red	Yellow	Red	Yellow	Red

Yellow flashing or red/yellow flashing indicates that the current lags the voltage by 60 degrees or more (power factor less than 0.5), or that the current leads the voltage by 30 degrees or more. Red/yellow also indicates negative power (energy flowing from the load to the grid). Yellow flashing (positive power) can happen for a variety of reasons, some of which occur during correct operation.

- Small appliances sometimes have low power factors.
- At light loads, motors, power supplies, and some other devices have low power factors.
- Traditional florescent light ballasts can have power factors as low as 0.4.
- Three-phase delta configurations can result in low power factors, especially if one of the phases is grounded.
- The CTs are not installed on the correct line phases. For example, if you connect phases A, B and C to the respective VAC inputs on the WattNode, but then the CTs for A, B, and C are connected in the wrong order to the WattNode, say B, A, C, then the power measured on phases A and B will have an extra 120 degree phase shift between voltage and current, resulting in a low power factor and probably negative power.

Red/yellow flashing (negative power) is less common and indicates incorrect installation unless you are generating power, as with PV (solar) power generation. When monitoring house (or building) power with PV (solar) power generation, the combination of the house load and the PV generated power can result in a net power with a low power factor.

In general, if you see yellow or yellow/red flashing for one or more phases check the following:

- Check that your load is turned on (since standby power supplies can have low power factors).

- Check that the CT phases match the phases for the VAC connections.
- Check that none of the CTs are installed backwards on the current carrying wire and that the white and black CT leads are installed in the correct screw terminals on the WattNode (the black wire should match up to the black circle on the label and the white wire should match up to the white circle on the label).
- Consider whether your load may have an unusual power factor. Loads like heaters, incandescent lights, and power factor corrected loads should have a power factor near 1.0 and should not cause the LEDs to flash yellow. Loads like motors, florescent light ballasts, etc. may have low power factors, in which case, yellow flashing may be normal.

Erratic Flashing

A	Off	Grn	Off	Red	Off	
B	Red	Off	Yellow	Off	Red	
C	Grn	Off	Red	Grn	Red	Off

If the LEDs are flashing slowly and erratically, sometimes green, sometimes red or yellow, this generally indicates one of the following:

- Earth ground is not connected to the WattNode (the top connection on the green screw terminal).
- Voltage is connected for a phase, but the current transformer is not connected, or the CT has a loose connection.
- In some cases, particularly for a circuit with no load, this may be due to electrical noise. This is not harmful and can generally be disregarded, provided that you are not seeing substantial measured power when there shouldn't be any. Try turning on the load to see if the erratic flashing stops.

To fix this, try the following:

- Make sure earth ground is connected.
- If there are unused current transformer inputs, install a shorting jumper for each unused CT (a short length of wire connected between the white and black dots marked on the label).
- If there are unused voltage inputs (on the green screw terminal), connect them to neutral (if present) or earth ground (if neutral isn't available).
- If you suspect noise may be the problem, try moving the WattNode away from the source of noise. Also try to keep the CT wires as short as possible and cut off excess wire.

WattNode Not Operating

A	Off
B	Off
C	Off

It should not be possible for all three LEDs to stay off when the WattNode is powered, because the phase powering the WattNode will have line voltage present. Therefore, if all LEDs are off, the WattNode is either not receiving sufficient line voltage to operate, or is malfunctioning and needs to be returned for service. Verify that the voltage on the VAC screw terminals is within ±20% of the nominal operating voltages printed in the white rectangle on the front label.

WattNode Error

A	Red
B	Red
C	Red
	← 3.0sec →

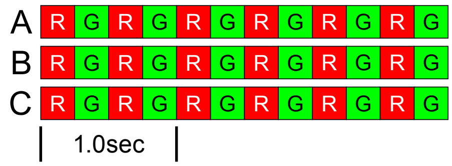
If the WattNode experiences an internal error, it will light all LEDs red for three seconds. If you see this happen repeatedly, return the WattNode for service.

Bad Calibration

A	Red
B	Red
C	Yellow

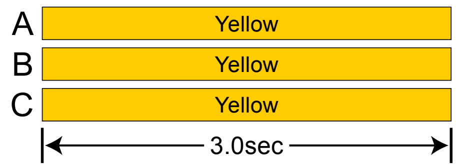
This indicates that the WattNode has detected bad calibration data and must be returned for service.

Line Voltage Too High



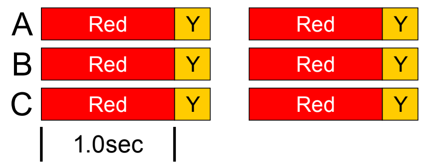
Whenever the WattNode detects line voltages over 125% of normal for one or more phases, it will display a fast red/green flashing for the affected phases. This is harmless if it occurs due a momentary surge, but if the line voltage is high continuously, **the power supply may fail. If you see continuous over-voltage flashing, disconnect the WattNode immediately!** Check that the WattNode model and voltage rating is correct for the circuit.

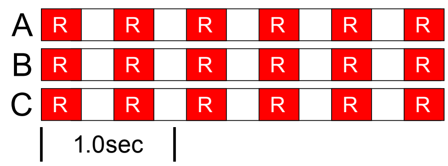
Bad Line Frequency



If the WattNode detects a power line frequency below 45 Hz or above 70 Hz, it will light all the LEDs yellow for at least three seconds. The LEDs will stay yellow until the line frequency returns to normal. During this time, the WattNode should continue to accurately measure power. This can occur in the presence of extremely high noise, such as if the WattNode is too close to an unfiltered variable frequency drive.

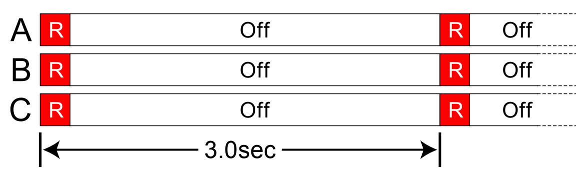
Low Line Voltage





These LED patterns occur if the line voltage is too low for the WattNode to operate correctly and the WattNode reboots repeatedly. The pattern will be synchronized on all three LEDs. Verify that the voltage on the VAC screw terminals is no lower than 15% below the nominal operating voltages printed in the white rectangle on the front label. If the voltages are in the normal range and the WattNode continues to display one of these patterns, return the WattNode for service.

No Line Voltage



If the measured line voltage on all three phases is less than 20% of the nominal line VAC, then the WattNode will briefly flash all three status LEDs together every three seconds. This is very rare, but can indicate the following:

- You have purchased a DC instrument powered WattNode and the WattNode has power, but the circuit being monitored is off. You can check for this by measuring the AC volts from neutral to each phase or between phases for delta circuits.
- The WattNode measurement circuitry has been damaged and cannot read the line voltages.

Measurement Troubleshooting

There are a variety of possible measurement problems. The following procedure should help narrow down the problem. This assumes you can communicate with the WattNode and read registers. You can combine these diagnostic steps with the status LED diagnostics above.

Voltage

Start by checking the reported voltage (***VoltA***, ***VoltB***, ***VoltC***) for active (connected) phases. Make sure the voltages match the expected line-to-neutral voltages (or line-to-ground for delta circuits). You should check the actual voltages present at the WattNode with a DMM (multimeter) if possible. The WattNode does not measure line-to-line voltages, so you will not be able to verify them.

- If one or more voltages are zero, then you either have a wiring problem or something is wrong with the WattNode. Verify the actual voltages with a DMM (multimeter).

- If one or more voltages are too low (by more than 5%), then make sure you have the correct WattNode model. For example, a WNC-3Y-208-MB expects line-to-neutral voltages of 120 VAC and can measure up to about 150 VAC. If you apply 208 VAC line-to-neutral, the WattNode will read a voltage in the 150 VAC to 180 VAC range.
- If any voltages read high, then check your wiring. If the wiring is correct, contact support.
- If the voltages are within 5% of the measured (or expected) values, continue with the next step.

Power

Next, check the measured power for each active phase (***PowerA***, ***PowerB***, ***PowerC***). If possible, estimate or measure the actual power. Also, make sure the load you are measuring is currently on.

- If one or more active phases are reporting zero power, then the problem is probably one of the following:
  - There is no active power (the load is off) or the power is too low to measure (generally less than 1/1000th of full-scale).
  - CT wires are not securely connected.
  - The CT or its wires are damaged.
  - There is strong electrical interference, as might occur if the WattNode is in very close proximity to a variable speed drive (also called variable frequency drive or inverter).
  - The WattNode is not functioning correctly: try swapping the WattNode for another unit.
- If one or more active phases are reporting negative power:
  - The current transformer has been installed backward on the wire being measured. CTs are marked with either an arrow or a label saying "This side toward source". If the arrow or label are not oriented toward the source of power (generally the panel or breaker), then the measured current will be inverted and the power negative. This can be fixed either by flipping the CT or by swapping the white and black wires where they enter the WattNode.
  - The current transformer white and black wires have been swapped where they enter the WattNode (at the black screw terminal block).
  - The voltage phases (green screw terminal block) are not matched up with the current phases (black screw terminal block). For example, the phase A CT is around the phase B wire.
  - This may be normal if you are measuring in an environment were power may be consumed or generated, such as a house with PV panels.
- If one or more phases are reporting low or high power:
  - Make sure the ***CtAmps*** configuration is set correctly for your current transformers.
  - The current transformers may have a rated current too high or too low for your application. CTs should be used between 10% and 100% of their rated current for best results. They generally work with reduced accuracy down as low as 0.5% to 0.1% of rated current.
  - The CTs may not be installed properly. Check for: CTs touching each other or pre-existing CTs; CT opening too large for the wire being measured.
  - The voltage phases (green screw terminal block) are not matched up with the current phases (black screw terminal block). The easiest way to determine this is to skip ahead to the next troubleshooting section: **Power Factor and Reactive Power**.
  - Interference from a variable frequency or variable speed drive: VFD, VSD, inverter, or the like. Generally, these drives should not interfere with the WattNode, but if they are in very close proximity, or if the CT leads are long, interference can occur. Try moving the WattNode at least one meter (three feet) away from any VFDs. Use short CT leads if

possible. **NEVER** install the WattNode downstream of a VFD: the varying line frequency and extreme noise will cause problems!

  - Our current transformers can only measure AC currents. Furthermore, strong DC currents will saturate the magnetic core of the CT, preventing an accurate measurement of the AC current. The overwhelming majority of AC powered electric devices do not draw significant DC current, so this is a rare occurrence.
  - Loads with a high current crest factor (ratio of the peak current to the RMS current) can cause clipping in the WattNode measurement circuitry, resulting in lower than expected readings. You can check for this with a handheld power quality analyzer that can measure crest factor (CF) or by trying a CT with a higher rated current, which should allow the WattNode to measure the peak current accurately.
  - In rare cases, the CTs are defective or mislabeled. If possible, use a current clamp to verify the current, then use a DMM (multimeter) to measure the AC voltage between the white and black wires from the CT (leave them connected to the WattNode during this test). At rated current, the CT output voltage should equal 0.333 VAC (333 millivolts AC). At lower currents, the voltage should scale linearly, so at 20% of rated current, the output voltage should be 0.20 * 0.333 = 0.0666 VAC (66.6 millivolts AC).
  - If possible, verify the expected power with a handheld power meter. Current clamps can be useful to very roughly estimate the power, but since they measure current, not power, the estimated power (voltage times current) may be off by 50% or more.

Power Factor and Reactive Power

The measured power factor and reactive power are very useful in determining if there is a phasing mismatch between the voltage and current measurement phases on the WattNode. For example, the phase A CT is around the phase B wire.

However, this troubleshooting is complicated because different loads have different typical power factors and the power factor can vary significantly for some devices, like motors, as a function of the mechanical load on the motor. Here are some general guidelines:

- **Motors, idling or with a light load**: power factor from 0.1 to 0.6, positive reactive power.
- **Motors, normal or heavy load**: power factor from 0.5 to 0.8, positive reactive power.
- **Motor with VSD**: power factor between 0.5 and 0.9.
- **Incandescent lighting**: power factor near 1.0, small negative reactive power.
- **Florescent lighting**: power factor between 0.4 and 1.0.
- **Electrical heating**: power factor near 1.0.
- **Office equipment**: power factor between 0.6 and 1.0, reactive power may be positive or negative.

If the measured power factor or reactive power appears to be outside the normal ranges, this most commonly indicates that the voltage and current phases on the WattNode are not connected properly, although some loads fall outside the normal ranges. Check the following:

- The CT connected to the **ϕA CT** terminal is installed around the line wire being measured by the **ϕA** VAC terminal (green terminal block).
- The CT connected to the **ϕB CT** terminal is installed around the line wire being measured by the **ϕB** VAC terminal (green terminal block).
- The CT connected to the **ϕC CT** terminal is installed around the line wire being measured by the **ϕC** VAC terminal (green terminal block).

If this doesn't solve your problem, contact technical support for more assistance.

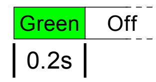
MODBUS Communication Diagnostics

The “**Com**” LED indicates many MODBUS communication conditions by lighting green, yellow, or red. Other MODBUS errors are indicated by returning a MODBUS exception response to the master and by saving an error code to the ***ErrorStatus*** registers.

MODBUS Idle

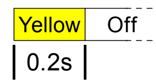
Whenever the MODBUS network is idle, the **Com** LED will stay off.

WattNode Received Packet / Sending Response



Every time the WattNode receives a properly formatted packet it will light the LED green for 200 milliseconds.

Other MODBUS Activity

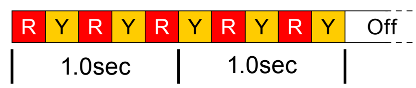


If the WattNode sees packets on the bus addressed to other devices, it will light the LED yellow for 200 milliseconds or longer if the packet duration is longer than 200 milliseconds.

MODBUS Address Zero Invalid

MODBUS address 0 is reserved for broadcast messages, so if the WattNode DIP switch is set for address zero, the **Com** LED will light red continuously and the WattNode will not respond to any MODBUS packets.

MODBUS Address Conflict



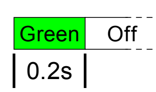
If two or more WattNodes or other devices share the same MODBUS address, then they will both try to respond to messages from the master, resulting in an RS-485 bus conflict and corrupted packets. One or more of the conflicting WattNodes will generally detect this and flash the “**Com**” LED red/yellow for two seconds and the ***ErrorStatus*** registers will report 248 or 249.

Invalid MODBUS Packet

The WattNode will light the **Com** LED red for one second for any of the following errors (the ***ErrorStatus*** registers will also be set, but depending on the problem you may not be able to read register values).

- **CRC error**: this could indicate noise on the RS-485 bus.
- **Framing error**: this normally indicates a bad baud rate or noise on the RS-485 bus. This can happen if you have the “**A-**” and “**B+**” wires swapped and your network isn’t properly biased. Properly biased networks will transparently auto-detect that “**A-**” and “**B+**” wires are swapped and correct. **Note:** some RS-485 PC interfaces label “A” and “B” the opposite of the WattNode or just use “+” and “-” indications.
- **Buffer overrun error**: the packet was longer than 256 bytes.
- **Parsing error**: the packet could not be correctly parsed.
- **Non-MODBUS packet**: the packet does not appear to be a valid MODBUS packet.

WattNode Received Invalid Request



If the WattNode receives a valid packet, but with an invalid request (see below), then the WattNode will return a MODBUS exception and store an error in the ***ErrorStatus*** registers. Because the packet was valid, the WattNode will light the **Com** LED green for 200 milliseconds.

MODBUS Exceptions

If the WattNode receives an invalid request, it will reply with a MODBUS exception code. In most cases, your PC software should be able to display the code, which should help you determine the problem. For more information about the problem, check the ***ErrorStatus*** registers, which will provide more detailed error codes.

- **02 - Illegal data address**
  - ErrorStatus 206: the specified registers contained an invalid address.
- **03 - Illegal data value**
  - ErrorStatus 202: When changing the ***ConfigPasscode***, the confirmation entry didn't match the first entry.
  - ErrorStatus 203: Error writing ***ConfigPasscode***. Must write both registers **1601**, **1602**.
  - ErrorStatus 205: Invalid ***ConfigPasscode*** value entered. You will have to wait five seconds to try again.
  - ErrorStatus 207, 208: An attempt was made to write an illegal data value to a register.
  - ErrorStatus 211, 212: The MODBUS packet contained an invalid count of registers or an invalid byte count.
- **04 - Slave device failure**
  - ErrorStatus 200: The correct ***ConfigPasscode*** must be entered before changing configuration registers, or resetting the energy or demand registers.
  - ErrorStatus 19, 20, 72, 79, 80: Internal hardware failure.
  - ErrorStatus 67: Calibration data lost. WattNode will report a slave device failure until it is calibrated.
- **06 - Slave device busy**
  - ErrorStatus 209: Attempts to unlock the configuration with ***ConfigPasscode*** are locked out for five seconds after entering an invalid passcode.

Diagnostic Registers

If MODBUS communications are working, but with intermittent problems, check the following diagnostic registers (see **Diagnostic Registers** for details): ***ErrorStatus***, ***CrcErrorCount***, ***FrameErrorCount***, ***PacketErrorCount***, ***OverrunCount***.

Operating Instructions

Quick Start

To start communicating with a WattNode using a PC, you'll need to complete the following steps:

- Set the MODBUS address and baud rate of the WattNode using the DIP switches (see **Setting the MODBUS Address**).
- Find and install MODBUS software for your PC. Modscan32 is a good inexpensive package for this purpose, with a free demo version (http://www.win-tech.com/html/modbus1.htm).
- Find and install an EIA RS-485 interface for your PC. The most common versions are RS-232 to RS-485 converters and RS-485 USB interfaces (Ethernet and PCI adapters are also available). The RS-485 USB interfaces are generally the best choice, because they are USB powered and don't require a serial port on your PC.
- Configure your MODBUS software for the correct baud rate, COM port, MODBUS RTU (not MODBUS ASCII), and N81 parity (no parity, eight data bits, one stop bit).

Now you should be able to send commands to the WattNode and receive responses. As a test, try reading the integer frequency register at **1221**. You should see the AC line frequency times 10 (approximately 600 for 60Hz power). If you don't get a good response, check the section **MODBUS Communication Diagnostics**.

WattNode Basic Configuration

Out of the box, the WattNode is ready to start measuring as soon as the current transformer rated amps (***CtAmps***) are configured (the default value is five amps).

- Set the ***CtAmps (1603)*** register to the correct rated CT amps of your current transformers. For example, if you are using 100A CTs, write 100 to register **1603** (16 bit integer register).

Verify Operation

You should be able to read several registers to check that the WattNode is correctly installed and measuring power and energy. If your MODBUS software supports floating point MODBUS registers, you may want read from the set **Basic Register List - Floating Point**. If you cannot easily read floating point values, use **Basic Register List - Integer** instead. Verify registers in the following sequence:

- ***Freq*** **(power line frequency)**: should be near 50 or 60 Hz (or 500 or 600 if you are reading the integer registers).
- ***VoltA, VoltB, VoltC***: should match your line-to-neutral voltage.
- ***PowerA, PowerB, PowerC***: should be positive (unless you are measuring something that can generate power like a PV system) and in a reasonable range for the load being measured (make sure your load is ON). Note: the integer power registers are scaled, so if you expect to see 75,000 W (75 kW) and instead you see 7500, that is probably because the WattNode is reporting integer power in 10 W increments. See ***PowerIntScale*** for more details.
- ***ErrorStatus***: this will return 0 if there are no errors. If you see any non-zero values, write them down and check the **Diagnostic Registers** section below to determine the problem.

If you are measuring floating point values and the numbers are way off, your software may be combining the floating point registers in the wrong order. Check to see if your software has an option like "Float - swapped" or "Float - reversed"; if so, see if this fixes the problem.

- **If you don't get reasonable results, check Measurement Troubleshooting above.**

Measurement Overview

The WattNode performs measurements every one second. The measurements are used to update three types of registers:

- **Energy registers**: These accumulate up (or sometimes down) based on the consumed energy during each measurement period. Energy values are preserved across power failures.
- **Instantaneous registers**: These are non-accumulating values, like power, volts, current, etc. These are not preserved across power failures.
- **Demand registers**: these accumulate data from each measurement, but the reported demand values only update at the completion of a demand interval (or subinterval), which is typically every 15 minutes. Only the peak demand and peak demand timestamp are preserved across power failures.

MODBUS Communication

The MODBUS WattNode uses MODBUS RTU communication. For full specifications, see http://www.modbus.org/specs.php. MODBUS RTU is a binary protocol consisting of message frames. Each frame contains a one byte address, a one byte function code, a variable number of data bytes, and a two byte CRC. The end of a frame is signalled by a pause with no bytes transmitted; the pause duration must be at least equivalent to 3.5 character (byte) periods. At 9600 baud the pause must last 3.6 milliseconds.

The MODBUS RTU serial specification requires that the default serial protocol use 8 data bits, even parity, and one stop bit. However, very few devices follow this part of the MODBUS standard, so the WattNode defaults to 8 data bits, no parity, and one stop bit instead. Contact us if your application requires even parity.

The MODBUS protocol is a master/slave protocol, with only one master and many slaves. The WattNode is always a slave device, and responds only when queried.

MODBUS on EIA RS-485 allows for either full-duplex or half-duplex communication, but the WattNode only supports half-duplex, meaning that the same wires are used both for transmitting and receiving and only one device can be transmitting at a time. To avoid conflicts (two devices trying to transmit at the same time), the MODBUS protocol only allows the master to initiate a request. After the master has finished transmitting, if the WattNode has received a valid packet addressed for it, then it may transmit its response.

MODBUS Functions

In most cases, your MODBUS software will automatically use the correct MODBUS command for any action you wish to perform, so you may be able to skip this section. The MODBUS specifications list numerous possible commands, but the WattNode only supports the following:

- **03 (0x03) - Read Holding Registers:** Holding registers can be read and written and are intended for configuration values, but the WattNode treats input registers and holding registers interchangeably, so you can use functions 04 or 03 to read any registers.
- **04 (0x04) - Read Input Registers:** Input registers are generally read-only and report power, energy, and related values. The WattNode treats input registers and holding registers as interchangeable, so you can use functions 04 or 03 to read any registers.
- **06 (0x06) - Write Single Register:** This writes a new value to a single register.
- **16 (0x10) - Write Multiple Registers:** This writes a new value to a range of registers.
- **17 (0x11) - Report Slave ID**: This returns a packet containing an ASCII text identification string. See the next section for details.

Report Slave ID

The report slave ID function returns the following standard packet:

Name	Length	Value	Description
Address	1 byte	Varies	MODBUS Address of the WattNode
Function Code	1 byte	0x11	Report Slave ID function code
Byte Count	1 byte	Varies	Number of bytes in Slave ID, Run Indicator Status, and Additional Data
Slave ID	1 byte	0x02	WattNode MODBUS Slave ID byte
Run Indicator Status	1 byte	0xFF = ON	WattNode always returns 0xFF
Additional Data	Variable, typically 64	ASCII string, null terminated	Example: "Continental Control Systems LLC, WattNode MODBUS, WNC-3Y-208-MB"
CRC	2 bytes	Varies	Packet checksum

Table 7: Report Slave ID Response

The standard values for the Additional Data field follow:

WattNode Model	Response String
WNC-3Y-208-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3Y-208-MB
WNC-3Y-400-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3Y-400-MB
WNC-3Y-480-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3Y-480-MB
WNC-3Y-600-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3Y-600-MB
WNC-3D-240-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3D-240-MB
WNC-3D-400-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3D-400-MB
WNC-3D-480-MB	Continental Control Systems LLC, WattNode MODBUS, WNC-3D-480-MB

Table 8: Slave ID Additional Data Field Values

MODBUS Register Lists

This section lists the MODBUS registers. The following sections provide detailed information about each register. The registers are grouped as follows:

- **Basic Registers**: Floating Point
- **Basic Registers**: Integer
- **Advanced Registers**: Floating Point
- **Advanced Registers**: Integer
- **Configuration Registers**: Integer
- **Customer Diagnostic Registers**: Integer

MODBUS Register Addressing

There are a few points about MODBUS register addressing that can cause confusion.

- In the MODBUS specification, register numbers are documented as "one based", but transmitted as "zero based". For example, we document that ***EnergySum*** appears at address **1001**. If you are using any MODBUS software or MODBUS aware device, you should use "1001" as the register address. However, if you are writing your own low-level MODBUS driver or firmware, you will need to subtract one from the register number when creating the MODBUS frame (or packet), so the actual register number that appears on the RS-485 bus will be "1000" (or in hexadecimal 0x03E8).

- A common MODBUS convention adds a leading digit onto the register number (or address), so that a register like ***EnergySum*** (**1001**) would be documented as **41001**. In this case, the leading digit matches the MODBUS function code used to read this type of register. So all input registers (function code 04) would use the form **4xxxx**, while holding registers (function code 03) would use the form **3xxxx**. Since the WattNode treats holding registers and input registers interchangeably, we do not use this convention. If your MODBUS software tool expects a leading "3" or "4", you may use either digit for most registers, and should use "3" for configuration registers.

Floating Point and Integer Registers

Most registers are available in floating point and integer formats. We generally recommend using the floating point registers, because they provide more precision and dynamic range and they never requiring scaling. However, for energy variables, the 32 bit integer registers may be a better choice, because they provide a constant resolution of 0.1 kWh. Since most of the integer registers are 16 bits, they are faster to transfer over the MODBUS interface and may require less space if they are being logged.

The floating point registers are 32 bits long (single precision) and use two adjacent MODBUS registers (16 bits each). Since floating point values require two registers, the first register (lower number) provides the lower 16 bits, and the second register (higher number) provides the upper 16 bits of the 32 bit floating point value. This is the default for many programs that read floating point MODBUS values, but if this results in bizarre values (very large, very small, strange exponents, invalid values), look for an option to reverse the registers when reading floating point values: commonly referred to as "Float - Swapped" or "Float - Reversed". Do not select double precision formats.

Most of the integer registers are 16 bit signed integers that can report positive or negative values from -32768 to +32767. In a few special cases, such as the energy registers, we use 32 bit signed integer registers, which use two adjacent MODBUS registers and can report values up to approximately ± two billion.

Reading and Writing 32 Bit Registers

Since floating point and 32 bit integer registers require two adjacent registers to store 32 bits, there are some things to note when reading and writing these 32 bit dual registers:

- The first register (at the lower address) contains the least significant 16 bits of data.
- When reading a 32 bit register, read both registers with a single MODBUS read command. The WattNode is guaranteed to return consistent results for a single multiple register read command. If you (or your software) issues two separate read commands for the two registers making up a 32 bit register, the underlying 32 bit register may be updated between the two read commands, resulting in an inconsistent or scrambled value.
- When writing to 32 bit registers, the recommended approach is to use the **Write Multiple Registers (16)** command to update both registers at the same time. However, WattNode incorporates logic to allow two **Write Single Register (06)** commands within 30 seconds, provided no other MODBUS commands are issued between the two writes.

Basic Register List - Floating Point

The following registers provide the most commonly used measurements in floating point units. See the **Basic Register List - Integer** below for miscellaneous registers, which don't appear in the floating point list. See **Basic Registers** below for detailed information.

Registers	Name	Units	Description
Energy Registers			
1001, 1002	EnergySum*	kWh	Total net (bidirectional) energy
1003, 1004	EnergyPosSum*	kWh	Total positive energy
1005, 1006	EnergySumNR*	kWh	Total net (bidirectional) energy - non resettable
1007, 1008	EnergyPosSumNR*	kWh	Total positive energy - non resettable
Power Registers			
1009, 1010	PowerSum	W	Real power, sum of active phases
1011, 1012	PowerA	W	Real power, phase A
1013, 1014	PowerB	W	Real power, phase B
1015, 1016	PowerC	W	Real power, phase C
Voltage Registers			
1017, 1018	VoltAvgLN	V	Average phase-to-neutral voltage
1019, 1020	VoltA	V	RMS voltage, phase A to neutral
1021, 1022	VoltB	V	RMS voltage, phase B to neutral
1023, 1024	VoltC	V	RMS voltage, phase C to neutral
1025, 1026	VoltAvgLL	V	Average line-to-line voltage
1027, 1028	VoltAB	V	RMS voltage, line-to-line, phase A to B
1029, 1030	VoltBC	V	RMS voltage, line-to-line, phase B to C
1031, 1032	VoltAC	V	RMS voltage, line-to-line, phase A to C
Frequency Register			
1033, 1034	Freq	Hz	Power line frequency

**These registers are preserved across power failures.*

Basic Register List - Integer

The following registers provide the most commonly used measurements in integer units. The energy registers are 32 bit signed integer values, which require two registers, the first register provides the lower 16 bits, and the second register provides the upper 16 bits of the 32 bit value. See **Basic Registers** below for detailed information.

Registers	Name	Units	Description
Energy Registers			
1201, 1202	EnergySum*	0.1 kWh	Total net (bidirectional) energy
1203, 1204	EnergyPosSum*	0.1 kWh	Total positive energy
1205, 1206	EnergySumNR*	0.1 kWh	Total net (bidirectional) energy - non resettable
1207, 1208	EnergyPosSumNR*	0.1 kWh	Total positive energy - non resettable
Power Registers			
1209	PowerSum	PowerIntScale	Real power, sum of active phases
1210	PowerA	PowerIntScale	Real power, phase A
1211	PowerB	PowerIntScale	Real power, phase B
1212	PowerC	PowerIntScale	Real power, phase C
Voltage Registers			
1213	VoltAvgLN	0.1 V	Average phase-to-neutral voltage
1214	VoltA	0.1 V	RMS voltage, phase A to neutral
1215	VoltB	0.1 V	RMS voltage, phase B to neutral
1216	VoltC	0.1 V	RMS voltage, phase C to neutral
1217	VoltAvgLL	0.1 V	Average line-to-line voltage
1218	VoltAB	0.1 V	RMS voltage, line-to-line, phase A to B
1219	VoltBC	0.1 V	RMS voltage, line-to-line, phase B to C
1220	VoltAC	0.1 V	RMS voltage, line-to-line, phase A to C
Frequency Register			
1221	Freq	0.1 Hz	Power line frequency

**These registers are preserved across power failures.*

Advanced Register List - Floating Point

The following registers provide more advanced measurements in floating point units. See **Advanced Registers** below for detailed information.

Registers	Name	Units	Description
Energy Registers			
1101, 1102	EnergyA*	kWh	Net (bidirectional) energy, phase A
1103, 1104	EnerygB*	kWh	Net (bidirectional) energy, phase B
1105, 1106	EnergyC*	kWh	Net (bidirectional) energy, phase C
1107, 1108	EnergyPosA*	kWh	Positive energy, phase A
1109, 1110	EnergyPosB*	kWh	Positive energy, phase B
1111, 1112	EnergyPosC*	kWh	Positive energy, phase C
1113, 1114	EnergyNegSum*	kWh	Negative energy, sum of active phases
1115, 1116	EnergyNegSumNR*	kWh	Negative energy, sum of active phases - non resettable
1117, 1118	EnergyNegA*	kWh	Negative energy, phase A
1119, 1120	EnergyNegB*	kWh	Negative energy, phase B
1121, 1122	EnergyNegC*	kWh	Negative energy, phase C
1123, 1124	EnergyReacSum*	kWh	Reactive energy, sum of active phases
1125, 1126	EnergyReacA*	kWh	Net reactive energy, phase A
1127, 1128	EnergyReacB*	kWh	Net reactive energy, phase B
1129, 1130	EnergyReacC*	kWh	Net reactive energy, phase C
1131, 1132	EnergyAppSum*	kWh	Apparent energy, sum of active phases
1133, 1134	EnergyAppA*	kWh	Apparent energy, phase A
1135, 1136	EnergyAppB*	kWh	Apparent energy, phase B
1137, 1138	EnergyAppC*	kWh	Apparent energy, phase C
Power Factor Registers			
1139, 1140	PowerFactorAvg		Power factor, average
1141, 1142	PowerFactorA		Power factor, phase A
1143, 1144	PowerFactorB		Power factor, phase B
1145, 1146	PowerFactorC		Power factor, phase C
Reactive and Apparent Power Registers			
1147, 1148	PowerReacSum	VAR	Reactive power, sum of active phases
1149, 1150	PowerReacA	VAR	Reactive power, phase A
1151, 1152	PowerReacB	VAR	Reactive power, phase B
1153, 1154	PowerReacC	VAR	Reactive power, phase C
1155, 1156	PowerAppSum	VA	Apparent power, sum of active phases
1157, 1158	PowerAppA	VA	Apparent power, phase A
1159, 1160	PowerAppB	VA	Apparent power, phase B
1161, 1162	PowerAppC	VA	Apparent power, phase C
Current Registers			
1163, 1164	CurrentA	A	RMS current, phase A
1165, 1166	CurrentB	A	RMS current, phase B
1167, 1168	CurrentC	A	RMS current, phase C
Demand Registers			
1169, 1170	Demand	W	Real power demand averaged over the demand period
1171, 1172	DemandMin*	W	Minimum power demand
1173, 1174	DemandMax*	W	Maximum power demand
1175, 1176	DemandApp	W	Apparent power demand

**These registers are preserved across power failures.*

Advanced Register List - Integer

These registers provide advanced integer measurements. The energy registers are 32 bit signed dual registers: the first register provides the lower 16 bits, and the second register provides the upper 16 bits of the 32 bit value. See **Advanced Registers** below for detailed information.

Registers	Name	Units	Description
Energy Registers			
1301, 1302	EnergyA*	0.1 kWh	Net energy, phase A
1303, 1304	EnergygB*	0.1 kWh	Net energy, phase B
1305, 1306	EnergyC*	0.1 kWh	Net energy, phase C
1307, 1308	EnergyPosA*	0.1 kWh	Positive energy, phase A
1309, 1310	EnergyPosB*	0.1 kWh	Positive energy, phase B
1311, 1312	EnergyPosC*	0.1 kWh	Positive energy, phase C
1313, 1314	EnergyNegSum*	0.1 kWh	Negative energy, sum of active phases
1315, 1316	EnergyNegSumNR*	0.1 kWh	Negative energy, sum of active phases - non resettable
1317, 1318	EnergyNegA*	0.1 kWh	Negative energy, phase A
1319, 1320	EnergyNegB*	0.1 kWh	Negative energy, phase B
1321, 1322	EnergyNegC*	0.1 kWh	Negative energy, phase C
1323, 1324	EnergyReacSum*	0.1 kWh	Reactive energy, sum of active phases
1325, 1326	EnergyReacA*	0.1 kWh	Net reactive energy, phase A
1327, 1328	EnergyReacB*	0.1 kWh	Net reactive energy, phase B
1329, 1330	EnergyReacC*	0.1 kWh	Net reactive energy, phase C
1331, 1332	EnergyAppSum*	0.1 kWh	Apparent energy, sum of active phases
1333, 1334	EnergyAppA*	0.1 kWh	Apparent energy, phase A
1335, 1336	EnergyAppB*	0.1 kWh	Apparent energy, phase B
1337, 1338	EnergyAppC*	0.1 kWh	Apparent energy, phase C
Power Factor Registers			
1339	PowerFactorAvg	0.01	Power factor, average
1340	PowerFactorA	0.01	Power factor, phase A
1341	PowerFactorB	0.01	Power factor, phase B
1342	PowerFactorC	0.01	Power factor, phase C
Reactive and Apparent Power Registers			
1343	PowerReacSum	PowerIntScale	Reactive power VAR, sum of active phases
1344	PowerReacA	PowerIntScale	Reactive power VAR, phase A
1345	PowerReacB	PowerIntScale	Reactive power VAR, phase B
1346	PowerReacC	PowerIntScale	Reactive power VAR, phase C
1347	PowerAppSum	PowerIntScale	Apparent power VA, sum of active phases
1348	PowerAppA	PowerIntScale	Apparent power VA, phase A
1349	PowerAppB	PowerIntScale	Apparent power VA, phase B
1350	PowerAppC	PowerIntScale	Apparent power VA, phase C
Current Registers			
1351	CurrentA	CurrentIntScale	RMS current, phase A
1352	CurrentB	CurrentIntScale	RMS current, phase B
1353	CurrentC	CurrentIntScale	RMS current, phase C
Demand Registers			
1354	Demand	PowerIntScale	Real power demand averaged over the demand period
1355	DemandMin*	PowerIntScale	Minimum power demand
1356	DemandMax*	PowerIntScale	Maximum power demand
1357	DemandApp	PowerIntScale	Apparent power demand

**These registers are preserved across power failures.*

Configuration Register List

These integer registers configure and customize the WattNode. For simple installations, only ***CtAmps*** needs to be set. By default, there is no passcode for the configuration, but if security is required, a passcode can be assigned. The configuration registers are all integer format. See **Configuration Registers** below for detailed information.

Registers	Name	Units	Default	Description
1601, 1602	ConfigPasscode		0	Optional passcode to prevent unauthorized changes to configuration
1603	CtAmps*	1 A	5	Current transformer rated current
1604	CtAmpsA*	1 A	0	Optional CT rated current override for phase A
1605	CtAmpsB*	1 A	0	Optional CT rated current override for phase B
1606	CtAmpsC*	1 A	0	Optional CT rated current override for phase C
1607	CtDirections*		0	Optionally invert CT orientations
1608	Averaging*		1 (fast)	Configure measurement averaging
1609	PowerIntScale*	1 W	0 (auto)	Scale factor for integer power registers
1610	DemPerMins*	1 minute	15	Demand period
1611	DemSubints*		1	Number of demand subintervals
1612	GainAdjustA*	1/10000th	0	Optional power/energy adjustment for phase A
1613	GainAdjustB*	1/10000th	0	Optional power/energy adjustment for phase B
1614	GainAdjustC*	1/10000th	0	Optional power/energy adjustment for phase C
1615	PhaseAdjustA*	0.001 deg	0	Optional CT phase angle adjust for phase A
1616	PhaseAdjustB*	0.001 deg	0	Optional CT phase angle adjust for phase B
1617	PhaseAdjustC*	0.001 deg	0	Optional CT phase angle adjust for phase C
1618	CreepLimit*		1500	Configure minimum power for a non-zero reading
1619	PhaseOffset*	1 degree	120	Nominal angle between primary voltage phases (120 or 180)
1620	ZeroEnergy		-	Write 1 to zero all resettable energy registers
1621	ZeroDemand		-	Write 1 to zero all demand values

**These registers are preserved across power failures.*

Communication Register List

These integer registers can be used to override the DIP switch address and baud rate settings and for more advanced communication settings, like even parity or 38.400 baud. See **Communication Registers** below for details.

Registers	Name	Default	Description
1651	ApplyComConfig	0	Writing 1234 applies the configuration settings below. Reads 1 if changes not applied yet.
1652	Address*	0	MODBUS address (if non-zero, overrides DIP switches)
1653	BaudRate*	0	0 = DIP Switch Assigned 4 = 9600 baud 5 = 19200 baud 6 = 38400 baud
1654	ParityMode*	0	0 = N81 (no parity, one stop bit) 1 = E81 (even parity, one stop bit)
1655	ModbusMode*	0	0=RTU 1=TCP-RTU

**These registers are preserved across power failures.*

Diagnostic Register List

These registers provide information and diagnostics for the WattNode. The diagnostic registers are all integer values. The registers ***UptimeSecs*** and ***TotalSecs*** are 32 bit signed integer dual registers: the first register provides the lower 16 bits, and the second register provides the upper 16 bits of the 32 bit value. See **Diagnostic Registers** and **Error Codes** below for detailed information.

Registers	Name	Units	Description
0001, 0002	DummyReg		Dummy register; always returns zero; can be used to scan for active MODBUS addresses
1701, 1702	SerialNumber*		The unique WattNode serial number
1703, 1704	UptimeSecs	Seconds	Time in seconds since last power on
1705, 1706	TotalSecs*	Seconds	Total seconds of operation
1707	Model*		Encoded WattNode model
1708	Version*		Firmware version
1709	Options*		WattNode options
1710	ErrorStatus*	n.a.	List of recent errors and events
1711	PowerFailCount*		Power failure count
1712	CrcErrorCount		Count of MODBUS CRC communication errors
1713	FrameErrorCount		Count of MODBUS framing errors
1714	PacketErrorCount		Count of bad MODBUS packets
1715	OverrunCount		Count of MODBUS buffer overruns
1716	ErrorStatus1	n.a.	Newest error or event (0 = no errors)
1717	ErrorStatus2	n.a.	Next oldest error or event
1718	ErrorStatus3	n.a.	Next oldest error or event
1719	ErrorStatus4	n.a.	Next oldest error or event
1720	ErrorStatus5	n.a.	Next oldest error or event
1721	ErrorStatus6	n.a.	Next oldest error or event
1722	ErrorStatus7	n.a.	Next oldest error or event
1723	ErrorStatus8	n.a.	Oldest error or event

**These registers are preserved across power failures.*

Basic Registers

Energy Registers

Commonly known as kWh (kilowatt-hours), the energy is the integral of power over time. Many installations will only use the energy measurement. It is commonly used for billing or sub-metering. Because energy is an accumulated value, it can be used on networks that are accessed infrequently (like a utility meter that only needs to be read once a month). All energy register values are preserved through power failures.

In the WattNode, most energy registers can be reset to zero by writing "1" to the ***ZeroEnergy*** register. All energy registers ending with "NR" (for non-resetting) cannot be reset to zero for billing security. All energy registers wrap around to zero when they reach 100 gigawatt-hours (100 x 10^9 watt-hours) or negative 100 gigawatt-hours (only some energy registers allow negative values).

During a power outage, the energy consumed will not be measured. Whenever the line voltage drops below 60–80% of nominal, the WattNode will shut down until power is restored. To preserve the energy measurement across power outages, the WattNode writes the energy to non-volatile (ferroelectric RAM) memory every second. When power returns, the last stored value is recovered.

EnergySum, EnergySumNR

EnergySum is the net real energy sum of all active phases, where "net" means negative energy will subtract from the total. This value is appropriate for net metering applications (i.e.

photovoltaic) where you wish to measure the net energy in situations where you may sometimes consume energy and other times generate energy. Use ***EnergyPosSum*** instead if you don't want negative energy to subtract from the total.

EnergySum is reset to zero when "1" is written to the ***ZeroEnergy*** register.

The ***EnergySumNR*** is identical to ***EnergySum*** except that it cannot be reset to zero.

EnergyPosSum, EnergyPosSumNR

EnergyPosSum is equivalent to a traditional utility meter that can only spin in one direction. Every second, the measured real energies for each active phase are added together. If the result is positive, it is added to ***EnergyPosSum***. If it is negative, then ***EnergyPosSum*** is left unchanged.

EnergyPosSum is reset to zero when "1" is written to the ***ZeroEnergy*** register.

The ***EnergySumPosNR*** is identical to ***EnergySumPos*** except that it cannot be reset to zero.

Power Registers

PowerA, PowerB, PowerC

The WattNode measures real power (watts) for each phase (***PowerA, PowerB, PowerC***). The measured power is generally positive, but may also be negative, either because you are generating power (such as with solar panels), or because the WattNode isn't connected properly.

The integer power registers are scaled by ***PowerIntScale*** to prevent overflow. The integer power registers can only report values from -32767 to +32767. To allow for large power values, ***PowerIntScale*** acts as a multiplier to multiply by 1, 10, 100, or 1000. See **Configuration Registers** for details. To scale the integer ***PowerA***, ***PowerB***, ***PowerC***, or ***PowerSum*** to watts, use the following equation:

$$Power(W) = PowerSum \bullet PowerIntScale$$

For example, if ***PowerIntScale*** (**1609**) is 100, and the integer ***PowerSum*** (**1209**) reports 2500, then the power sum is 2500 * 100 = 250,000 W (or 250 kW).

PowerSum

This is the sum of the real power for active phases (line voltage above 20% of nominal). This can include negative values, so if one phase is negative, it will reduce the reported ***PowerSum***.

Voltage Registers

All integer voltage registers are reported in units of 0.1 VAC, so 1234 = 123.4 VAC.

VoltAvgLN

This is the average line-to-neutral voltage (average of ***VoltA***, ***VoltB***, and ***VoltC***). Only active phases are included (phases where the voltage is above 20% of nominal).

VoltA, VoltB, VoltC

These are the RMS AC voltages for each phase. These are measured relative to the neutral connection on the WattNode. If neutral is not connected, then these are measured relative to the ground connection on the WattNode.

Voltage phases that are not connected may report small random voltages, but the WattNode treats any phase reporting less than 20% of the nominal VAC as inactive and will not measure power or energy on inactive phases.

VoltAvgLL

This is the average line-to-line voltage (average of ***VoltAB***, ***VoltBC***, and ***VoltAC***). All phases are included in the average.

VoltAB, VoltBC, VoltAC

The WattNode cannot directly measure line-to-line voltages. It provides these registers just as estimates of the line-to-line voltage. In order to estimate these voltages, the WattNode must know the phase offset or the type of electrical service (see ***PhaseOffset*** configuration register). This estimate is only accurate for balanced two-phase and three-phase circuits. Special configurations like the four-wire delta will not result in accurate line-to-line voltage estimates.

Frequency

Freq

The WattNode measures the AC line frequency in Hertz. The integer ***Freq*** register reports the frequency in units of 0.1 Hz. All phases must have the same line frequency; otherwise this value will be erratic or incorrect.

Advanced Registers

Per-Phase Energy Registers

EnergyA, EnergyB, EnergyC

The per-phase energy registers report the net real energy for each phase, where "net" means negative energy will subtract from the total. This value is appropriate for net metering applications (i.e. photovoltaic) where you wish to measure the net energy in situations where you may sometimes consume energy and other times generate energy.

These values are reset to zero when "1" is written to the ***ZeroEnergy*** register.

Positive Energy

EnergyPosA, EnergyPosB, EnergyPosC

The per-phase positive energy registers measure the positive real energy for each phase. Negative energy is ignored (instead of subtracting from the total). Energy is measured once per second, so the determination of whether the energy is positive is based on the overall energy for the second.

These values are reset to zero when "1" is written to the ***ZeroEnergy*** register.

Negative Energy

The negative energy registers are exactly like the positive energy registers except they accumulate negative energy. The reported energy values will be positive. In other words, if the WattNode measures 1000 kWh of negative energy, ***EnergyNegSum*** will report 1000 (not -1000).

EnergyNegSum

Every second, the measured real energies for each active phase are added together. If the result is negative, it is added to ***EnergyNegSum***. If it is positive, then ***EnergyNegSum*** is left unchanged.

This value is reset to zero when "1" is written to the ***ZeroEnergy*** register.

EnergyNegSumNR

The ***EnergySumNegNR*** is identical to ***EnergyNegPos*** except that it cannot be reset to zero.

EnergyNegA, EnergyNegB, EnergyNegC

These are the per-phase negative real energy registers.

These values are reset to zero when "1" is written to the ***ZeroEnergy*** register.

Reactive Energy

EnergyReacSum, EnergyReacA, EnergyReacB, EnergyReacC

Reactive energy is also known as VAR-hours. Inductive loads, like motors, generate positive reactive power and energy, while capacitive loads generate negative reactive energy. These are all bidirectional registers that can count up or down depending on the sign of the reactive power.

The WattNode only measures the fundamental reactive energy, not including harmonics.

These values are reset to zero when "1" is written to the ***ZeroEnergy*** register.

Apparent Energy

EnergyAppSum, EnergyAppA, EnergyAppB, EnergyAppC

Apparent energy is the integral (or accumulation) of apparent power over time. The apparent power is essentially the RMS voltage multiplied by the RMS current for each phase. For example, if you have 120 VAC RMS, 10 amps RMS, one phase, the apparent power will be 1200 VA. At the end of an hour, the apparent energy will be 1.2 kVA-hour. Apparent energy is always positive.

The WattNode's measurement of apparent energy includes some, but not all harmonic apparent energy content.

These values are reset to zero when "1" is written to the ***ZeroEnergy*** register.

Power Factor

The power factor is the ratio of the real power to the apparent power. Resistive loads, like incandescent lighting and electric heaters, should have a power factor near 1.0. Power-factor corrected loads, like computers, should be near 1.0. Motors can have power factors from 0.2 to 0.9, but are commonly in the 0.5 to 0.7 range.

If the power for a phase is negative, the power factor will also be negative. The reported power factor will be 1.0 for any phases measuring zero power, and will be 0.0 for any inactive phases (line voltage below 20% of nominal VAC).

The WattNode measures the displacement or fundamental power factor, which does not include harmonics.

Integer power factor registers are reported in units of 0.01, so 85 equals a power factor of 0.85.

PowerFactorA, PowerFactorB, PowerFactorC

These are the power factor values for each phase.

PowerFactorAvg

This is the average power factor, computed as ***PowerSum*** / ***ApparentPowerSum***.

Reactive Power

Reactive power is also known as VARs. Inductive loads, like motors, generate positive reactive power, while capacitive loads generate negative reactive power. Reactive power transfers no net energy to the load and generally is not metered by the utility. Loads with high reactive power relative to the real power will tend to have lower power factors. The integer reactive power registers are scaled by ***PowerIntScale***.

The WattNode only measures the fundamental reactive power, not including harmonics.

To scale the integer ***PowerReacA***, ***PowerReacB***, ***PowerReacC***, or ***PowerReacSum*** to VARs, use the following equation:

$$PowerReac(VAR) = PowerReacSum \cdot PowerIntScale$$

For example, if ***PowerIntScale*** (**1609**) is 100, and the integer ***PowerReacSum*** (**1343**) reports 1500, then the reactive power sum is 1500 * 100 = 150,000 VAR (or 150 kVAR).

PowerReacA, PowerReacB, PowerReacC

These are the per-phase reactive power measurements.

PowerReacSum

The ***PowerReacSum*** is the sum of the reactive power of active phases. This can include negative values, so if one phase is negative, it will reduce the reported ***PowerReacSum***.

Apparent Power

Apparent power (VA) can be described three ways:

- The RMS voltage multiplied by the RMS current.
- The square root of the real power squared plus the reactive power squared.
- The absolute value or magnitude of the complex power.

The WattNode's measurement of apparent power includes some, but not all harmonic apparent power content.

Apparent power is always a positive quantity. The integer apparent power registers are scaled by ***PowerIntScale***.

PowerAppA, PowerAppB, PowerAppC

These are the per-phase apparent power measurements.

PowerAppSum

The ***PowerAppSum*** is the sum of apparent power for active phases.

Current

The MODBUS WattNode measures the RMS current for each phase. This is an indirect measurement and does not include all harmonic content, so the current is not as accurate as the power and energy measurements.

CurrentA, CurrentB, CurrentC

Technically, AC current does not have a sign (positive or negative), but the WattNode sets the sign of the current to match the sign of the real power for the same phase. For example, if the power on phase A is negative, then the current for phase A (***CurrentA***) will also be negative.

The floating point current registers are in units of amps. The integer current registers are in scaled amps (***CurrentIntScale***), so you will need to use the following equations to convert back to amps (if ***CtAmpsA***, ***CtAmpsB***, or ***CtAmpsC*** are set to specify different CTs for different phases, then they are used instead of ***CtAmps***):

$$CurrentIntScale = CtAmps / 20000$$

$$Ia = CurrentA \cdot CurrentIntScale$$

For example, with 200 amp current transformers, ***CurrentIntScale*** = 200 / 20000 = 0.01. So if ***CurrentA*** (**1351**) reports 5000, the actual current is 5000 * 0.01 = 50.00 amps. Note: ***CurrentIntScale*** is not an actual register and cannot be read or written.

Demand

Demand is defined as the average power over a specified time interval. Typical demand intervals are 5, 10, 15 (default), 30, 60, etc. up to 720 minutes, but the WattNode supports arbitrary demand intervals from 5 to 720 minutes. The WattNode records the peak demand with a time stamp for metering applications where the measurements may only be accessed weekly or monthly.

Since the WattNode can measure bidirectional power (positive and negative), and the demand is the average power over an interval, demand can also be positive or negative. This is only likely to occur with something like a grid-tied PV system, where you may put energy back into the grid at certain times of the day (negative power). In this case, you would see negative demand. If you have both positive and negative power during a demand interval, both the positive and the negative data will be averaged together, such that the negative power subtracts from the positive, reducing the overall demand.

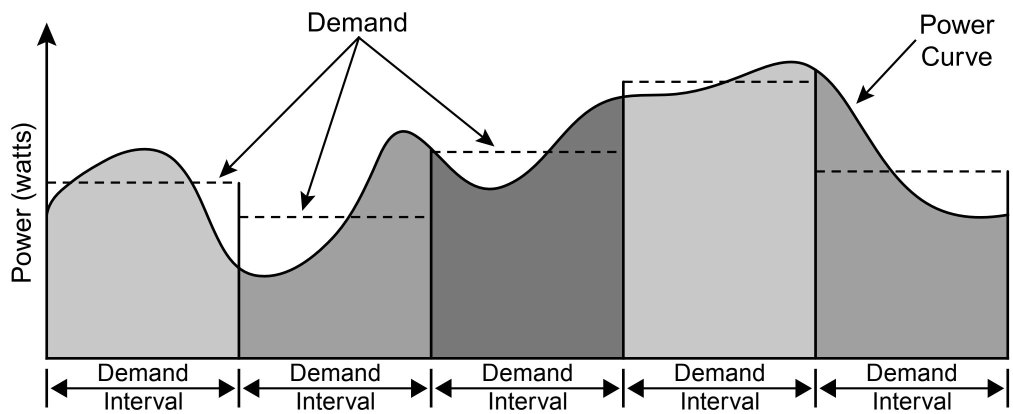


Figure 10: Demand Measurement

The WattNode also supports rolling demand (also called "sliding window"), in which the demand intervals are evenly divided into a fixed number of subintervals. At the end of each subinterval, the average power over the demand interval is computed and output. This results in better accuracy, especially for demand peaks which would not have lined up with the demand interval without subintervals. The first measurement will not be reported until one complete demand interval has elapsed. From 1 to 8 subintervals are supported. A subinterval count of one (or zero) results in the standard demand measurement without rolling demand. See **Configuration Registers** for information on configuring the demand.

Any changes to the demand configuration (***DemPerMins, DemSubints***) or CT configuration (***CtAmps***, ***CtAmpsA, CtAmpsB, CtAmpsC***, ***CtDirections***) will zero the reported demand and start a new demand measurement. The ***DemandMin*** and ***DemandMax*** will not be reset by configuration changes.

To manually zero some or all of the demand registers, see the ***ZeroDemand*** register in **Configuration Registers** below.

The floating point demand registers are reported in units of watts, while the integer demand registers must be scaled by ***PowerIntScale*** to compute watts. To scale the integer ***Demand***, ***DemandMin***, ***DemandMax***, or ***DemandApp***, use the following equation:

$$Demand(W) = Demand \cdot PowerIntScale$$

For example, if ***PowerIntScale*** (**1609**) is 100, and the integer ***Demand*** (**1354**) reports 4700, then the demand is 4700 * 100 = 470,000 watts (or 470 kW).

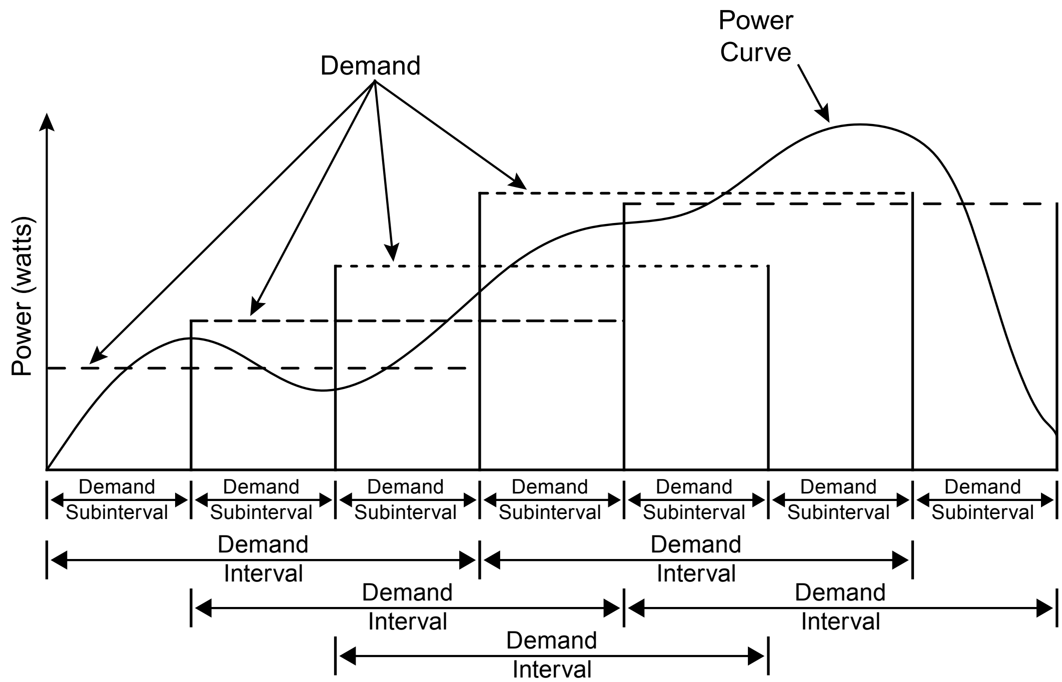


Figure 11: Rolling Demand with Three Subintervals

Demand

The ***Demand*** register is updated at the end of every subinterval with the average real power over a full demand interval. After a power cycle or configuration change, it will take one full demand interval before the first reading appears.

DemandMin

The ***DemandMin*** is the smallest measured demand (this may be negative for systems with power generation). It is preserved across power failures.

DemandMax

The ***DemandMax*** is the largest measured demand. It is preserved across power failures.

DemandApp

DemandApp is computed the same way as ***Demand***, but using apparent power instead of real power.

Configuration Registers

ConfigPasscode (1601, 1602)

The WattNode has an optional configuration passcode to prevent unauthorized changes to the configuration. As shipped from the factory, the ***ConfigPasscode*** is set to “0”, disabling the passcode. If a passcode is set, the WattNode must be unlocked by writing the correct value to ***ConfigPasscode*** before any configuration registers can be changed and before the energy or demand registers can be reset to zero.

You can read the ***ConfigPasscode*** register to determine if the WattNode is locked. You cannot read the actual passcode itself. If you lose your passcode, contact support for assistance.

- ***0*** - Unlocked
- ***1*** - Locked

Invalid unlock attempts will result in the MODBUS error 03 - “Illegal data value”, and prevent more attempts for five seconds. An unlocked WattNode will become locked again after five minutes or when “1” is written twice to ***ConfigPasscode***.

The passcode can be set (or changed) by writing the new passcode to ***ConfigPasscode*** twice in a row within 30 seconds. If a passcode is already set, the WattNode must be unlocked before writing the new passcode.

Valid passcode values are:

- 0 - this disables the passcode.
- 2 to 2,147,483,647 - we recommend using at least six digits to have a reasonably secure passcode.

The passcode is a 32 bit value, so both register locations **1601** and **1602** must be written when unlocking the WattNode or setting a passcode.

CtAmps (1603)

The ***CtAmps*** is an integer register in units of amps used to set the rated current of an attached current transformer. Rated current is the 100% value, or the current that results in a 0.33333 VAC output from the CT.

The specified rated CT amps for each phase (either ***CtAmps*** or ***CtAmpsA***, ***CtAmpsB***, and ***CtAmpsC***), affect the scaling “*CurrentIntScale*“ for the integer current registers ***CurrentA***, ***CurrentB***, and ***CurrentC***. See section **Current** above for details.

CtAmpsA, CtAmpsB, CtAmpsC (1604 , 1605, 1606)

If you have different current transformers connected to different phases, set ***CtAmpsA***, ***CtAmpsB***, and/or ***CtAmpsC*** to non-zero values to override ***CtAmps*** for the specified phase.

CtDirections (1607)

On occasion, current transformers are installed with the label “This side towards source” facing the load instead of the source, or with the white and black wires swapped at the WattNode. If the electrical installer notices this, they can fix it, but sometimes the problem isn’t noticed until the electrician is gone and some or all of the reported power values are unexpectedly negative.

You can correct this with the ***CtDirections*** register:

- ***0*** - All CTs normal
- ***1*** - Flip phase A CT
- ***2*** - Flip phase B CT
- ***4*** - Flip phase C CT
- ***3*** - Flip phase A CT and flip phase B CT
- ***5*** - Flip phase A CT and flip phase C CT
- ***6*** - Flip phase B CT and flip phase C CT
- ***7*** - Flip all CTs (A, B, and C)

Note, this cannot be used to correct for situations where CT phases do not match the voltage phases, such as swapping phases A and B on the current transformer inputs.

Averaging (1608)

The WattNode includes averaging for these registers: ***PowerSum***, ***PowerA***, ***PowerB***, ***PowerC***, ***VoltAvgLN***, ***VoltA***, ***VoltB***, ***VoltC***, ***VoltAvgLL***, ***VoltAB***, ***VoltBC***, ***VoltAC***, ***Freq***, ***PowerFactorAvg***, ***PowerFactorA***, ***PowerFactorB***, ***PowerFactorC***, ***PowerReacSum***, ***PowerReacA***, ***PowerReacB***, ***PowerReacC***, ***PowerAppSum***, ***PowerAppA***, ***PowerAppB***, ***PowerAppC***, ***CurrentA***, ***CurrentB***, ***CurrentC***.

Averaging is beneficial because it reduces measurement noise, and if the WattNode is being polled less often than once a second (say once a minute), then the average over the last minute provides a more accurate reading than just the data from the last second, which might be randomly high or low. Averaging is configured by setting the ***Averaging*** (**1608**) register to one of the following values:

Averaging Register	Description	Averaging Period	Update Rate
0	Fastest	1 second	Every 1 second
1	Fast (default)	5 seconds	Every 1 second
2	Medium	20 seconds	Every 4 seconds
3	Slow	60 seconds	Every 12 seconds

Table 9: Averaging Settings

When medium or slow averaging are specified, the reported values for averaged registers will only update every 4 or 12 seconds respectively, instead of once a second.

PowerIntScale (1609)

In order to report power as an integer value (±32,767), the WattNode must scale the power so that it doesn't overflow. By default, the WattNode selects a ***PowerIntScale*** value of 1, 10, 100, or 1000 whenever the ***CtAmps*** (or ***CtAmpsA***, ***CtAmpsB***, or ***CtAmpsC***) are changed. The WattNode selects a value that won't overflow unless the power exceeds 120% of full-scale.

PowerIntScale	Power Resolution	Maximum Power Reading
0 (default)	Auto-configure	
1	1 watt	±32767 W
10	10 watt	±327.67 kW
100	100 watts	±3276.7 kW
1000	1000 watts	±32767 kW
Custom Values	PowerIntScale • 1W	±(PowerIntScale • 32767W)

Table 10: PowerIntScale Settings

You may also choose your own custom value for ***PowerIntScale*** including values that are not multiples of 10.

If ***PowerIntScale*** is set to auto-configure, then reading ***PowerIntScale*** will show the actual scale factor instead of 0.

To compute the actual power from integer power registers, use the following equation (note, there is no scaling for the floating-point power registers, which always report power in watts):

$$\mathit{ActualPower(W)} = \mathit{PowerRegister} \cdot \mathit{PowerIntScale}$$

PowerIntScale is used with the following registers: ***PowerSum***, ***PowerA***, ***PowerB***, ***PowerC***, ***PowerReacSum***, ***PowerReacA***, ***PowerReacB***, ***PowerReacC***, ***PowerAppSum***, ***PowerAppA***, ***PowerAppB***, ***PowerAppC***, ***Demand***, ***DemandMin***, ***DemandMax***, ***DemandApp***

Demand Configuration

DemPerMins, DemSubints (1610, 1611)

The variable ***DemPerMins*** sets the demand interval in minutes (default 15 minutes), and ***DemSubints*** sets the number of demand intervals (default 1). The time period of each subinterval is the demand interval divided by the number of subintervals. Setting ***DemSubints*** to 1 disables subinterval computations. The demand period cannot be longer than 12 hours (720 minutes), and a demand subinterval cannot be less than 1 minutes. The ***DemSubints*** can be set from 1 to 8.

An example configuration could use a demand period of 60 minutes with 4 subintervals. This would result in a subinterval period of fifteen minutes. Every fifteen minutes, the average power over the last hour would be computed and reported.

GainAdjustA, GainAdjustB, GainAdjustC (1612, 1613, 1614)

You may need to adjust the WattNode to match the results from a reference meter (such as the utility meter) or to correct for known current transformer errors. The ***GainAdjust*** registers effectively adjust the power, energy, and current calibration or registration for each phase.

The default values for the ***GainAdjust*** registers are 10,000, resulting in no adjustment. Setting the value to 10,200 increases all the power, energy, and current readings from the WattNode by 2% (10,200 / 10,000 = 102%). Setting the value to 9,800 decreases the readings by 2% (9,800 / 10,000 = 98%). The allowed range is from 5,000 to 20,000 (50% to 200%).

PhaseAdjustA, PhaseAdjustB, PhaseAdjustC (1615, 1616, 1617)

For maximum accuracy, there may be cases where you wish to compensate for the phase angle error of the current transformers you are using. The ***PhaseAdjust*** registers allow the phase angle to be adjusted on each phase by up to ±5 degrees in increments of one millidegree. For example, if your CT causes a phase lag of 0.6 degrees (or 36 minutes), you could correct for this by setting ***PhaseAdjustA***, ***B***, and ***C*** to +600, which adds a 600 millidegree or 0.6 degree phase lead. Use negative values to set a phase lag (to compensate for a phase lead in the CT). The default adjustment is zero.

CreepLimit (1618)

Creep refers to the situation where the wheel on an traditional electro-mechanical energy meter moves even though there is no power being consumed. The WattNode has no wheel, but still must address this situation. All electrical systems have some noise, which can cause small readings in the absence of any power consumption. In order to prevent these bogus readings due to noise, the WattNode forces the measured power and reactive power values to zero if these readings fall below a certain fraction of full-scale power. This also forces the associated energy values to zero for the measurement interval. This is performed independently for each measurement phase using the following equation.

$$MinimumPower = FullScalePower / CreepLimit$$

Any measured power or reactive power below *MinimumPower* is forced to zero. *FullScalePower* is defined as the nominal phase-to-neutral VAC (see **Specifications - Models**) multiplied by the full-scale or rated CT current.

Generally, the default value of 1500 (which sets the creep limit to 1/1500th of full-scale power) works fine. Sometime, however, in electrically noisy environments, you may see non-zero power readings when you are certain the power is zero. You can adjust the creep limit upward to eliminate this problem. For example, if you want to adjust the creep limit to 1/500th of full-scale (0.2%), just set ***CreepLimit*** to 500.

PhaseOffset (1619)

The WattNode cannot directly measure line-to-line voltages. In order to estimate these voltages, the WattNode must know the phase offset, which depends on the type of electrical service being measured.

PhaseOffset (degrees)	Service Type
0	Single-phase
120 (default)	Three-phase: 120/208, 230/400, 277/480, 347/600
180	Two-phase: 120/240

Table 11: PhaseOffset Values

Zeroing Registers

ZeroEnergy (1620)

All of the energy registers except those ending in "NR" (for non-resettable) can be reset to zero. Writing 1 to ***ZeroEnergy*** will simultaneously set all of the energy registers to zero. If a ***ConfigPasscode*** has been set, then you must unlock the WattNode before you can zero energy.

As a security measure, there are three energy registers—***EnergySumNR***, ***EnergyPosSumNR***, ***EnergyNegSumNR***—that can never be reset to zero.

ZeroDemand (1621)

The ***ZeroDemand*** register can be written with three values (or zero which does nothing). If a ***ConfigPasscode*** has been set, then you must unlock the WattNode before you can zero demand.

- ***1*** - Zero ***DemandMin*** and ***DemandMax*** registers.
- ***2*** - Zero ***Demand*** and ***DemandApp*** registers. Start a new demand interval.
- ***3*** - Zero ***DemandMin***, ***DemandMax***, ***Demand***, and ***DemandApp*** registers. Start a new demand interval.

Communication Registers

Most customers will never need these registers, but they can be useful for special situations. If you are using these registers to configure multiple WattNodes, you may want to use the broadcast address (0) so that all WattNodes will update together. This won't work for setting the address, because then multiple WattNodes will share the same address.

The communication configuration can be restored to factory defaults by switching all the DIP switches to the OFF position and leaving them there for 10 seconds, then setting them back to the desired address and baud rate.

ApplyComConfig (1651)

If any of the following communication configuration registers are changed, the new values will not take effect until "1234" (decimal) is written to this register. This makes it easier to configure multiple changes and have them all take effect together.

Reads of ApplyComConfig will return "1" if there are any pending changes, otherwise "0".

Address (1652)

This register can override the DIP switch address setting and also allows addresses to be assigned up to 247 (the DIP switches can only set addresses up to 127). Set this register back to zero to use the DIP switch setting.

BaudRate (1653)

This register overrides the DIP switch baud rate setting and allows the baud rate to be set to 38,400 baud if higher throughput is needed.

- ***0*** - Use DIP switch assigned baud rate
- ***4*** - 9,600 baud
- ***5*** - 19,200 baud
- ***6*** - 38,400 baud

ParityMode (1654)

The WattNode MODBUS defaults to no parity, eight data bits, and one stop bit, but even parity is also supported with this register.

- ***0*** - N81 (no parity, one stop bit)
- ***1*** - E81 (even parity, one stop bit)

ModbusMode (1655)

- ***0*** - RTU - This is the default MODBUS RTU binary protocol
- ***1*** - TCP-RTU - Emulates the MODBUS TCP/IP binary protocol

For some applications, it is desirable to convert the RS-485 to TPC/IP over Ethernet. The most common approaches are the following:

1) Use a MODBUS RTU RS-485 to MODBUS TPC/IP Ethernet gateway. These devices can translate the RTU packets into MODBUS TCP/IP packets and retransmit them over Ethernet. These work well, but are specialized devices and somewhat expensive.
2) Use an RS-485 to Ethernet serial device adapter. These are less expensive than the MODBUS gateways, but they do not convert from MODBUS RTU to MODBUS TCP/IP. Most software designed to receive MODBUS over an Ethernet connection will expect the MODBUS TCP/IP protocol. In order to make this work, the WattNode can switch to the MODBUS TCP/IP protocol, which is nearly identical to MODBUS RTU, but with a different header and no CRC bytes (TCP/IP has a built-in CRC).

For more information on MODBUS over TCP/IP, see "MODBUS Messaging on TCP/IP Implementation Guide - V1.0b". Implementing a system using MODBUS TCP/IP may be complex, so we recommend contacting Continental Control Systems for assistance.

Diagnostic Registers

SerialNumber (1701, 1702)

This is a 32 bit integer register containing the WattNode's serial number, as printed on the label.

UptimeSecs (1703, 1704)

This 32 bit dual register counts the number of seconds the WattNode has been running since the last power failure or WattNode reset. Resets can be caused by power brownouts or severe errors.

TotalSecs (1705, 1706)

This 32 but dual register counts the total seconds that this WattNode has operated since the original factory calibration.

Model (1707)

This register can be used to determine the WattNode model without looking at the label.

- ***201*** - WNC-3Y-208-MB
- ***202*** - WNC-3Y-400-MB
- ***203*** - WNC-3Y-480-MB
- ***204*** - WNC-3Y-600-MB
- ***205*** - WNC-3D-240-MB
- ***206*** - WNC-3D-400-MB
- ***207*** - WNC-3D-480-MB

Version (1708)

This register reports the firmware version of the MODBUS WattNode. The firmware is not field upgradable.

Options (1709)

This register indicates factory configured options. The ***Options*** register can only be set at the factory, but some of the options (TCP-RTU, EP, and 38K) can be emulated in the field using the **Communication Registers**.

- ***0*** - No options
- ***1*** - Option TCP-RTU: emulate the MODBUS TCP/IP protocol
- ***2*** - Option EP: default to even parity
- ***4*** - Option 38K: default to 38,400 baud
- ***8*** - Option 232: the WattNode has an RS-232 transceiver in place of the normal RS-485 transceiver. The RS-232 option does not support multidrop wiring.
- ***16*** - Option TTL: the WattNode has a 5V TTL transceiver in place of the normal RS-485 transceiver. The TTL option does support multidrop wiring, so it is possible to connect multiple WattNodes to one MODBUS master device.

Note, if multiple options are selected, then the bit values add together. For example, if you order Option 38K (4) with Option TTL (16), the ***Options*** register will read back a value of 20.

The communication options TCP-RTU, EP, and 38K can be overridden in the field using the **Communication Registers**. If you wish to revert to the factory configured options, set all the DIP switches to the OFF position for ten seconds to restore all communication configuration registers to their factory defaults—including any selected options.

PowerFailCount (1711)

This counts (up to 32767) the number of times power has been cycled on this WattNode.

Communication Error Counts

The following four registers report communication error counts. Each register counts up to 32767 and stops. All four of these registers are reset to zero whenever power is cycled or by writing zero to any of them.

CrcErrorCount (1712)

This counts (up to 32767) the number of MODBUS packets with an invalid CRC (cyclic redundancy check).

FrameErrorCount (1713)

This counts (up to 32767) the number of MODBUS packets with framing errors. A framing error can indicate bad baud rate, bad parity setting, RS-485 noise or interference, or an RS-485 bus collision.

PacketErrorCount (1714)

This counts (up to 32767) the number of MODBUS packets that could not be parsed.

OverrunCount (1715)

This counts (up to 32767) the number of times the MODBUS input buffer has been overrun. The buffer is 256 bytes and normal requests are less than 80 bytes, so an overrun normally indicates non-MODBUS traffic on the RS-485 bus or severe noise on the bus.

Error Codes

ErrorStatus (1710)

ErrorStatus1 - ErrorStatus8 (1716 - 1723)

The ErrorStatus registers hold queues of the most recent eight errors or status notifications.

ErrorStatus allows access to the eight most recent errors from a single MODBUS register. Each time you read it, you'll get another value (starting with the oldest). When there are no more errors, ***ErrorStatus*** will report 0. The ***ErrorStatus*** values are preserved across power failures. ***ErrorStatus*** is generally best used with unattended data logging, since each error will only be reported once.

ErrorStatus1 through ***ErrorStatus8*** also list the eight most recent errors, but with a few differences. ***ErrorStatus1*** lists the most recent error or status, while ***ErrorStatus8*** lists the oldest. Reading these registers won't change the reported values for ***ErrorStatus1*** through ***ErrorStatus8***, so they can be read repeatedly without clearing the values. ***ErrorStatus1*** through ***ErrorStatus8*** can all be cleared by writing 0 to any of them. They are **not** preserved across power failures. ***ErrorStatus1*** through ***ErrorStatus8*** are generally best used when a person will be looking at the values in real time, because they provide a visual history of recent errors and events and will not be cleared when they are read.

The following lists all the error and status code values. In most cases, you should contact technical support for any of these marked with "ERROR".

- **0**: No error or status messages
- **1-57, 60-61, 72-73**: ERROR: Internal firmware error. Contact technical support.
- **58**: WARNING: RS-485 overrun (received characters lost).
- **59**: ERROR: Non-volatile data lost: energy, peak demand, etc.
- **62-66**: WARNING: Internal energy measurement overflow
- **67**: ERROR: Calibration data lost. WattNode will not function until it is recalibrated.
- **68**: ERROR: Configuration data lost (CtAmps, etc.)
- **69**: WARNING: Could not measure AC line frequency, may indicate high noise condition.
- **70, 74**: ERROR: Non-volatile memory failure: energy, demand, etc. will be lost when power fails.
- **75-77**: ERROR: Internal measurement error.
- **78-83**: WARNING: Measured high AC line voltage. Sustained high voltage may damage the WattNode.
- **84**: INFO: ***EnergyA*** register overflowed 100 gigawatt-hours, reset to 0.
- **85**: INFO: ***EnergyB*** register overflowed 100 gigawatt-hours, reset to 0.
- **86**: INFO: ***EnergyC*** register overflowed 100 gigawatt-hours, reset to 0.
- **87**: INFO: ***EnergySum*** register overflowed 100 gigawatt-hours, reset to 0.
- **88**: INFO: ***EnergySumNR*** register overflowed 100 gigawatt-hours, reset to 0.
- **89**: INFO: ***EnergyReacA*** register overflowed 100 gigawatt-hours, reset to 0.
- **90**: INFO: ***EnergyReacB*** register overflowed 100 gigawatt-hours, reset to 0.
- **91**: INFO: ***EnergyReacC*** register overflowed 100 gigawatt-hours, reset to 0.
- **92**: INFO: ***EnergyReacSum*** register overflowed 100 gigawatt-hours, reset to 0.
- **93**: INFO: ***EnergyPosA*** register overflowed 100 gigawatt-hours, reset to 0.
- **94**: INFO: ***EnergyPosB*** register overflowed 100 gigawatt-hours, reset to 0.
- **95**: INFO: ***EnergyPosC*** register overflowed 100 gigawatt-hours, reset to 0.
- **96**: INFO: ***EnergyPosSum*** register overflowed 100 gigawatt-hours, reset to 0.
- **97**: INFO: ***EnergyPosSumNR*** register overflowed 100 gigawatt-hours, reset to 0.
- **98**: INFO: ***EnergyNegA*** register overflowed 100 gigawatt-hours, reset to 0.
- **99**: INFO: ***EnergyNegB*** register overflowed 100 gigawatt-hours, reset to 0.
- **100**: INFO: ***EnergyNegC*** register overflowed 100 gigawatt-hours, reset to 0.
- **101**: INFO: ***EnergyNegSum*** register overflowed 100 gigawatt-hours, reset to 0.

- **102**: INFO: ***EnergyNegSumNR*** register overflowed 100 gigawatt-hours, reset to 0.
- **103**: INFO: ***EnergyAppA*** register overflowed 100 gigawatt-hours, reset to 0.
- **104**: INFO: ***EnergyAppB*** register overflowed 100 gigawatt-hours, reset to 0.
- **105**: INFO: ***EnergyAppC*** register overflowed 100 gigawatt-hours, reset to 0.
- **106**: INFO: ***EnergyAppSum*** register overflowed 100 gigawatt-hours, reset to 0.
- **109**: WARNING: UART overrun. The WattNode lost incoming MODBUS bytes.
- **200**: WARNING: Configuration register cannot be changed without entering ***ConfigPasscode*** first.
- **201**: WARNING: Calibration update error. DIP switches not set correctly.
- **204**: WARNING: Calibration update error. Invalid calibration passcode.
- **210**: WARNING: Must enter calibration passcode before changing calibration registers.
- **202**: WARNING: ***ConfigPasscode*** update failed because second write (verify) did not match the first write.
- **203**: WARNING: A write to a dual register (typically ***ConfigPasscode***) was aborted.
- **205**: WARNING: Invalid ***ConfigPasscode*** entered.
- **206**: WARNING: Invalid MODBUS register address specified.
- **207**: WARNING: Invalid MODBUS register data value specified.
- **208**: WARNING: Invalid configuration register value specified.
- **209**: INFO: ***ConfigPasscode*** unlock attempt rejected because it was within five seconds of a previous failed attempt.
- **211**: WARNING: Invalid MODBUS write length specified.
- **212**: WARNING: Invalid MODBUS function code specified.
- **220**: INFO: Factory reset completed. This should only occur at the factory.
- **221**: INFO: Factory FRAM test passed. This should only occur at the factory.
- **222**: ERROR: Factory FRAM test failed. This should only occur at the factory.
- **236-241**: ERROR: Internal firmware error. Contact technical support.
- **242**: WARNING: MODBUS collision. WattNode received data bytes after receiving a command (but before sending the response). This may indicate a MODBUS address conflict or electrical interference.
- **243**: WARNING: Invalid MODBUS message length.
- **244**: WARNING: Timeout while receiving a MODBUS TCP header. This only applies when in MODBUS TCP-485 mode.
- **245**: WARNING: Invalid length in the MODBUS TCP header. This only applies when in MODBUS TCP-485 mode.
- **246**: WARNING: MODBUS collision. WattNode received data bytes after receiving a command (but before sending the response). This may indicate a MODBUS address conflict or electrical interference.
- **247**: WARNING: RS-485 parity error. Generally caused by baud rate mismatch, parity mode mismatch, or electrical interference.
- **248**: WARNING: RS-485 bus contention during transmit. Generally caused by two or more WattNodes with duplicate MODBUS addresses.
- **249**: WARNING: Duplicate MODBUS address detected.
- **250**: WARNING: MODBUS receiver overrun. This is generally caused by non-MODBUS data on the bus or packets longer than 256 bytes.
- **251**: WARNING: RS-485 receiver error. Generally caused by baud rate mismatch, parity mode mismatch, or electrical interference.

- **252-253**: WARNING: Short MODBUS packet detected (less than four bytes). MODBUS RTU uses a brief pause (3.5 byte periods) to indicate the end of a packet, so any break in the stream of bytes can cause this.
- **254**: WARNING: False MODBUS start bit. This generally indicates electrical noise, or inadequate termination or biasing. See **Termination** and **Biasing** sections under **Connecting MODBUS Outputs** for more information.
- **255**: WARNING: Invalid MODBUS packet cyclic redundancy check (CRC). This generally indicates electrical noise on the RS-485 bus.

Maintenance and Repair

The WattNode requires no routine maintenance. There are no fuses or batteries in the WattNode. It contains no user serviceable or replaceable parts. There are no diagnostic tests that can be performed by the user, other than checking for errors via the MODBUS interface and with the status LEDs.

The WattNode should not normally need to be cleaned, but if cleaning is desired, power must be disconnected first and a dry cloth or brush should be used.

The WattNode is not user serviceable. In the event of any failure, the WattNode must be returned for service. In the case of a new installation, follow the instructions in sections **Installation LED Diagnostics** and **Measurement Troubleshooting** before returning the WattNode for service, to ensure that the problem is not connection related.

Specifications

Models

Model	Nominal VAC phase-to-neutral	Nominal VAC phase-to-phase	Phases	Wires
WNC-3Y-208-MB	120	208–240	3	4
WNC-3Y-400-MB	230	400	3	4
WNC-3Y-480-MB	277	480	3	4
WNC-3Y-600-MB	347	600	3	4
WNC-3D-240-MB	120*	208–240	3	3–4
WNC-3D-400-MB	230*	400	3	3–4
WNC-3D-480-MB	277*	480	3	3–4

Table 12: WattNode Models

**Note: the delta models have an optional neutral connection that may be used for measuring wye circuits. The delta WattNode models use the phase A and phase B connections to power the WattNode.*

Current Transformers

The WattNode uses CTs with built-in burden resistors generating 0.333 VAC at rated AC current. The maximum input current rating is dependent on the CT frame size (see the tables below). Exceeding the maximum input current rating may damage CTs.

The WattNode should only be used with UL recognized current transformers, which are available from Continental Control Systems. Using non-approved transformers will invalidate the WattNode's UL listing. The following sections list approved UL recognized current transformers.

Split-Core CTs

Also called "opening" current transformers. These are UL recognized under UL file number E96927: CTS-0750-xxx, CTS-1250-xxx, CTS-2000-xxx, where **xxx** indicates the full scale current rating between 0005 and 1500 amps.

The accuracy and phase angle of the split-core CTs are specified from 10% to 130% of rated current. These CTs do not measure DC current and the accuracy will be degraded in the presence of DC current. Some low current split-core CTs have unspecified phase angle errors. The following table shows the available split-core CTs. The CT suffix **xxx** is the rated current.

Model	Inside Diameter	Rated Amps	Accuracy / Phase Angle	Maximum Amps
CTS-0750-xxx	0.75" (19.0mm)	5, 15, 20, 30, 50	±1% / not spec.	200
CTS-0750-xxx	0.75" (19.0mm)	70, 100, 150	±1% / <2°	200
CTS-1250-xxx	1.25" (31.7mm)	70, 100	±1% / not spec.	600
CTS-1250-xxx	1.25" (31.7mm)	150, 200, 250, 300, 400, 600	±1% / <2°	600
CTS-2000-xxx	2.00" (50.8mm)	600, 800, 1000, 1200, 1500	±1% / <2°	1500

Table 13: Split-core CTs

Split-Core Bus Bar CTs

Also called "opening" current transformers. This series of CTs is referred to as "bus bar" CTs because they are available in larger and custom sizes appropriate for use with bus bars or multiple large conductors. These are UL recognized under UL file number E325972:

CTB-wwwXhhh-xxx, where **www** and **hhh** indicate the width and height in inches, and **xxx** indicates the full scale current rating.

The accuracy of the split-core bus bar CTs is specified from 10% to 100% of rated current. The phase angle is specified at 50% of rated current. These CTs do not measure DC current and the accuracy will be degraded in the presence of DC current. The following table shows the available split-core bus bar CTs.

Model	Opening	Rated Amps	Accuracy / Phase Angle	Maximum Amps
CTB-1.5X3.5-0600	1.5" x 3.5" (38.1mm x 88.9mm)	600	±1.5% / <1.5°	750
CTB-4.0X4.0-0800	4.0" x 4.0" (101.6mm x 101.6mm)	800	±1.5% / <1.5°	1000
CTB-4.0X4.0-1200	4.0" x 4.0" (101.6mm x 101.6mm)	1200	±1.5% / <1.5°	1500
CTB-4.0X4.0-2000	4.0" x 4.0" (101.6mm x 101.6mm)	2000	±1.5% / <1.5°	2500
CTB-4.5X4.0-3000	4.5" x 4.0" (114.3mm x 101.6mm)	3000	±1.5% / <1.5°	3750
CTB-wwwXhhh-xxxx	Custom (www by hhh inches)	xxxx	±1.5% / <1.5°	4000

Table 14: Split-core Bus Bar CTs

Solid-Core CTs

Also called "toroid" or "donut" current transformers. These are UL recognized under UL file number E96927: CTT-0750-100N, CTT-1250-400N, CTT-0300-030N, CTT-0500-060N, CTT-1000-200N, CTT-0300-005N, CTT-0300-015N, CTT-0500-050N, CTT-0500-030N, CTT-0500-015N, CTT-0750-070N, CTT-0750-050N, CTT-0750-030N, CTT-1000-150N, CTT-1000-100N, CTT-1000-070N, CTT-1000-050N, CTT-1250-300N, CTT-1250-250N, CTT-1250-200N, CTT-1250-150N, CTT-1250-100N, CTT-1250-070N.

The accuracy of the solid-core CTs is specified from 10% to 130% of rated current. The phase angle error is specified at 50% of rated current. These CTs do not measure DC current and the accuracy will be degraded in the presence of DC current. The following table shows the available solid-core CTs. The CT suffix **xxx** is the rated current. The "N" at the end of the part number indicates a nickel core material, which is the only core material available for our solid-core CTs.

Model	Inside Diameter	Rated Amps	Accuracy / Phase Angle	Maximum Amps
CTT-0300-xxxN	0.30" (7.6mm)	5, 15, 20, 30	±1% / <1°	30
CTT-0500-xxxN	0.50" (12.7mm)	15, 20, 30, 50, 60	±1% / <1°	60
CTT-0750-xxxN	0.75" (19.0mm)	30, 50, 70, 100	±1% / <1°	100
CTT-1000-xxxN	1.00" (25.4mm)	50, 70, 100, 150, 200	±1% / <1°	200
CTT-1250-xxxN	1.25" (31.7mm)	70, 100, 150, 200, 250, 300, 400	±1% / <1°	400

Table 15: Solid-core CTs

Measurement

Creep Limit: (Default) 0.067% (1/1500th) of full-scale. Whenever the power or reactive power for a phase drops below the creep limit, the power or reactive power for the phase will be forced to zero. Also, if the line voltage for a phase drops below 20% of nominal VAC, all outputs for the phase will be forced to zero. These limits prevent spurious readings due to measurement noise. The creep limit can be customized (see ***CreepLimit (1618)*** in **Configuration Registers**).

Update Rate: 1.0 second. Internally, all measurements are performed at this rate.

Start-Up Time: Approximately 1.0 second. The WattNode starts measuring 50-100 milliseconds after AC power is applied, but requires a full 1.0 second measurement cycle before it starts reporting data. The WattNode does not respond to MODBUS packets during this start-up time.

Over-Voltage Limit: 125% of nominal VAC. If the line voltage for one or more phases exceeds this limit, the status LEDs for these phases will flash alternating red-green as a warning. Extended over-voltage operation can damage the WattNode and void the warranty. See **Line Voltage Too High** in the **Installation LED Diagnostics** section.

Over-Current Limit: 120% of rated current. Exceeding 120% of rated current will not harm the WattNode but the current and power will not be measured accurately.

Accuracy

The following accuracy specifications do not include errors caused by the current transformers.

Condition 1 - Normal Operation

Line voltage: 80% - 115% of nominal

Power factor: 1.0

Frequency: 48 - 62 Hz

Ambient Temperature: 25°C

Current: 5% - 100% of rated current

Accuracy: ±0.5% of reading

Condition 2 - Low Current

All conditions the same as Condition 1 except:

Current: 1% - 5% of rated current

Accuracy: ±1.0% of reading

Condition 3 – Very Low Current

All conditions the same as Condition 1 except:

Current: 0.2% - 1% of rated current

Accuracy: ±3.0% of reading

Condition 4 - High Current

All conditions the same as Condition 1 except:

Current: 100% - 120% of rated current

Accuracy: ±1.0% of reading

Condition 5 - Low Power Factor

All conditions the same as Condition 1 except:

Power factor: 0.5 (±60 degree phase shift between current and voltage)

Additional Error: ±0.5% of reading

Condition 6 - Temperature Variation

All conditions the same as Condition 1 except:

Ambient Temperature: -30°C to +55°C

Accuracy: ±0.5% of reading

Electrical

Power Consumption: The following typical power consumption values are with all three phases powered. The WattNode's power supply draws most of the total power consumed, while the measurement circuitry draws 1-10% of the total (6-96 milliwatts per phase, depending on the model). Due to the design of the power supply, the WattNode draws more power at 50Hz.

Model	Active Power at Nominal VAC, 60Hz	Active Power at Nominal VAC, 50Hz	Typical Power Factor	Rated Power*
WNC-3Y-208-MB	1.5W	1.8W	0.79	3W
WNC-3Y-400-MB	1.6W	1.8W	0.73	3W
WNC-3Y-480-MB	1.6W	2.0W	0.69	4W
WNC-3Y-600-MB	1.0W	1.3W	0.76	3W
WNC-3D-240-MB	1.2W	1.5W	0.70	4W
WNC-3D-400-MB	1.1W	1.4W	0.67	3W
WNC-3D-480-MB	1.2W	1.6W	0.70	4W

Table 16: WattNode Power Consumption

**Note: This is the maximum rated power at 115% of nominal VAC at 50Hz. This is the same as the rated power that appears on the front label of the WattNode.*

Maximum Operating Voltage Range: -20% to +15% of nominal

Operating Frequencies: 50/60 Hz

Measurement Category: CAT III: Measurement category III is for measurements performed in the building installation. Examples are measurements on distribution boards, circuit-breakers, wiring, including cables, bus-bars, junction boxes, switches, socket-outlets in the fixed installation, and equipment for industrial use and some other equipment, for example, stationary motors with permanent connection to the fixed installation.

The line voltage measurement terminals on the WattNode are rated for the following CAT III voltages (these ratings also appear on the WattNode front label):

Model	CAT III Voltage Rating
WNC-3Y-208-MB, WNC-3D-240-MB	240 VAC
WNC-3Y-400-MB, WNC-3D-400-MB	400 VAC
WNC-3Y-480-MB, WNC-3D-480-MB	480 VAC
WNC-3Y-600-MB	600 VAC

Table 17: WattNode CAT III Ratings

Current Transformer Inputs:

Nominal Input Voltage: 0.333 VAC RMS

Absolute Maximum Input Voltage: 5.0 VAC RMS

Input Impedance at 50/60 Hz: 23kΩ

Recommended CT Wire Length: 2.4m (8 feet)

MODBUS Communication

Protocol: MODBUS RTU (binary)

Baud Rates: 9,600 and 19,200

Duplex: Half (two-wire plus common)

Polarity Auto-detect: will automatically correct swapped A- and B+ terminals provided network has at least 200 millivolt bias between A- and B+.

Parity: N81 (no parity, eight data bits, one stop bit)

MODBUS Buffer: 256 bytes

Response Time: 5 - 300 milliseconds

EIA RS-485 Interface:

- **Driver Output Voltage (Open Circuit):** ±6 V maximum
- **Driver Output Voltage (54Ω load):** ±1.5 V minimum
- **Driver Output Current (54Ω load):** ±60 mA typical
- **Driver Output Rise Time (54Ω || 50pF load):** 900nS typical
- **Receiver Common-Mode Voltage Range:** -7 V to +12 V maximum
- **Receiver Sensitivity:** ±200 mV
- **Receiver Bus Load:** 1/8 unit load (up to 256 WattNodes per subnet)
- **Receiver Failsafe Modes:** bus open, bus shorted, bus idle

Certifications

Safety: UL 61010-1; CAN/CSA-C22.2 No. 61010-1-04; IEC 61010-1

Emissions: FCC Part 15, Class B; EN 55022: 1994, Class B

Environmental

Operating Temperature: -30°C to +55°C (-22°F to 131°F)

Altitude: Up to 2000 m (6560 ft)

Operating Humidity: 5 to 90% relative humidity (RH) up to 40°C, decreasing linearly to 50% RH at 55°C.

Pollution: POLLUTION DEGREE 2 - Normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected.

Indoor Use: Suitable for indoor use.

Outdoor Use: Suitable for outdoor use when mounted inside an electrical enclosure (Hammond Mfg., Type EJ Series) that is rated NEMA 3R or 4.

Mechanical

Enclosure: High impact, ABS plastic

- **Flame Resistance Rating:** 94V-0, IEC FV-0
- **Size:** 143mm × 85mm × 38mm (5.63” × 3.34” × 1.5”)
- **Weight:** 305 gm (10.8 oz)

Connectors: Euroblock style pluggable terminal blocks

- **Green:** 22 to 12 AWG (1.0mm - 3.2mm), 600 V
- **Black:** 22 to 12 AWG (1.0mm - 3.2mm), 300 V

Warranty

All products sold by Continental Control Systems, LLC (CCS) are guaranteed against defects in material and workmanship for a period of three years from the date of shipment. CCS's responsibility is limited to repair, replacement, or refund, any of which may be selected by CCS at its sole discretion. CCS reserves the right to substitute functionally equivalent new or serviceable used parts.

This warranty covers only defects arising under normal use and does not include malfunctions or failures resulting from: misuse, neglect, improper application, improper installation, water damage, acts of nature, lightning, or repairs by anyone other than CCS.

Except as set forth herein, CCS makes no warranties, expressed or implied, and CCS disclaims and negates all other warranties, including without limitation, implied warranties of merchantability and fitness for a particular purpose. Some states or jurisdictions do not allow limitations on implied warranties, so these limitations may not apply to you.

In no event shall CCS be liable for any indirect, special, incidental, or consequential damages. Some states or jurisdictions do not allow the exclusion or limitation of incidental or consequential damages, so the above exclusion or limitation may not apply to you.