

# *WATTNODE<sup>®</sup> BACNET<sup>®</sup>*

## Installation and Operation Manual

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

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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.

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## Overview

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Congratulations on your purchase of the WattNode® BACnet® watt/watt-hour transducer (meter). The WattNode meter offers precision energy and power measurements in a compact package. It 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 meter communicates on an EIA RS-485 two-wire bus using the BACnet 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 BACnet meter 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

One WattNode BACnet meter can measure up to three different “single-phase two-wire with neutral” branch circuits from the same service by separately monitoring the phase A, B, and C values. If necessary, you can use different CTs on the different circuits.

## Communication

The WattNode meter uses a half-duplex EIA RS-485 interface for communication. The standard baud rates are 9,600, 19,200, 38,400, and 76,800 baud. The meter uses the industry standard BACnet MS/TP communication protocol, allowing up to 64 devices per RS-485 subnet.

## Diagnostic LEDs

The meter 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 and red for negative power. Other conditions are signaled with different LED patterns. See [Installation LED Diagnostics \(p. 22\)](#) for details.

The BACnet WattNode meter includes a communication LED that lights green, yellow, or red to diagnose the RS-485 network. See [BACnet Communication Diagnostics \(p. 28\)](#) for details.

## Options

The WattNode BACnet meter can be ordered with options. For more details and documentation, see article [WattNode BACnet - Options](#) on our website.

### General Options

- **Option CT=xxx** - Pre-assign xxx as the **CtAmpsA, B, and C** values.
- **Option CT=xxx/yyy/zzz** - Pre-assign xxx to **CtAmpsA**, yyy to **CtAmpsB**, and zzz to **CtAmpsC**.

## Current Transformers

The WattNode meter uses solid-core (toroidal), split-core (opening), and bus-bar style current transformers (CTs) with a full-scale voltage output of 0.33333 Vac. Split-core and bus-bar CTs are easier to install without disconnecting the circuit being measured. Solid-core CTs are more compact, generally more accurate, and less expensive, but installation requires that you disconnect the circuit to install the CTs.

## Additional Literature

These additional documents are available on the Continental Control Systems, LLC website or BACnet.org website.

- WattNode BACnet - Quick Install Guide
- WattNode BACnet Register List (Excel format): [WNC-BACnet-Register-List-V1\\_0.xls](#)
- Continental Control Systems, LLC website
  - [http://www.ccontrols.com/w/WattNode\\_BACnet](http://www.ccontrols.com/w/WattNode_BACnet) - main page.
  - [http://www.ccontrols.com/w/Category:WattNode\\_BACnet](http://www.ccontrols.com/w/Category:WattNode_BACnet) - support articles.
- <http://www.bacnet.org>
  - BACnet Standard: ASHRAE/ANSI Standard 135-2010

## Front Label

This section describes the connections, information, and symbols on the front label.

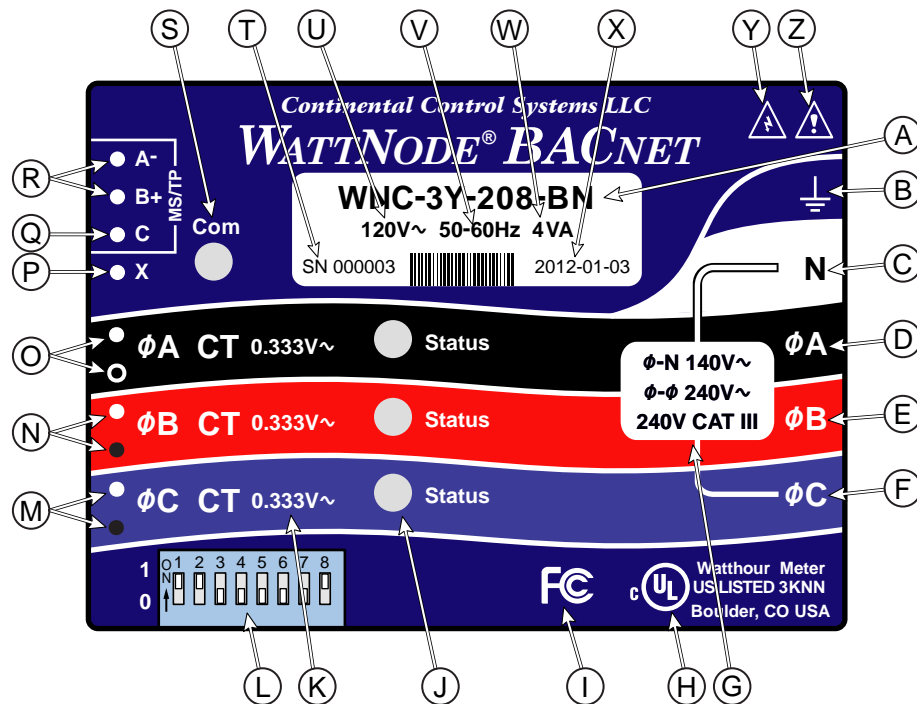





Figure 1: Front Label Diagram

**A: WattNode model number.** The “WNC” indicates a third generation WattNode meter. The “3” indicates a three-phase model. The “Y” or “D” indicates wye or delta models, although delta models can measure wye circuits (the difference is in the power supply). The “208” (or other value) indicates the nominal line-to-line voltage. Finally, the “BN” indicates BACnet output.

**B: Functional ground.** This terminal should be connected to earth ground if possible. It is not required for safety grounding, but ensures maximum meter accuracy.

- C: Neutral.** This terminal “N” should be connected to neutral when available.
- D, E, F: Line voltage inputs.** These terminals connect to the  $\phi A$  (phase A),  $\phi B$  (phase B), and  $\phi C$  (phase C) electric mains. On wye models the meter is powered from the  $\phi A$  and N terminals. On delta models, the meter is powered from the  $\phi A$  and  $\phi B$  terminals.
- G: Line voltage measurement ratings.** This block lists the nominal line-to-neutral “ $\phi-N 120V\sim$ ” voltage, line-to-line “ $\phi-\phi 240V\sim$ ” voltage, and the rated measurement voltage and category “240V CAT III” for this WattNode model. See the [Specifications \(p. 49\)](#) 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 meter complies with part 15 of the FCC rules.
- J: Status LEDs.** These are status LEDs used to verify and diagnose meter operation. See [Installation LED Diagnostics \(p. 22\)](#) for details.
- K: Current transformer (CT) voltage rating.** These markings “0.333V $\sim$ ” indicate that the meter must be used with CTs that generate a full-scale output of 0.333 Vac (333 millivolts).
- L: DIP switch.** This DIP switch block is used to set the BACnet MAC (network) address and baud rate. See [Setting the BACnet Address \(p. 19\)](#).
- M, N, O: Current transformer (CT) inputs.** These indicate CT screw terminals. Note the white and black circles at the left edge of the label: these indicate the color of the CT wire that should be inserted into the corresponding screw terminal. The terminals marked with black circles are connected together internally.
- P: Auxiliary output terminal.** This screw terminal is used for the X terminal options.
- Q: BACnet common terminal.** This is the common or ground terminal for BACnet EIA RS-485 communication wiring. It is also the common for the X terminal options if they are installed.
- R: BACnet signal terminals.** These are the RS-485 A- and B+ signals (half-duplex, two-wire). There are several names for these terminals:
- **Inverting pin:** A-, A, -, TxD-, RxD-, D0, and on rare devices “B”
  - **Non-inverting pin:** B+, B, +, TxD+, RxD+, D1, and on rare devices “A”
- S: Communication status.** This LED indicates communication status. See [BACnet Communication Diagnostics \(p. 28\)](#) for details.
- T: Serial number.** This shows meter serial number and options if any are selected. The barcode contains the serial number in Code 128C format.
- U: Mains supply rated voltage.** This is the rated supply voltage for this model. The V $\sim$  indicates AC voltage. For wye models, this voltage should appear between the N and  $\phi A$  terminals. For delta models, this voltage should appear between the  $\phi A$  and  $\phi B$  terminals.
- V: Mains frequencies.** This indicates the rated mains frequencies for the meter.
- W: Maximum rated volt-amps.** This is the maximum apparent power consumption (volt-amps) for this model.
- X: Manufacture date.** This is the date of manufacture for this WattNode meter.
- Y: Caution, risk of electrical shock.** This symbol indicates that there is a risk of electric shock when installing and operating the meter if the installation instructions are not followed correctly.
- Z: Attention - consult Manual.** This symbol indicates that there can be danger when installing and operating the meter 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.
	CE Marking	Complies with the regulations of the European Union for Product Safety and Electro-Magnetic Compatibility. <ul style="list-style-type: none"><li>• Low Voltage Directive – EN 61010-1: 2001</li><li>• EMC Directive – EN 61327: 1997 + A1/1998 + A2/2001</li></ul>



# Installation

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## Precautions



### DANGER – HAZARDOUS VOLTAGES

**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.

Always adhere to the following checklist:

- 1) Only qualified personnel or **licensed electricians** should install the WattNode meter. The mains voltages of 120 Vac to 600 Vac can be lethal!
- 2) Follow all applicable local and national electrical and safety codes.
- 3) Install the meter in an electrical enclosure (panel or junction box) or in a limited access electrical room.
- 4) Verify that circuit voltages and currents are within the proper range for the meter model.
- 5) 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 (ratio) CTs such as 1 amp or 5 amp output CTs: they will destroy the meter and may create a shock hazard.** See [Current Transformers \(p. 54\)](#) for CT maximum input current ratings.
- 6) Ensure that the line voltage inputs to the meter are protected by fuses or circuit breakers (not needed for the neutral wire). See [Circuit Protection \(p. 18\)](#) for details.
- 7) Equipment must be disconnected from the HAZARDOUS LIVE voltages before access.
- 8) The terminal block screws are **not** insulated. Do not contact metal tools to the screw terminals if the circuit is live!
- 9) 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.
- 10) Before applying power, check that all the wires are securely installed by tugging on each wire.
- 11) Do not install the meter where it may be exposed to temperatures below  $-30^{\circ}\text{C}$  or above  $55^{\circ}\text{C}$ , excessive moisture, dust, salt spray, or other contamination. The meter requires an environment no worse than pollution degree 2 (normally only non-conductive pollution; occasionally, a temporary conductivity caused by condensation must be expected).
- 12) Do not drill mounting holes using the meter as a guide; the drill chuck can damage the screw terminals and metal shavings can fall into the connectors, causing an arc risk.
- 13) If the meter is installed incorrectly, the safety protections may be impaired.

## Electrical Service Types

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

Model	Type	Line-to-Neutral	Line-to-Line	Electrical Service Types
WNC-3Y-208-BN	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-BN	Wye	230 Vac	400 Vac	1 Phase 2 Wire 230V with neutral 3 Phase 4 Wire Wye 230V/400V with neutral
WNC-3Y-480-BN	Wye	277 Vac	480 Vac	3 Phase 4 Wire Wye 277V/480V with neutral 1 Phase 2 Wire 277V with neutral
WNC-3Y-600-BN	Wye	347 Vac	600 Vac	3 Phase 4 Wire Wye 347V/600V with neutral
WNC-3D-240-BN	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-BN	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-BN	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 conductors are neutral and line. For these models, the meter is powered from the **N** and  $\phi$ **A** terminals.

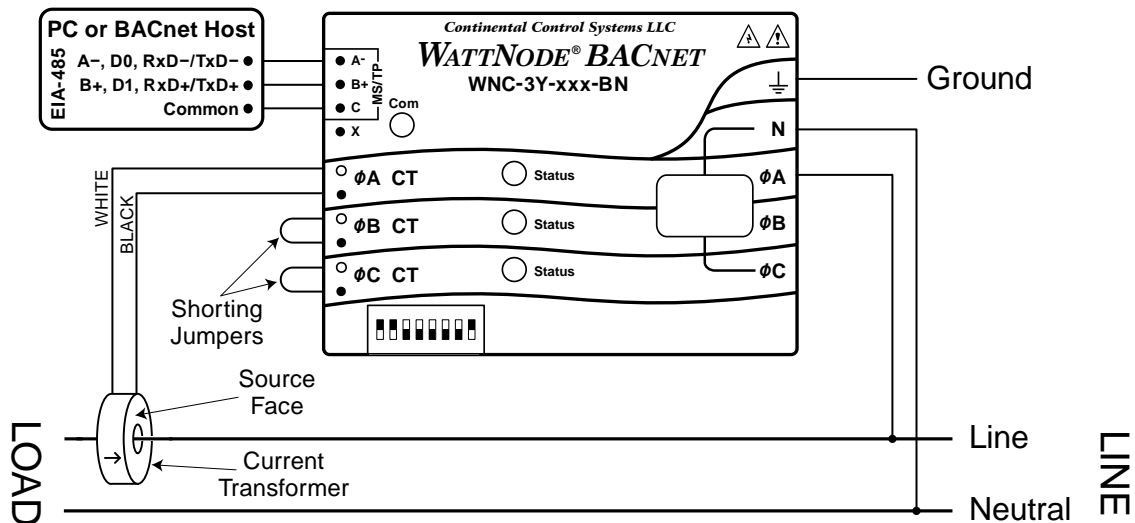


Figure 2: Single-Phase Two-Wire Connection

### 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-BN
230 Vac	WNC-3Y-400-BN
277 Vac	WNC-3Y-480-BN

### Single-Phase Three-Wire (Mid-Point Neutral)

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

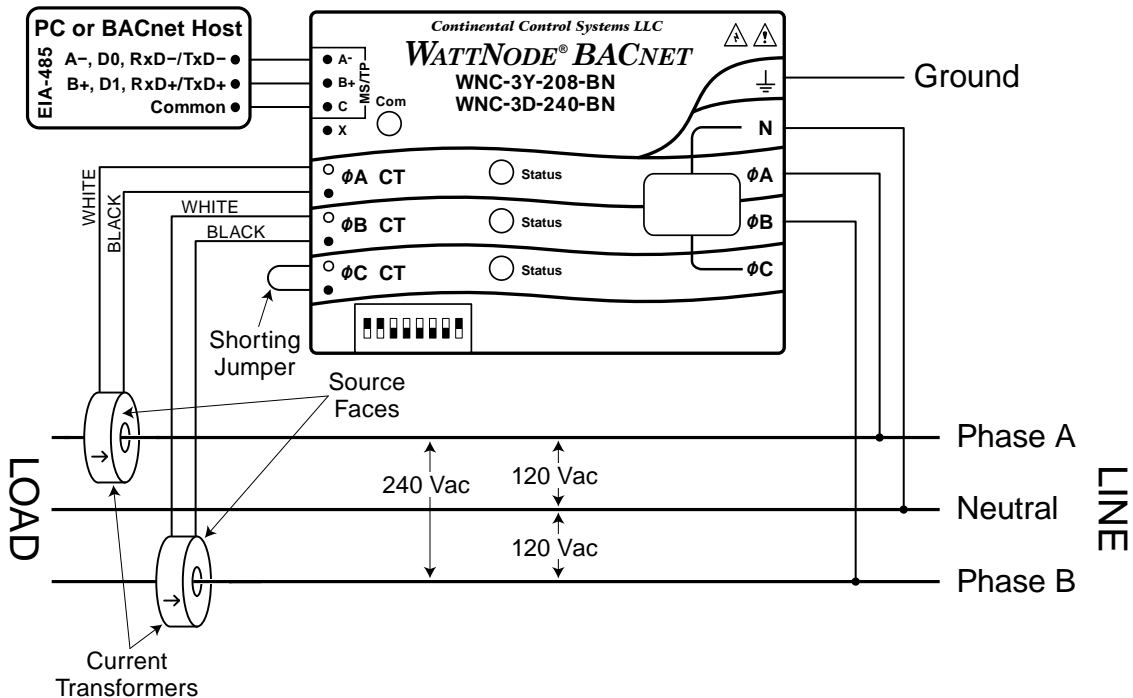


Figure 3: Single-Phase Three-Wire Connection

### 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 WNC-3D-240-BN (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-BN (see [Single-Phase Two-Wire with Neutral](#) above).

Meter Power Source	WattNode Model
<b>N</b> and <b>φA</b> (Neutral and Phase A)	WNC-3Y-208-BN
<b>φA</b> and <b>φB</b> (Phase A and Phase B)	WNC-3D-240-BN

## Single-Phase Two-Wire without Neutral

This is seen in residential and commercial service with 208 to 240 Vac for large appliances. The two conductors have AC waveforms 120° or 180° out of phase. Neutral is not used. For this configuration, the meter is powered from the  $\phi A$  and  $\phi B$  (phase A and phase B) terminals.

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

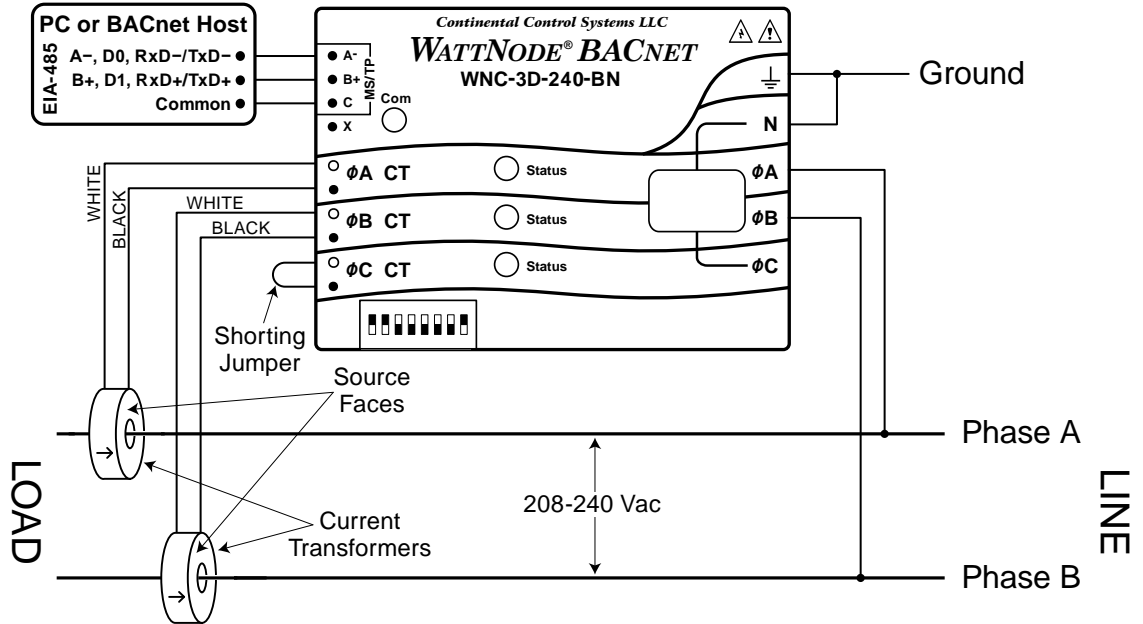


Figure 4: Single-Phase Two-Wire without Neutral Connection

### Recommended WattNode Model

This configuration is normally measured with the following WattNode model.

Line-to-Line Voltage	WattNode Model
208 - 240 Vac	WNC-3D-240-BN

If neutral is available, you may also use the WNC-3Y-208-BN model. If you use the WNC-3Y-208-BN, you will need to hook up the meter as shown in section **Single-Phase Three-Wire (Mid-Point Neutral)** and connect neutral. You will need two CTs.

If one of the conductors (phase A or phase B) is grounded, see **Grounded Leg Service** below for recommendations.

## Three-Phase Four-Wire Wye

This is typically seen in commercial and industrial environments. The conductors are neutral and three power lines with AC waveforms shifted 120° between phases. The line voltage conductors may be connected to the  $\phi A$ ,  $\phi B$ , and  $\phi C$  terminals in any order, **so long as the CTs are connected to matching phases**. It is important that you connect **N** (neutral) for accurate measurements. For wye “-3Y” models, the meter is powered from the **N** and  $\phi A$  terminals.

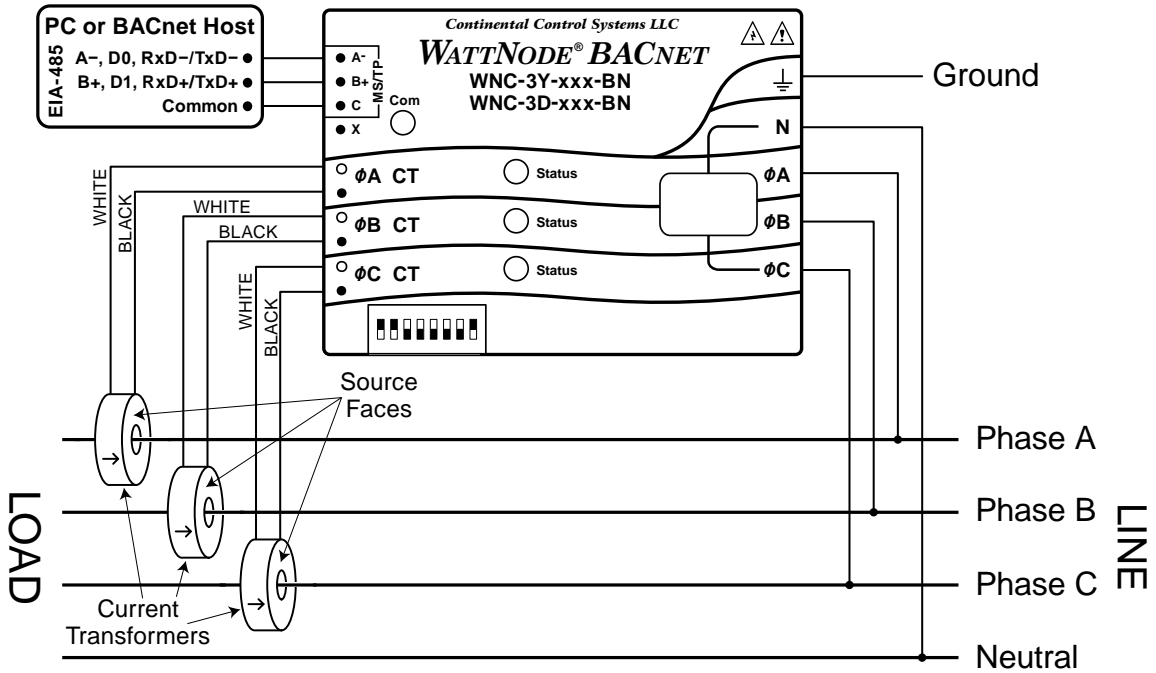


Figure 5: Three-Phase Four-Wire Wye Connection

### 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-BN
230 Vac	400 Vac	WNC-3Y-400-BN
277 Vac	480 Vac	WNC-3Y-480-BN
347 Vac	600 Vac	WNC-3Y-600-BN

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  $\phi A$  and  $\phi B$ , rather than **N** and  $\phi A$ . 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-BN
230 Vac	400 Vac	WNC-3D-400-BN
277 Vac	480 Vac	WNC-3D-480-BN

## Three-Phase Three-Wire Delta Without 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  $\phi A$ ,  $\phi B$ , and  $\phi C$  terminals in any order, **so long as the CTs are connected to matching phases**. For these models, the meter is powered from the  $\phi A$  and  $\phi B$  (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 will not cause ground current to flow because the neutral terminal is not used to power the meter.

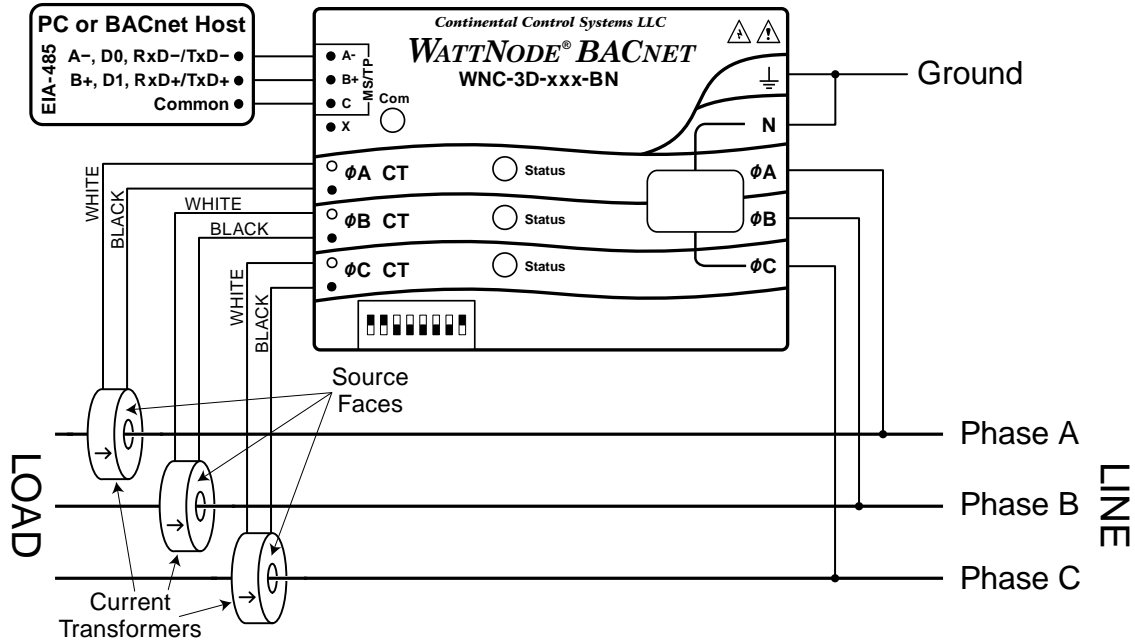


Figure 6: Three-Phase Three-Wire Delta Connection

### 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-BN
400 Vac	WNC-3D-400-BN
480 Vac	WNC-3D-480-BN

## Three-Phase Four-Wire Delta (Wild Leg)

The uncommon four-wire delta electrical service is a three-phase delta service with a center-tap on one of the transformer windings to create a neutral for single-phase loads.

See [http://www.ccontrols.com/w/Four\\_Wire\\_Delta\\_Circuits](http://www.ccontrols.com/w/Four_Wire_Delta_Circuits) for details.

## Grounded Leg Service

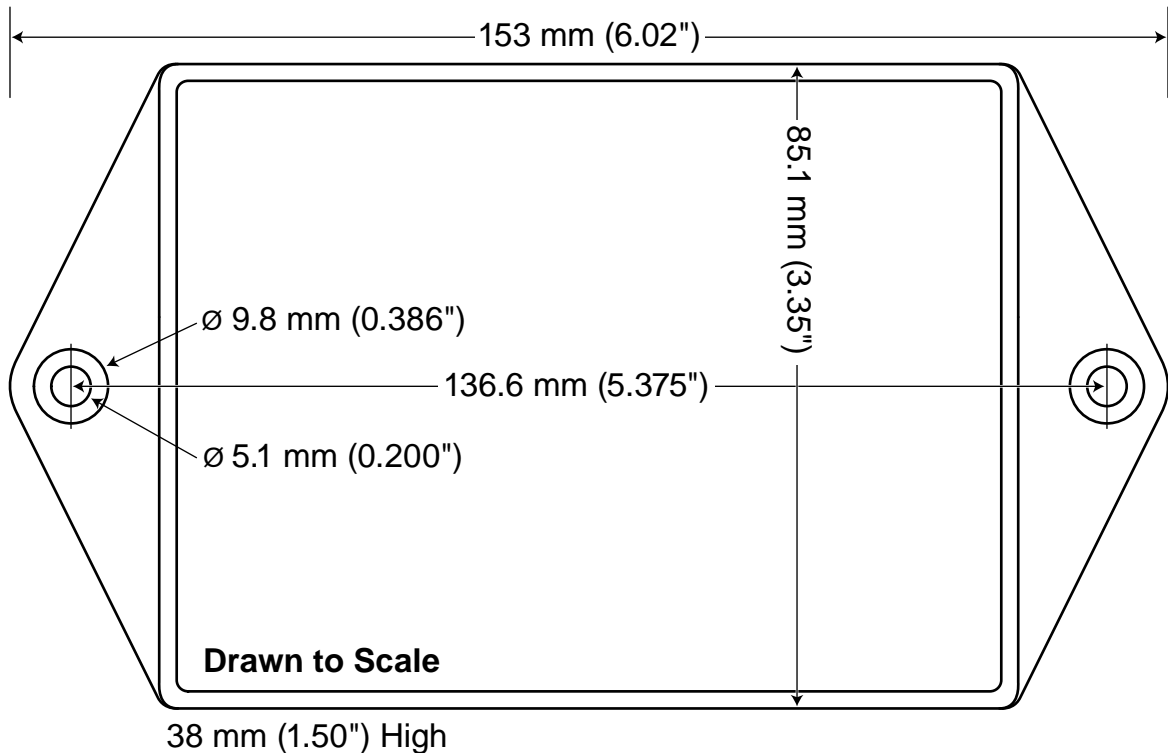
In rare cases with delta services or single-phase two-wire services without neutral, one of the phases may be grounded. You can check for this by using a multimeter (DMM) to measure the voltage between each phase and ground. If you see a reading between 0 and 5 Vac, that leg is probably grounded (sometimes called a “grounded delta”).

The WattNode meter will correctly measure services with a grounded leg, but the measured voltage and power for the grounded 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 indicate low power factor because this type of service results in unusual power factors.

For optimum accuracy with a grounded leg, you should also connect the **N** (neutral) terminal on the meter to the ground terminal; this will not cause any ground current to flow because the neutral terminal is not used to power the meter. 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 **ØB** or **ØC** inputs and attaching a note to the meter indicating this configuration for future reference.

## Mounting

Protect the WattNode meter 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 meter. Due to its exposed screw terminals, the meter must be installed in an electrical service panel, an enclosure, or an electrical room. The meter may be installed in any orientation, directly to a wall of an electrical panel or junction box.



**Figure 7: WattNode Meter Dimensions**

The WattNode meter has two mounting holes spaced 5.375 inches (137 mm) 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 meter or **Figure 7** may be used as a template to mark mounting hole positions, but **do not drill the holes with the meter in the mounting position** because the drill may damage the connectors and leave drill shavings in the connectors.

You may mount the meter with the supplied #8 self-tapping sheet metal screws using 1/8 inch pilot hole (3.2 mm). Or you may use hook-and-loop fasteners. If you use screws, avoid

over-tightening which can crack the case. If you don't use the supplied screws, the following sizes should work (**bold** are preferred); use washers if the screws could pull through the mounting holes

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

**Table 2: Mounting Screws**

## Selecting Current Transformers

The rated full-scale 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 **Current Transformers (p. 54)**.

We only offer CTs that measure AC current, not DC current. Significant DC current can saturate the CT magnetic core, reducing the AC accuracy. Most loads only have AC current, but some rare loads draw DC current, which can cause measurement errors. See our website for more information: [http://www.ccontrols.com/w/DC\\_Current\\_and\\_Half-Wave\\_Rectified\\_Loads](http://www.ccontrols.com/w/DC_Current_and_Half-Wave_Rectified_Loads).

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 meter (**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 (the RMS current is the value reported by multimeters and the WattNode meter). Resistive loads like heaters and incandescent lights have nearly sinusoidal current waveforms with a crest factor near 1.4. Power factor corrected loads such as electronic lighting ballasts and computer power supplies typically have a crest factor of 1.4 to 1.5. Battery chargers, VFD motor controls, and other nonlinear loads can have current crest factors ranging from 2.0 to 3.0, and even higher.

High current crest factors are usually not an issue when metering whole building loads, but can be a concern when metering individual loads with high current crest factors. If the peak current is too high, the meter's CT inputs can clip, causing inaccurate readings.

This means that when measuring loads with high current crest factors, 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 meter will not be able to accurately measure the 30 amp peak current. Note: this is a limitation of the meter measurement circuitry, not the CT.

The following graph shows the maximum RMS current for accurate 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%. Eighty-five percent 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%. Forty-two percent of a 100 amp CT is 42 amps, so you would need a 100 amp CT to accurately measure this 40 amp load.

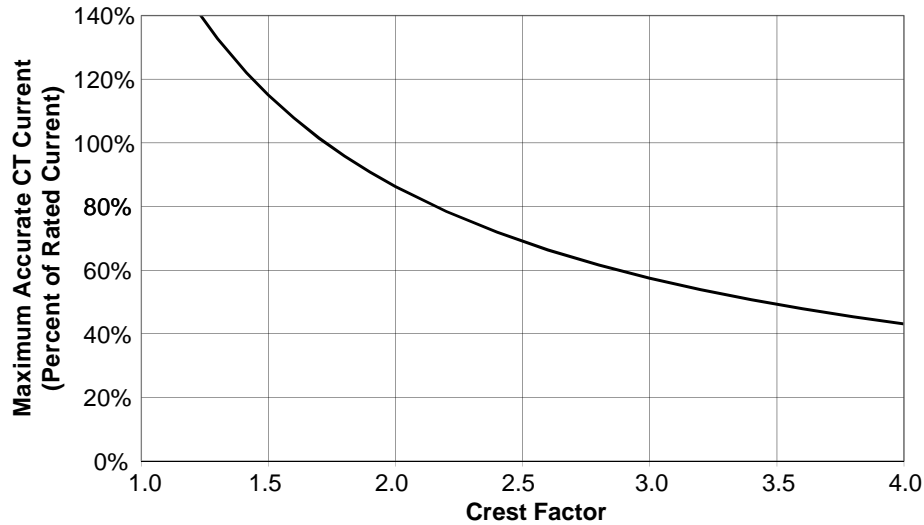


Figure 8: Maximum CT Current vs. Crest Factor

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 0.33333 Vac (333.33 millivolts AC) at rated current. See [Current Transformers \(p. 54\)](#) for the maximum input current ratings.
- **Do not** use ratio (current output) CTs such as 1 amp or 5 amp output CTs: they will **destroy** the meter and present a shock hazard! These are commonly labelled with a ratio like 100:5.
- 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 diagnostic LEDs indicates negative power with flashing red LEDs.
- Be careful to match up the current transformers to the voltage phases being measured. Make sure the **ΦA CT** is measuring the line voltage connected to **ΦA**, and the same for phases B and C. Use the supplied colored labels or tape 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 should not be much larger than the conductor. If the CT opening is much larger, position the conductor in the center of the CT opening.
- Because CT signals are susceptible to interference, we recommend keeping the CT wires short and cutting off any excess length. It is generally better to install the meter near the line voltage conductors instead of extending the CT wires. However, you may extend the CT wires by 300 feet (100 m) or more by using shielded twisted-pair cable and by running the CT wires away from high current and line voltage 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 meter. **Always remove power before disconnecting any live wires.** Put the line conductors through the CTs as shown in the section **Electrical Service Types (p. 10)**. You may measure generated power by treating the generator as the source.

For solid-core CTs, disconnect the line voltage conductor to install it through the CT opening.

Split-core and bus-bar CTs can be opened for installation around a wire. Different models have different opening mechanisms, so you should familiarize yourself with the CT mechanism before starting the installation. A nylon cable tie can be secured around the CT to prevent inadvertent opening.

Some split-core CT models have flat mating surfaces. When installing this type of CT, make sure that mating surfaces are clean. Any debris between the mating surfaces will increase the gap, decreasing accuracy.

Connect the CT lead wires to the meter terminals labeled **ΦA CT**, **ΦB CT**, and **ΦC CT**. Route the twisted black and white wires from the CT to the meter. Strip 1/4 inch (6 mm) of insulation off the ends of the CT leads and connect to the six position black screw terminal block. Connect each CT lead 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.

Record the CT rated current as part of the installation record for each meter. If the conductors 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 conductor passes through the CT.

## Circuit Protection

The WattNode meter 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 meter and must be as close as practical to the meter. If a switch or disconnect is used, then there must also be a fuse or circuit breaker of appropriate rating protecting the meter.
- WattNode meters only draw 10-30 milliamps; CCS recommends using circuit breakers or fuses rated for between 0.5 amps and 20 amps and rated for the line voltages and the current interrupting rating required.
- The circuit breakers or fuses must protect the ungrounded supply conductors (the terminals labeled **ΦA**, **ΦB**, and **ΦC**). If neutral is also protected (this is rare), then the overcurrent protection device must interrupt neutral and the supply conductors simultaneously.
- Any switches or disconnects should have at least a 1 amp rating and must be rated for the line voltages.
- 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<sup>2</sup> or 2.5 mm<sup>2</sup>) stranded wire, rated for 300 or 600 volts. Solid wire may be used, but must be routed carefully to avoid putting excessive stress on the screw terminal.
- The WattNode meter 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 turn off or disconnect power** before connecting the voltage inputs to the meter. Connect each phase voltage to the appropriate input on the green terminal block; also connect ground and neutral (if required).

The voltage inputs to the meter do not need to be powered from the same branch circuit as the load being monitored. In other words, if you have a three-phase panel with a 100 A three-pole breaker powering a motor that you wish to monitor, you can power the meter (or several meters) from a separate 20 A three-pole breaker installed in the same, or even adjacent panel, so long as the load and voltage connections are supplied from the same electric service.

The green screw terminals handle wire up to 12 AWG (2.5 mm<sup>2</sup>). Strip the wires to expose 1/4" (6 mm) of bare copper. When wiring the meter, do not put more than one wire under a screw. If you need to distribute power to other meters, use wire nuts or a power distribution block. The section [Electrical Service Types \(p. 10\)](#) shows the proper connections for the different meter models and electrical services. **Verify that the voltage line phases match the CT phases.**

If there is any doubt that the meter voltage rating is correct for the circuit being measured, unplug the green terminal block (to protect the meter), turn on the power, and use a voltmeter to compare the voltages (probe the terminal block screws) to the values in the white box on the meter front label. After testing, plug in the terminal block, making sure that is pushed in all the way.

The WattNode meter is powered from the voltage inputs:  $\phi A$  (phase A) to **N** (neutral) for wye “-3Y” models, or  $\phi A$  to  $\phi B$  for delta “-3D” models. If the meter is not receiving at least 80% of the nominal line voltage, it may stop operating. Since the meter consumes a small amount of power itself (typically 1-3 watts), you may wish to power the meter from a separate circuit or place the current transformers downstream of the meter, so its power consumption is not measured

For best accuracy, always connect the **N** (neutral) terminal on the meter. If you are using a delta meter and the circuit has no neutral, then jumper the earth ground to the **N** (neutral) terminal.

When power is first applied to the meter, check that the LEDs behave normally (see [Installation LED Diagnostics \(p. 22\)](#) below): if you see the LEDs flashing red-green-red-green, then disconnect the power immediately! This indicates the line voltage is too high for this model.

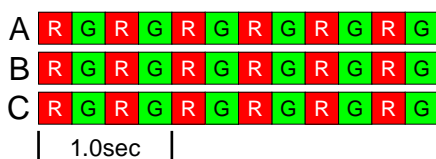


Figure 9: WattNode LED Overvoltage Warning

## Setting the BACnet Address

Every device on a BACnet network must have a unique address and the correct baud rate. The WattNode BACnet meter sets the address and baud rate with an eight position DIP switch.

The WattNode meter supports BACnet addresses from 0 to 63 using the DIP switch. As shipped from the factory, the meter will be configured with an address of 0.

Set the BACnet address by switching DIP switch positions 1-6, each of which adds a different value to the address. The change will take effect immediately.

DIP Switch	1	2	3	4	5	6
Up (1) Value	1	2	4	8	16	32
Address	Examples					
1	Up	Down	Down	Down	Down	Down
1+2+4 = 7	Up	Up	Up	Down	Down	Down
4+16 = 20	Down	Down	Up	Down	Up	Down
1+2+16+32 = 51	Up	Up	Down	Down	Up	Up

**Table 3: BACnet 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 BACnet address is 4 + 16 = 20.

## Baud Rate

Select the baud rate by setting DIP switch positions 7 and 8 as shown below. The change will take effect immediately.

Baud Rate	DIP Switch Position 7	DIP Switch Position 8
9,600 (default)	0 (Down)	0 (Down)
19,200	<b>1 (Up)</b>	0 (Down)
38,400	0 (Down)	<b>1 (Up)</b>
76,800	<b>1 (Up)</b>	<b>1 (Up)</b>

**Table 4: Baud Rate Selection**

## Connecting BACnet Outputs

The BACnet WattNode meter communicates using a serial EIA RS-485 interface. The meter uses half-duplex two-wire (plus common) communication, so the same pair of wires is used for sending AND receiving. Although the BACnet MS/TP standard allows a maximum of 128 devices on the same RS-485 bus, only 64 WattNode meters can be used together on the same RS-485 bus.

## Planning the BACnet 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, BACnet host, or monitoring device and then run to each meter in turn. Try to avoid branches, and avoid home-run wiring (where each meter has its own wire back to the PC or host). For best results, especially for longer distances, use wire recommended for RS-485.

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

**Table 5: Recommended RS-485 Cabling**

- Since the RS-485 wiring may be located near line voltage wiring, use wires or cables rated for the highest voltage present, generally 300 V or 600 V 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 meter 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 1200 m (4000 ft) at up to 38,400 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 meter, you may use stubs or branches. Long stubs or branches—greater than 30 m (100 ft)—may cause signal reflections and should be avoided.

## Termination

Networks shorter than 500 m (1650 ft) 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 meter 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 BACnet “**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 meter 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, so it is rare to need to add 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 WattNode meters.

- The BACnet terminals (**A-**, **B+**, **C**, and **X**) are completely isolated (4500 Vac RMS isolation) from dangerous voltages, so you can connect them with the meter powered. They are also isolated from the meter's earth ground and neutral connections.
- When connecting WattNode meters to a PC or monitoring device, connect all “**A-**” terminals together, all “**B+**” terminals together, and all “**C**” (common) terminals together.
- You may put two sets of wires in each screw terminal to make it easier to daisy-chain the network from one device 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 BACnet common “**C**” connection between all devices on the network.
- Connect the cable shield or BACnet common (if there is no shield) to earth ground at just the BACnet master end of the cable. Grounding both ends can cause ground loops. Leaving the common floating risks damaging the RS-485 circuitry.

## Installation Summary

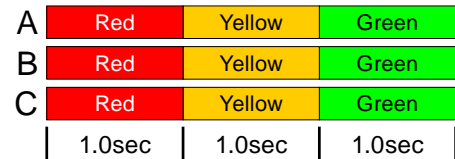
- 1) Mount the WattNode meter.
- 2) Turn off power before installing solid-core (non-opening) CTs or making voltage connections.
- 3) Mount the CTs around the line voltage conductors being measured. Take care to orient the CTs facing the source of power.
- 4) Connect the twisted white and black wires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

## Installation LED Diagnostics

The WattNode meter includes multi-color power diagnostic LEDs for each phase to help verify correct operation and diagnose incorrect wiring. 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.

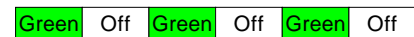
### Normal Startup

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.



### 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.



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

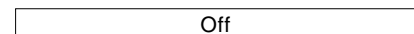
### Zero Power

For each phase, if line Vac is present, but the measured power is below the minimum that the meter will measure; see **Creep Limit (p. 50)**, the meter will display solid green for that phase.



### Inactive Phase

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



## Negative Power

If one or more of the phase LEDs are flashing red, it indicates negative 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:

- 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 current carrying wire or the white and black wires for the CT were reversed at the meter. This can be solved by flipping the CT on the wire or swapping the white and black wires at the meter. Alternatively, you can use the configuration objects *InvertCtA*, *InvertCtB*, and *InvertCtC* to reverse the polarity of one or more of the CTs.
- The CT wires are connected to the wrong inputs, such as if the CT wires for phases B and C are swapped or the CT wires are rotated one phase.

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 meter is experiencing an error or low line voltage, not negative power.

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

## Erratic Flashing

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

- Earth ground is not connected to the meter (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 meter away from the source of noise. Also try to keep the CT wires as short as possible and cut off excess wire.

A	Off	Grn	Off	Red	Off
B	Red	Off	Green	Off	Red
C	Grn	Off	Red	Grn	Red

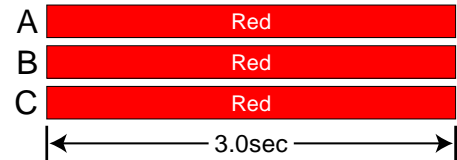
## Meter Not Operating

It should not be possible for all three LEDs to stay off when the meter is powered, because the phase powering the meter will have line voltage present. Therefore, if all LEDs are off, the meter 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  $\pm 20\%$  of the nominal operating voltages printed in the white rectangle on the front label.

A	Off
B	Off
C	Off

## Meter Error

If the meter experiences an internal error, it will light all LEDs red for three seconds or longer. Check the ***ErrorStatus (1710)*** register to determine the exact error. If this happens repeatedly, return the meter for service.



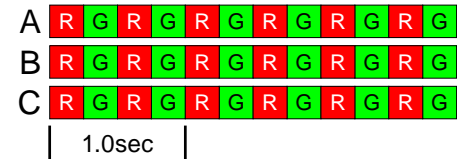
## Bad Calibration

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



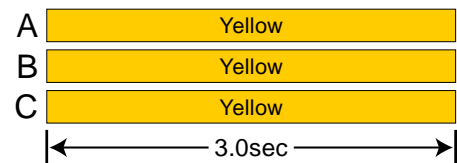
## Line Voltage Too High

Whenever the meter 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 meter immediately!** Check that the model and voltage rating is correct for the electrical service.



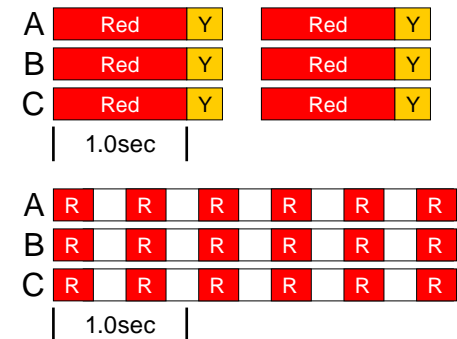
## Bad Line Frequency

If the meter 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 meter should continue to accurately measure power. This can occur in the presence of extremely high noise, such as if the meter is too close to an unfiltered variable frequency drive.



## Low Line Voltage

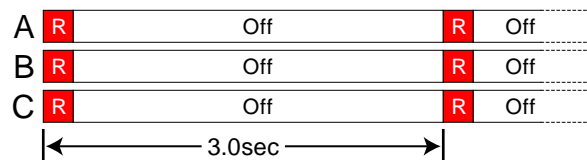
These LED patterns occur if the line voltage is too low for the meter to operate correctly and the meter reboots repeatedly. The pattern will be synchronized on all three LEDs. Verify that the voltage on the Vac screw terminals is not more than 20% lower than the nominal operating voltages printed in the white rectangle on the front label. If the voltages are in the normal range and the meter continues to display one of these patterns, return it 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 meter will briefly flash all three status LEDs every three seconds. This may indicate:

- The measurement circuitry has been damaged and cannot read the line voltages.



## Other Fixed Pattern

If you see any other steady (non-flashing) pattern, contact Continental Control Systems for support.



## 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 meter and read objects. 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 meter with a DMM (multimeter) if possible.

- If one or more voltages are zero, then you either have a wiring problem or something is wrong with the meter. Verify the actual voltages with a DMM (multimeter). In rare cases, with delta circuits, one phase may be grounded and will read zero volts.
- If one or more voltages are too low (by more than 5%), then make sure you have the correct model. For example, a WNC-3Y-208-BN 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 meter 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 close to 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 **CtAmps** configuration objects for one or more phases are set to zero.
  - The CT or its wires are damaged.
  - There is strong electrical interference, as might occur if the meter is in very close proximity to a variable speed drive (also called variable frequency drive or inverter).
  - The meter is not working correctly: try swapping it with a replacement WattNode meter.
- 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 meter.
  - The current transformer white and black wires have been swapped where they enter the WattNode meter (at the black screw terminal block).
  - The line voltage phases (green screw terminals) are not matched up with the current phases (black screw terminals). For example, the phase A CT is around the phase B wire.
  - This may be normal if you are measuring in an environment where 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 1% and 100% of their rated current for best results. They generally work with reduced accuracy 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 conductor 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 meter, but if they are in very close proximity, or if the CT leads are long, interference can occur. Try moving the WattNode meter at least three feet (one meter) away from any VFDs. Use short CT leads if possible. **NEVER** install the meter downstream of a VFD: the varying line frequency and extreme noise will cause problems!
- Our current transformers can only measure AC currents. 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 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 meter to measure the peak current accurately.
- The CTs may be malfunctioning. 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 meter 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 meter. For example, if 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.

Negative power factor values either indicate you are generating power (as with a PV system) or that the CTs are reversed.

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 meter 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.

## BACnet Communication Diagnostics

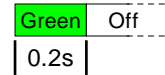
The “**Com**” LED indicates many BACnet communication conditions by lighting green, yellow, or red. Other BACnet errors are indicated by returning a BACnet exception response to the master and by saving an error code to the **ErrorStatus** registers.

### BACnet Idle

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

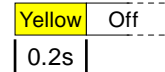
### Received Packet / Sending Response

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



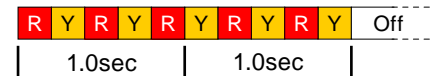
### Other BACnet Activity

If the WattNode meter 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.



### BACnet Address Conflict or Bus Contention

The meter displays this indication in these cases:



- It sees unexpected data on the RS-485 bus when it is preparing to respond to a command. This generally is due to another WattNode meter with the same address responding first, although it could also be extra bytes from the BACnet master or another device.
- It starts transmitting a response, but doesn't see the data it is transmitting on the RS-485 bus. This can happen if two devices have the same address and start transmitting at nearly the same time. It can also be caused by a short circuit on the bus or extreme interference.
- Your RS-485 adapter is configured for full duplex (four wire) operation instead of half-duplex.
- Your RS-485 adapter is continuing to drive the transmit lines after sending a packet; this can happen with older RS-232 to RS-485 adapters that require an RTS signal to transmit.

If you see this indication, make sure there are not two meters with the same BACnet address. You may want to disconnect all but one meter to see if the problem goes away.

### Invalid BACnet Packet

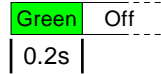
The meter will light the **Com** LED red for one second for any of the following errors (the **ErrorStatus** registers will also be set, but depending on the problem you may not be able to read register values).



- **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 meter or just use “+” and “-” indications.
- **Buffer overrun error:** the packet was longer than 512 bytes.
- **Parsing error:** the packet could not be correctly parsed as a BACnet packet.

## Invalid Request



If the WattNode BACnet meter receives a **valid packet**, but with an **invalid request** (see below), then the meter will respond with a BACnet error code and store an error in the ***ErrorStatus*** objects. Because the packet was valid, **Com** LED will flash green for 200 milliseconds.

# Operating Instructions

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## Quick Start

To start communicating with a WattNode BACnet meter using a PC or host device, you'll need to complete the following steps:

- Set the BACnet address and baud rate using the DIP switches (see [Setting the BACnet Address \(p. 19\)](#)).
- If you are using a PC:
  - Find and install BACnet software for your PC. For a list of some programs, see [http://www.ccontrols.com/w/BACnet\\_Software](http://www.ccontrols.com/w/BACnet_Software).
  - Find and install an EIA RS-485 interface for your PC. The RS-485 USB interfaces are generally the best choice, because they are USB powered, don't require a serial port on your PC, and automatically handle switching bus directions for the half-duplex bus.
- Configure the BACnet software or host baud rate, COM port, BACnet MS/TP, N81 parity (no parity, eight data bits, one stop bit), and the WattNode meter's BACnet address.

Now you should be able to send messages to the WattNode meter and receive responses. A good starting point is to try to self-discover the meter and the objects. If this works, try reading the frequency object. You should see the AC line frequency, generally 50 or 60 Hz. If you don't get a good response, check the section [BACnet Communication Diagnostics \(p. 28\)](#).

## WattNode Basic Configuration

- Set the **CtAmpsA**, **CtAmpsB**, and **CtAmpsC** objects to the correct rated CT amps of your current transformers. For example, if you are using 100 A CTs, write 100 to all three objects.
- If you are planning on using demand measurements and you don't want to use the default 15 minute interval, you should set the **DemPerMins** as well.

## Verify Operation

You should be able to read several objects to check that the meter is correctly installed and measuring power and energy. Verify objects in the following sequence:

- **Freq (power line frequency)**: should be near 50 or 60 Hz.
- **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).
- **ErrorStatus1**: this will return 0 if there are no errors. If you see any non-zero values, write them down and check the [Diagnostic Objects \(p. 45\)](#) section below to determine the problem.

If you don't get reasonable results, check [Measurement Troubleshooting \(p. 25\)](#) above.

## Measurement Overview

The WattNode meter performs measurements every second 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 values are preserved across power failures.

## BACnet Communication

The WattNode BACnet meter uses the BACnet MS/TP communication protocol. For full specifications, see <http://www.bacnet.org>. BACnet MS/TP is a binary protocol consisting of message frames.

The BACnet MS/TP specification requires 8 data bits, no parity, and one stop bit.

The BACnet MS/TP protocol supports multiple master and slave devices. The WattNode meter is a master device.

## BACnet Self-Discovery

The WattNode BACnet meter supports the standard BACnet types of self-discovery. Most BACnet host software and devices can perform self-discovery to read some or all of the following information. Depending on how the self-discovery is implemented and how much information is requested, full self-discovery can take as long as a couple of minutes.

- **Address:** the normal BACnet MS/TP polling mechanism should identify new WattNode meters on an RS-485 subnet within several seconds of when the devices are connected and powered up.
- **Object List:** once a new device has been detected, a BACnet host can read the **Object\_List** property of the **Device** object to get a list of all the objects in a WattNode meter.
- **Object Names:** each object implements an **Object\_Name** property which can be used to read out the names of the objects.
- **Properties:** for each object, the implemented properties can be discovered two ways: by reading each optional property in turn to see if the meter responds with a value or an error; or by using the **ReadPropertyMultiple** command with a specifier of ALL or OPTIONAL to get a response with the identifiers and values of all properties or all optional properties.
- **Multi-state Values:** for each **Multi-state** object, there is a **State\_Text** property, which is an array of strings describing the possible states.

## BACnet Object and Property Lists

This section lists the BACnet objects and properties provided in the WattNode BACnet meter. The following sections provide detailed information about each object. The objects are grouped by type as follows:

- **Device:** there is one device object for each meter, which provides information like the model, serial number, firmware version, etc.
- **Analog Input:** the analog input object type provides all the measurement values supported by the meter, such as energy, power, voltage, current, etc.
- **Analog Value:** the analog value object type implements several configuration and informational objects.
- **Binary Value:** the meter has a small set of binary value objects for configuration and simple toggle-style commands.
- **Multi-state Value:** the meter uses a few multi-state objects for configuration and information.

## BACnet Object and Property Addressing

Each object (**EnergySum**, **PowerSum**, **VoltA**, etc.) implements the required BACnet properties (**Object\_Identifier**, **Object\_Name**, **Object\_Type**, **Present\_Value**, etc.) for that object and may also implement some optional properties. In most cases, you will be interested in the **Present\_Value** property of each object, since this is the property that provides the measurements.

Although your software or host will generally handle the details, within the protocol, a given property of an object is addressed with a combination of the **Object\_Identifier** (which is composed

of the **Object\_Type** and the **Object\_Number**) and the **Property\_Identifier**. For example, if you want to read the AC line frequency, you would read the ANALOG\_INPUT (Object\_Type = 0), Freq (Object\_Number = 23), Present\_Value (Property\_Identifier = 85).

## Floating Point and Integer Values

Most object values are provided as floating point values (this is the standard format for **Analog Value** objects).

We also provide energy values in an optional 32 bit integer format using a custom property (Property\_Identifier = 1000) with a scaling of 0.1 kWh (so a count of 20 would equal 2.0 kWh). We generally recommend using the standard floating point values, because they provide more resolution and dynamic range and they never requiring scaling. However, for energy variables, the 32 bit integer values may be preferred, because they provide a constant resolution of 0.1 kWh.

## Device Object

There is one device object for each WattNode BACnet meter. The device object provides the following properties:

- **Object\_Identifier (75)**: A combination of the **Object\_Type** and **Object\_Number**. For the device object, this is a network-wide unique identifier. By default, the **Object\_Number** will be the meter's serial number, but the device **Object\_Identifier** can be changed if necessary to ensure uniqueness.
- **Object\_Name (77)**: A network-wide unique name for this object; defaults to a combination of the model name and serial number.
- **Object\_Type (79)**: Reports DEVICE (8) for all analog input objects.
- **System\_Status (112)**: This will return a value of OPERATIONAL (0).
- **Vendor\_Name (121)**: This will return "Continental Control Systems, LLC"
- **Vendor\_Identifier (120)**: This will return 500, the vendor ID for Continental Control Systems.
- **Model\_Name (70)**: This will return the model number; for example "WNC-3Y-208-BN".
- **Firmware\_Revision (44)**: This will return the meter firmware version number.
- **Application\_Software\_Version (12)**: This will return the meter firmware version number.
- **Location (58)**: This is a user configurable string for the meter's location (up to 30 characters).
- **Description (28)**: This is a user configurable string describing the meter.
- **Protocol\_Version (98)**: BACnet protocol version: 1
- **Protocol\_Revision (139)**: BACnet protocol revision: 10
- **Protocol\_Services\_Supported (97)**: This returns the supported services (commands).
- **Protocol\_Object\_Types\_Supported (96)**: This returns the supported object types.
- **Object\_List (76)**: This returns an array of all the objects in the WattNode meter.
- **Max\_APDU\_Length\_Accepted (62)**: This is the maximum application packet length supported (480 bytes). The longest MS/TP packet is 512 bytes because of physical and network layer overhead.
- **Segmentation\_Supported (107)**: This returns NO\_SEGMENTATION (3).
- **APDU\_Timeout (11)**: The time (in milliseconds) between retries for packets that are not acknowledged. This defaults to 3000.
- **Number\_Of\_APDU\_Retries (73)**: This is the number of retries for packets. It defaults to 3.
- **Device\_Address\_Binding (30)**: This required property is used to configure address bindings to other devices.
- **Database\_Revision (155)**: This integer value increments whenever objects are added, objects are removed, an **Object\_Identifier** is changed, or an **Object\_Name** is changed.

The WattNode meter only supports changing the **Object\_Identifier** or **Object\_Name** of the device object, so those are the only actions that will increment this number.

## Analog Input Objects - Measurements

For all the Analog Input objects the following properties are supported:

- **Present\_Value (85)**: This reports the measured value as a floating point number.
- **Object\_Identifier (75)**: A combination of the **Object\_Type** and **Object\_Number**.
- **Object\_Name (77)**: A string name for this object, such as **EnergySum**.
- **Object\_Type (79)**: Reports ANALOG\_INPUT (0) for all analog input objects.
- **Units (117)**: The units for this measurement.
- **Out\_Of\_Service (81)**: This True / False value indicates if the physical measurement is not in service.

For all the energy objects (including reactive and apparent energy), there is an additional optional property **Integer\_Value (1000)** that reports the energy value as a 32 bit signed integer value with units of 0.1 kWh (or 0.1 kVARh or 0.1 kVAh). In most cases, you will not need these integer energy values and many systems will not self-discover the custom property **Integer\_Value**.

Object #	Object Name	Units	Description
<b>Energy Objects</b>			
0	EnergySumNR*	kWh	Total net (bidirectional) energy - non-resettable
1	EnergyPosSumNR*	kWh	Total positive energy - non-resettable
2	EnergyNegSumNR*	kWh	Total negative energy- non-resettable
38	EnergySum*†	kWh	Total net (bidirectional) energy
39	EnergyPosSum*†	kWh	Total positive energy
40	EnergyNegSum*†	kWh	Total negative energy
41	EnergyA*†	kWh	Net (bidirectional) energy, phase A
42	EnergyB*†	kWh	Net (bidirectional) energy, phase B
43	EnergyC*†	kWh	Net (bidirectional) energy, phase C
44	EnergyPosA*†	kWh	Positive energy, phase A
45	EnergyPosB*†	kWh	Positive energy, phase B
46	EnergyPosC*†	kWh	Positive energy, phase C
47	EnergyNegA*†	kWh	Negative energy, phase A
48	EnergyNegB*†	kWh	Negative energy, phase B
49	EnergyNegC*†	kWh	Negative energy, phase C
<b>Reactive and Apparent Energy Objects</b>			
50	EnergyReacSum*†	kVARh	Reactive energy, sum of active phases
51	EnergyReacA*†	kVARh	Net reactive energy, phase A
52	EnergyReacB*†	kVARh	Net reactive energy, phase B
53	EnergyReacC*†	kVARh	Net reactive energy, phase C
54	EnergyAppSum*†	kVAh	Apparent energy, sum of active phases
55	EnergyAppA*†	kVAh	Apparent energy, phase A
56	EnergyAppB*†	kVAh	Apparent energy, phase B
57	EnergyAppC*†	kVAh	Apparent energy, phase C
<b>Power Objects</b>			
3	PowerSum	W	Real power, sum of active phases
4	PowerA	W	Real power, phase A
5	PowerB	W	Real power, phase B
6	PowerC	W	Real power, phase C
<b>Reactive and Apparent Power Registers</b>			
7	PowerReacSum	VAR	Reactive power, sum of active phases



Object #	Object Name	Units	Description
8	PowerReacA	VAR	Reactive power, phase A
9	PowerReacB	VAR	Reactive power, phase B
10	PowerReacC	VAR	Reactive power, phase C
11	PowerAppSum	VA	Apparent power, sum of active phases
12	PowerAppA	VA	Apparent power, phase A
13	PowerAppB	VA	Apparent power, phase B
14	PowerAppC	VA	Apparent power, phase C

#### Voltage Objects

15	VoltAvgLN	V	Average line-to-neutral voltage
16	VoltA	V	RMS voltage, phase A to neutral
17	VoltB	V	RMS voltage, phase B to neutral
18	VoltC	V	RMS voltage, phase C to neutral
19	VoltAvgLL	V	Average line-to-line voltage
20	VoltAB	V	RMS voltage, line-to-line, phase A to B
21	VoltBC	V	RMS voltage, line-to-line, phase B to C
22	VoltAC	V	RMS voltage, line-to-line, phase A to C

#### Frequency Object

23	Freq	Hz	Power line frequency
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#### Current Registers

24	CurrentA	A	RMS current, phase A
25	CurrentB	A	RMS current, phase B
26	CurrentC	A	RMS current, phase C

#### Power Factor Registers

27	PowerFactorAvg		Power factor, average
28	PowerFactorA		Power factor, phase A
29	PowerFactorB		Power factor, phase B
30	PowerFactorC		Power factor, phase C

#### Demand Registers

31	DemandSum	W	Real power sum demand
32	DemandApp	W	Apparent power sum demand
33	DemandA	W	Real power demand, phase A
34	DemandB	W	Real power demand, phase B
35	DemandC	W	Real power demand, phase C
36	DemandMin*	W	Minimum power sum demand
37	DemandMax*	W	Maximum power sum demand

\*These registers are preserved across power failures.

†These registers support resetting or presetting the value.

## Analog Value Objects - Configuration and Diagnostics

The WattNode meter uses Analog Value objects for configuration and diagnostics. For all the Analog Value objects the following properties are supported:

- **Present\_Value (85):** This reports or sets the configuration or diagnostic value as a floating point number.
- **Object\_Identifier (75):** A combination of the **Object\_Type** and **Object\_Number**.
- **Object\_Name (77):** A string name for this object, such as **CtAmpsA**.
- **Object\_Type (79):** This reports ANALOG\_VALUE (2) for all analog value objects.
- **Units (117):** The units for this object. Many of the Analog Value objects have “No Units”.

Object #	Object Name	Units	Default	Description
<b>Error Status Objects</b>				
0	ErrorStatus1*	No Units		Newest error or event (0 = no errors)
1	ErrorStatus2*	No Units		Next oldest error or event
2	ErrorStatus3*	No Units		Next oldest error or event
3	ErrorStatus4*	No Units		Next oldest error or event
4	ErrorStatus5*	No Units		Next oldest error or event
5	ErrorStatus6*	No Units		Next oldest error or event
6	ErrorStatus7*	No Units		Next oldest error or event
7	ErrorStatus8*	No Units		Oldest error or event
<b>Diagnostic Objects</b>				
8	UptimeSecs	Seconds		Time in seconds since last power on
9	TotalSecs*	Seconds		Total seconds of operation
10	PowerFailCount*	No Units		Number of power cycles on the meter
<b>Current Transformer Rated Amps</b>				
12	CtAmpsA*	1 A	5	$\phi$ A CT rated current (0 to 60000)
13	CtAmpsB*	1 A	5	$\phi$ B CT rated current (0 to 60000)
14	CtAmpsC*	1 A	5	$\phi$ C CT rated current (0 to 60000)
<b>Demand Configuration Objects</b>				
15	DemPerMins*	1 minute	15	Demand period (1 to 720)
16	DemSubints*		1	Number of demand subintervals (1 to 10)
<b>Miscellaneous Configuration Objects</b>				
11	ConfigPasscode*		0	Optional passcode to prevent unauthorized changes to configuration
23	CreepLimit*		1500	Minimum power for non-zero readings (100 to 10000)
24	PtRatio*		1.0	Potential transformer ratio
25	CalPasscode			Calibration passcode: not for customer use
<b>Gain and Phase Adjustments</b>				
17	GainAdjustA*	1/10000th	10000	$\phi$ A power/energy adjust (5000 to 20000)
18	GainAdjustB*	1/10000th	10000	$\phi$ B power/energy adjust (5000 to 20000)
19	GainAdjustC*	1/10000th	10000	$\phi$ C power/energy adjust (5000 to 20000)
20	PhaseAdjustA*	0.001 deg	0	$\phi$ A CT phase angle adjust (-8000 to 8000)
21	PhaseAdjustB*	0.001 deg	0	$\phi$ B CT phase angle adjust (-8000 to 8000)
22	PhaseAdjustC*	0.001 deg	0	$\phi$ C CT phase angle adjust (-8000 to 8000)

\*These registers are preserved across power failures.

## Binary Value Objects - Configuration

The binary value objects are primarily used for configuration and single action commands. Each object accepts or reports a **Present\_Value (85)** of ACTIVE (1) or INACTIVE (0). The binary value objects support the same properties as the analog value objects, but without a **Units** property and the following changes:

- **Present\_Value (85)**: This reports or sets the value to ACTIVE or INACTIVE.
- **Object\_Type (79)**: This reports BINARY\_VALUE (5) for all binary value objects.

Object #	Object Name	Default	Description
0	InvertCtA*	INACTIVE	Invert the polarity of the $\phi$ A CT
1	InvertCtB*	INACTIVE	Invert the polarity of the $\phi$ B CT
2	InvertCtC*	INACTIVE	Invert the polarity of the $\phi$ C CT
3	ClearErrors	INACTIVE	Write TRUE to zero all <b>ErrorStatus</b> objects
4	ZeroEnergy	INACTIVE	Write TRUE to zero all resettable energy registers
5	RecallDefaults	INACTIVE	Recall the factory default setup
6	Wink	INACTIVE	Display a special LED pattern

\*These registers are preserved across power failures.

## Multi-State Value Objects - Configuration and Diagnostics

The multi-state objects are primarily used for configuration and diagnostics. Each object accepts or reports a **Present\_Value (85)** that is an integer representing one of the possible states. The multi-state objects support the same properties as the analog value objects, but without a **Units** property and the following changes:

- **Present\_Value (85)**: This reports or sets the value as an integer representing the state.
- **Object\_Type (79)**: This reports MULTISTATE\_VALUE (19) for all binary value objects.
- **Number\_Of\_States (74)**: This is the number of possible states.
- **State\_Text (110)**: This is an array of strings with the descriptions of each possible state.

Object #	Object Name	States	Default	Description
0	BaudRate	0 = 9,600 Baud 1 = 19,200 Baud 2 = 38,400 Baud 4 = 76,800 Baud	N/A	Read the current baud rate. The baud rate is set with the DIP switches.
1	PasscodeEnabled	0 = No Passcode 1 = Locked 2 = Unlocked	0	Reads the state of user configuration access.
2	PhaseOffset*	0 = Single-Phase 1 = 3-Ph Grounded Delta 2 = 3-Ph High-Leg Delta 3 = 3-Ph Balanced 4 = 1-Ph Center Neutral	3	The circuit type used to compute line-to-line voltages
3	Averaging*	0 = Fastest 1 = Fast 2 = Medium 3 = Slow	1	Measurement averaging mode
4	ZeroDemand	0 = No Change 1 = Reset Min Max 2 = Start New Interval 3 = Reset and Start	0	Restart or reset demand measurements.

\*These registers are preserved across power failures.

## Measurement Objects

In all of the following, when reading or writing an object, the ***Present\_Value (85)*** property is assumed unless another property specified.

### Energy Objects

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 object values are preserved through power failures.

In the WattNode BACnet meter, most energy objects can be reset to zero by writing “ACTIVE” (1) to the ***ZeroEnergy*** object. They can also be set to zero or a preset value by writing the desired value directly to each object. All energy objects ending with “NR” (for non-resetting) cannot be reset to zero for billing security. You can protect all energy objects from being zeroed or preset by setting a ***ConfigPasscode***.

All energy objects wrap around to zero when they reach 100 gigawatt-hours (100 x 10<sup>9</sup> watt-hours) or negative 100 gigawatt-hours (only some energy objects 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 meter will shut down until power is restored. To preserve the energy measurement across power outages, the meter writes the energy to non-volatile flash memory. 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 “ACTIVE” (1) is written to the ***ZeroEnergy*** object.

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 “ACTIVE” (1) is written to the ***ZeroEnergy*** object.

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

### Per-Phase Energy Objects

#### ***EnergyA, EnergyB, EnergyC***

The per-phase energy objects 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 “ACTIVE” (1) is written to the ***ZeroEnergy*** object. You may also reset them to zero or load preset values by writing to these objects.

## Positive Energy

### *EnergyPosA, EnergyPosB, EnergyPosC*

The per-phase positive energy objects 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 “ACTIVE” (1) is written to the ***ZeroEnergy*** object. You may also reset them to zero or load preset values by writing to these objects.

## Negative Energy

The negative energy objects are exactly like the positive energy objects 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).

The negative energy objects are reset to zero (except for ***EnergySumNegNR***) when “ACTIVE” (1) is written to the ***ZeroEnergy*** object. You may also reset them to zero or load preset values (except for ***EnergySumNegNR***) by writing to these objects.

### *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.

### *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 objects.

## Reactive Energy

### *EnergyReacSum, EnergyReacA, EnergyReacB, EnergyReacC*

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

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

These values are reset to zero when “ACTIVE” (1) is written to the ***ZeroEnergy*** object. You may also reset them to zero or load preset values by writing to these objects.

## Apparent Energy

### *EnergyAppSum, EnergyAppA, EnergyAppB, EnergyAppC*

Apparent energy (kVA-hours) is the 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 meter’s apparent energy includes real harmonics, but not reactive harmonics.

These values are reset to zero when “ACTIVE” (1) is written to the ***ZeroEnergy*** object. You may also reset them to zero or load preset values by writing to these objects.

## Power Objects

### ***PowerA, PowerB, PowerC***

The WattNode meter 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 meter isn't connected properly.

### ***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***.

## 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 objects are scaled by ***PowerIntScale***.

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

### ***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 meter's measurement of apparent power includes real, but not reactive harmonic apparent power content.

Apparent power is always a positive quantity.

### ***PowerAppA, PowerAppB, PowerAppC***

These are the per-phase apparent power measurements.

### ***PowerAppSum***

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

## Voltage Objects

### ***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, measured relative to the neutral connection on the meter. If neutral is not connected, then they are measured relative to the ground connection.

Voltage phases that are not connected may report small random voltages, but the WattNode meter 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 meter cannot directly measure line-to-line voltages. It provides these objects as estimates of the line-to-line voltage. In order to estimate these voltages, the meter must know the phase offset or the type of electrical service (see ***PhaseOffset*** configuration object).

## **Frequency**

### ***Freq***

The WattNode meter measures the AC line frequency in Hertz. All phases must have the same line frequency; otherwise this value will be erratic or incorrect.

## **Current**

The WattNode BACnet meter estimates 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 meter 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.

## **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 meter measures the displacement or fundamental power factor, which does not include harmonics.

### ***PowerFactorA, PowerFactorB, PowerFactorC***

These are the power factor values for each phase.

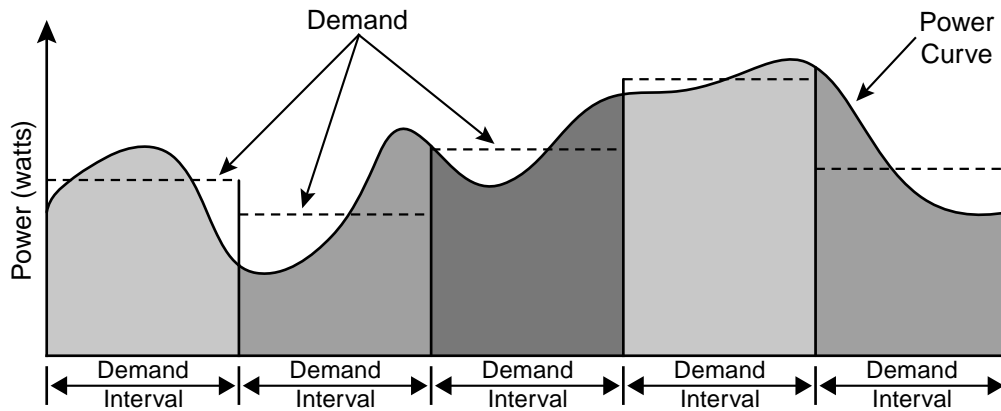
### ***PowerFactorAvg***

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

## **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 meter supports arbitrary demand intervals from 1 to 720 minutes (12 hours). The meter records the peak demand for metering applications where the measurements may only be accessed weekly or monthly.

Since the WattNode meter 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**

WattNode meters 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. On power up, the demand measurements will report zero until one full demand interval is completed. From 1 to 10 subintervals are supported. A subinterval count of one results in the standard demand measurement without rolling demand. See [Configuration and Diagnostic Objects](#) for information on configuring the demand.

Any changes to the demand configuration ([DemPerMins](#), [DemSubints](#)) or CT configuration ([CtAmpsA](#), [CtAmpsB](#), [CtAmpsC](#), [InvertCtA](#), [InvertCtB](#), [InvertCtC](#)) 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 objects, see the [ZeroDemand](#) object in [Configuration and Diagnostic Objects](#) below.

The demand object values are reported in units of watts.



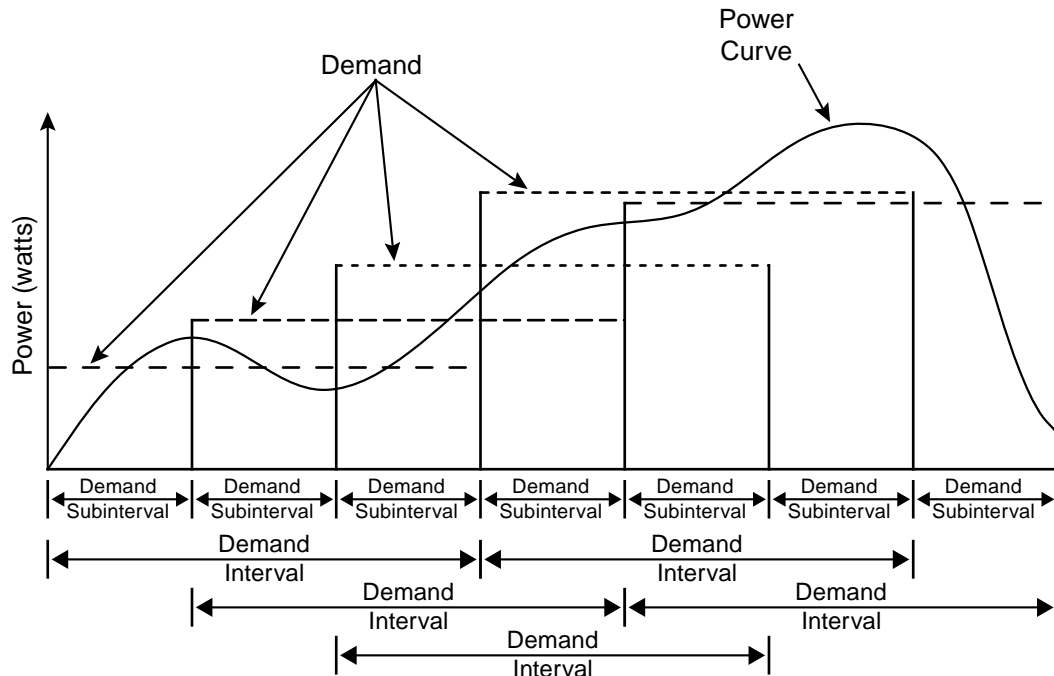


Figure 11: Rolling Demand with Three Subintervals

### ***DemandSum***

The ***DemandSum*** object is updated at the end of every subinterval with the average ***PowerSum*** over a full demand interval. After a power cycle or configuration change, ***DemandSum*** will report zero until the completion of one full demand interval.

### ***DemandA, DemandB, DemandC***

The real power demand is computed for each phase from ***PowerA, PowerB, and PowerC***.

### ***DemandMin***

The ***DemandMin*** is the smallest measured ***DemandSum*** (this may be negative for systems with power generation). It is preserved across power failures and can be reset with the ***ZeroDemand*** object. Note: there are no minimum or maximum demand objects for ***DemandA, DemandB, and DemandC***.

### ***DemandMax***

The ***DemandMax*** is the largest measured ***DemandSum***. It is preserved across power failures and can be reset with the ***ZeroDemand*** object.

### ***DemandApp***

***DemandApp*** is computed the same way as ***DemandSum***, but using the apparent power sum.

## **Configuration and Diagnostic Objects**

### ***ConfigPasscode***

The WattNode BACnet meter 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 meter must be unlocked by writing the correct value to ***ConfigPasscode*** before any configuration objects can be changed and before the energy or demand objects can be reset to zero.

You can read **PasscodeEnabled** object to determine if the meter is locked. You cannot read the actual passcode itself. If you lose your passcode, contact support for assistance. The **PasscodeEnabled** values are:

- **0** - No Passcode
- **1** - Locked
- **2** - Unlocked

Invalid unlock attempts will result in the property error “value-out-of-range” (37), and prevent more attempts for five seconds. An unlocked meter 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 within 30 seconds. If a passcode is already set, the meter must be unlocked first.

Valid passcode values are:

- 0 - this disables the passcode.
- Any floating point value - use at least six digits for a secure passcode.

### **CtAmpsA, CtAmpsB, CtAmpsC**

The CT amps objects are integer objects in units of amps used to set the rated current of the attached current transformers (CTs) on each phase. This allows the use of different CTs on different input phases: **ϕA**, **ϕB**, and **ϕC**. If you are using the same current transformers on all three phases, be sure to set **CtAmpsA**, **CtAmpsB**, and **CtAmpsC** to the same value. Rated current is the 100% value; the current that results in a 0.33333 VAC output from the CT.

You can order the meter from the factory with the CtAmps preconfigured using **Option CT=xxx** or **Option CT=xxx/yyy/zzz** if there are different CTs on phases A, B, and C. For example, **Option CT=100/100/50** sets **CtAmpsA** = 100, **CtAmpsB** = 100, and **CtAmpsC** = 50.

### **InvertCtA, InvertCtB, InvertCtC**

On occasion, current transformers are installed with the “Source” side facing the load instead of the source, or with the white and black wires swapped at the meter. 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 **InvertCtA**, **InvertCtB**, **InvertCtC** objects. Setting any of them to “ACTIVE” (1) will invert the effective polarity for that CT. This has the same effect as reversing the CT on the conductor being measured or swapping the white and black wires.

Flipping a CT with **InvertCtA**, **InvertCtB**, or **InvertCtC** will also reverse the status LED indications. So if the status LED for phase A was flashing red and you flip the CT with **InvertCtA**, the LED will change to green flashing. 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.

### **Wink**

Writing “ACTIVE” (1) to the **Wink** object instructs the meter to display a repeating red, yellow, green flashing pattern on the LEDs. This can be useful if you are trying to identify a particular WattNode meter from a BACnet management tool or software. Set this to “INACTIVE” (0) to turn off the wink pattern.

## Averaging

The WattNode meter includes averaging for these objects: **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 meter 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** object to one of the following values:

Averaging Values	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 7: Averaging Settings

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

## Demand Configuration

### **DemPerMins, DemSubints**

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 10.

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**

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

The default values for the **GainAdjust** objects are 10,000, resulting in no adjustment. Setting the value to 10,200 increases all the power, energy, and current readings from the meter 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**

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** objects allow the phase angle to be adjusted on each phase by up to  $\pm 8$  degrees in increments of one millidegree. For example, if your CT causes a phase lead of 0.6 degrees (or 36 minutes), you could correct for this by setting **PhaseAdjustA, B, and C** to -600, which subtracts 600 millidegree or 0.6 degree from the phase lead. Use negative values to compensate for a phase lead in the CT (most common). The default adjustment is 0.

## CreepLimit

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 meter has no wheel, but all electrical systems have some noise, which can cause small readings in the absence of any power consumption. To prevent readings due to noise, if the readings fall below the creep limit, the meter forces the real and reactive power values to zero, and stops accumulating energy. This is performed independently for each measurement phase using the following equation.

$$\text{MinimumPower} = \text{FullScalePower} / \text{CreepLimit}$$

Any measured power or reactive power below *MinimumPower* is forced to zero. *FullScalePower* is defined as the nominal line-to-neutral VAC (see [Specifications - Models \(p. 49\)](#)) 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 well. Sometime, in electrically noisy environments, you may see non-zero power readings when the power should be zero. You can adjust the creep limit to eliminate this problem. For example, to adjust the creep limit to 1/500th of full-scale (0.2%), set **CreepLimit** to 500.

## PhaseOffset

The WattNode meter cannot directly measure line-to-line voltages (**VoltAB**, **VoltBC**, **VoltAC**, **VoltAvgLL**). To estimate these voltages, the meter must know the circuit type or phase offset of the electrical service being measured. This setting has no effect on any other measurements or objects and is only needed if you plan to monitor the line-to-line voltages.

PhaseOffset Values	Electrical Service Type
0 = Single-Phase	Single-phase (all line-to-line voltages will read zero). Use this setting when monitoring multiple single-phase branch circuits.
1 = 3-Ph Grounded Delta	Three-phase grounded delta (grounded leg), where one phase is connected to earth (rare)
2 = 3-Ph High-Leg Delta	Four-wire delta (wild leg): 120/208/240
3 = 3-Ph Balanced (Default)	Three-phase circuits: 120/208, 230/400, 277/480, 347/600
4 = 1-Ph Center Neutral	Single-phase three-wire (mid-point neutral): 120/240 <b>VoltAB</b> will report the line-to-line voltage. <b>VoltBC</b> and <b>VoltAC</b> will report zero regardless of the actual phase C voltage.

Table 8: PhaseOffset Values

## Zeroing Objects

### RecallDefaults

Writing "ACTIVE" (1) to **RecallDefaults** will return all configuration objects to the factory default state: **CtAmpsA**, **CtAmpsB**, **CtAmpsC**, **DemPerMins**, **DemSubints**, **GainAdjustA**, **GainAdjustB**, **GainAdjustC**, **PhaseAdjustA**, **PhaseAdjustB**, **PhaseAdjustC**, **CreepLimit**, **PtRatio**, **InvertCtA**, **InvertCtB**, **InvertCtC**, **PhaseOffset**, and **Averaging**.

This will not change the accumulated energies, **ConfigPasscode**, **UptimeSecs**, **TotalSecs**, **PowerFailCount**, the calibration, and the **ErrorStatus** objects.

### ZeroEnergy

Writing "ACTIVE" (1) to **ZeroEnergy** will simultaneously set all of the energy objects to zero, except those ending in "NR" (for non-resettable). The energy objects can also be set to zero or a preset value by writing the desired value directly to each energy object. If a **ConfigPasscode** has been set, then you must unlock the meter before you can zero or preset the energy.

The meter will immediately set **ZeroEnergy** back to "INACTIVE", so if you read **ZeroEnergy** it will always report "INACTIVE".

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

### **ZeroDemand**

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

- **1 = Reset Min Max** - Zero **DemandMin** and **DemandMax** registers.
- **2 = Start New Interval** - Zero **Demand**, **DemandA**, **DemandB**, **DemandC** and **DemandApp** registers. Start a new demand interval.
- **3 = Reset and Start** - Zero **DemandMin**, **DemandMax**, **Demand**, **DemandA**, **DemandB**, **DemandC** and **DemandApp** registers. Start a new demand interval.

## **Diagnostic Objects**

### **UptimeSecs**

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

### **TotalSecs**

This 32 bit long integer counts the total seconds of meter operation since factory calibration.

### **PowerFailCount**

This counts the number of times power has failed (cycled) on this meter.

### **BaudRate**

This object reports the current baud rate, based on the DIP switch baud rate setting.

- **0** - 9,600 baud
- **1** - 19,200 baud
- **2** - 38,400 baud
- **4** - 76,800 baud

## **Error Codes**

### **ErrorStatus1 - ErrorStatus8**

**ErrorStatus1** through **ErrorStatus8** list the eight most recent errors. **ErrorStatus1** lists the most recent error or status, while **ErrorStatus8** lists the oldest. Reading these objects won't change the reported values, so they can be read repeatedly without clearing the values. They are preserved across power failures. The following lists many of the error and status code values. For any errors not listed or marked "ERROR" contact technical support.

- **0**: No error or status messages.
- **1**: ERROR: Energy measurement ASIC unexpectedly busy
- **2**: ERROR: Energy measurement data not processed before next sample period
- **3**: ERROR: Transmit buffer to energy measurement ASIC full
- **4**: ERROR: Receive buffer from energy measurement ASIC overflowed
- **5**: ERROR: Energy measurement ASIC data line stuck high
- **6**: ERROR: Energy measurement ASIC data line stuck low
- **7**: ERROR: Energy measurement ASIC reading an invalid line frequency
- **8**: ERROR: Energy measurement ASIC reading an invalid line voltage
- **9**: ERROR: Energy measurement ASIC power reading was invalid (too large)
- **10**: ERROR: Energy measurement ASIC reactive power reading was invalid (too large)

- 11: WARNING: Reached 100% of overvoltage limit
- 12: WARNING: Reached 110% of overvoltage limit
- 13: WARNING: Reached 120% of overvoltage limit
- 14: WARNING: Reached 130% of overvoltage limit
- 15: WARNING: Reached 140% of overvoltage limit
- 16: WARNING: Reached 150% of overvoltage limit
- 17: INFO: ENERGY\_LOWER\_BOUND
- 18: INFO: ENERGY\_UPPER\_BOUND
- 19: INFO: ENERGY\_PHASE\_A\_OVERFLOW
- 20: INFO: ENERGY\_PHASE\_B\_OVERFLOW
- 21: INFO: ENERGY\_PHASE\_C\_OVERFLOW
- 22: INFO: ENERGY\_RESET\_SUM\_OVERFLOW
- 23: INFO: ENERGY\_FIXED\_SUM\_OVERFLOW
- 24: INFO: NEG\_ENERGY\_PHASE\_A\_OVERFLOW
- 25: INFO: NEG\_ENERGY\_PHASE\_B\_OVERFLOW
- 26: INFO: NEG\_ENERGY\_PHASE\_C\_OVERFLOW
- 27: INFO: NEG\_ENERGY\_RESET\_SUM\_OVERFLOW
- 28: INFO: NEG\_ENERGY\_FIXED\_SUM\_OVERFLOW
- 29: INFO: POS\_ENERGY\_PHASE\_A\_OVERFLOW
- 30: INFO: POS\_ENERGY\_PHASE\_B\_OVERFLOW
- 31: INFO: POS\_ENERGY\_PHASE\_C\_OVERFLOW
- 32: INFO: POS\_ENERGY\_RESET\_SUM\_OVERFLOW
- 33: INFO: POS\_ENERGY\_FIXED\_SUM\_OVERFLOW
- 34: INFO: REAC\_ENERGY\_LOWER\_BOUND
- 35: INFO: REAC\_ENERGY\_UPPER\_BOUND
- 36: INFO: REAC\_ENERGY\_PHASE\_A\_OVERFLOW
- 37: INFO: REAC\_ENERGY\_PHASE\_B\_OVERFLOW
- 38: INFO: REAC\_ENERGY\_PHASE\_C\_OVERFLOW
- 39: INFO: REAC\_ENERGY\_SUM\_OVERFLOW
- 40: INFO: APP\_ENERGY\_LOWER\_BOUND
- 41: INFO: APP\_ENERGY\_UPPER\_BOUND
- 42: INFO: APP\_ENERGY\_PHASE\_A\_OVERFLOW
- 43: INFO: APP\_ENERGY\_PHASE\_B\_OVERFLOW
- 44: INFO: APP\_ENERGY\_PHASE\_C\_OVERFLOW
- 45: INFO: APP\_ENERGY\_SUM\_OVERFLOW
- 46: ERROR: FLASH\_BUSY
- 47: ERROR: RS485\_TX\_BYTE\_COUNT
- 48: ERROR: RS485\_TX\_COLLISION
- 49: ERROR: RS485\_UART\_OVERRUN
- 50: ERROR: RS485\_UART\_FRAMING
- 51: ERROR: RS485\_FRAME\_SIZE
- 52: ERROR: RS485\_HEADER\_CRC
- 53: ERROR: RS485\_DATA\_CRC
- 54: ERROR: RS485\_FRAME\_ABORT\_TIME

- 55: ERROR: RS485\_UART\_SOURCE
- 56: ERROR: RS485\_RX\_FIFO\_FULL
- 57: ERROR: RS485\_FRAME\_INVALID\_TYPE
- 58: ERROR: DATALINK\_TX\_FIFO\_FULL
- 59: ERROR: DATALINK\_TX\_LENGTH
- 60: ERROR: AUTO\_CONFIG\_CASE
- 61: ERROR: UPDATE\_LED\_CASE
- 62: ERROR: NORMAL\_LED\_CASE
- 63: ERROR: OVER\_VOLT\_LED\_CASE
- 64: ERROR: LOW\_POWER\_LED\_CASE
- 65: ERROR: NO\_LINE\_VOLT\_LED\_CASE
- 66: ERROR: NO\_FLASH\_LED\_CASE
- 67: ERROR: STARTUP\_LED\_CASE
- 68: ERROR: POST\_LED\_CASE
- 69: ERROR: ILLUMINATE\_LED\_CASE
- 70: ERROR: SET\_LED\_COLOR\_CASE
- 71: ERROR: PHASE\_ACTIVE\_CASE
- 72: ERROR: LINE\_TO\_LINE\_CASE
- 73: ERROR: GPIO\_INTERRUPT\_CASE
- 74: ERROR: AVERAGING\_PERIOD\_GT\_MAX
- 75: ERROR: AVERAGING\_PERIOD\_LT\_MIN
- 76: ERROR: USE\_DEFAULT\_CAL
- 77: ERROR: USE\_DEFAULT\_USER\_CONFIG
- 78: ERROR: WRITE\_PRIMARY\_CAL
- 79: ERROR: WRITE\_BACKUP\_CAL
- 80: ERROR: ERASE\_BACKUP\_SECTOR
- 81: ERROR: SAVED\_PARAMETER\_BAD\_CRC
- 82: ERROR: NO\_SAVED\_OBJECTS
- 83: INFO: CAL\_PASSCODE\_TIMEOUT\_ACCESS
- 84: INFO: USER\_PASSCODE\_TIMEOUT\_ACCESS
- 85: INFO: BACKDOOR\_PASSCODE\_TIMEOUT\_ACCESS
- 86: INFO: INVALID\_CAL\_PASSCODE
- 87: INFO: INVALID\_USER\_PASSCODE
- 88: INFO: INVALID\_BACKDOOR\_PASSCODE
- 89: INFO: DENIED\_CAL\_ACCESS
- 90: INFO: DENIED\_USER\_CONFIG\_ACCESS
- 91: WARNING: OBJECT\_NOT\_WRITABLE
- 92: ERROR: GPIO\_FALL\_EDGE\_INT
- 93: ERROR: GPIO\_RISE\_EDGE\_INT
- 94: ERROR: POWER\_FAIL\_STUCK
- 95: ERROR: FLASH\_SIGNATURE
- 96: ERROR: SET\_VALUE\_MIN\_BOUND
- 97: ERROR: SET\_VALUE\_MAX\_BOUND
- 98: ERROR: SET\_INVALID\_VALUE

- **99:** ERROR: WRITE\_FILE\_SIZE
- **100:** ERROR: FILE\_WRITE\_OVERRUN
- **101:** ERROR: FILE\_IMAGE\_SIZE\_ZERO
- **102:** ERROR: FILE\_SIGNATURE
- **103:** ERROR: BAD\_PRIMARY\_FLASH\_SECTOR
- **104:** ERROR: BAD\_BACKUP\_FLASH\_SECTOR
- **105:** ERROR: WRITE\_USER\_CONFIG\_FAILED
- **106:** ERROR: WRITE\_CALIBRATION\_FAILED
- **107:** ERROR: ERROR\_QUEUE\_OVERFLOW
- **108:** WARNING: UNKNOWN\_OBJECT
- **109:** WARNING: UNKNOWN\_PROPERTY
- **110:** WARNING: UNSUPPORTED\_OBJECT\_TYPE
- **111:** WARNING: VALUE\_OUT\_OF\_RANGE
- **112:** ERROR: WRITE\_ACCESS\_DENIED
- **113:** ERROR: ACCESS\_FIRMWARE\_FLASH
- **114:** ERROR: CAL\_FLASH\_ACCESS
- **116:** ERROR: EXTERNAL\_RESET
- **117:** ERROR: A serious error caused a watchdog reset
- **118:** INFO: A line power brownout condition caused a meter reset
- **119:** ERROR: UNKNOWN\_RESET
- **120:** ERROR: An RS-485 parity error was detected. This should not occur because parity is not used with BACnet MS/TP.
- **121:** INFO: An RS-485 break condition was detected on the bus
- **123:** INFO: A power failure was detected
- **124:** ERROR: SPI\_ISR\_MAX\_BYTES
- **125:** ERROR: A serious error caused a software reset

## Maintenance and Repair

The WattNode BACnet meter requires no maintenance. There are no user serviceable or replaceable parts except the pluggable screw terminals.

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

The WattNode meter is not user serviceable. In the event of any failure, the meter must be returned for service (contact CCS for an RMA). In the case of a new installation, follow the diagnostic and troubleshooting instructions before returning the meter for service, to ensure that the problem is not connection related.



# Specifications

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## Models

Model	Nominal Vac Line-to-Neutral	Nominal Vac Line-to-Line	Phases	Wires
WNC-3Y-208-BN	120	208–240	3	4
WNC-3Y-400-BN	230	400	3	4
WNC-3Y-480-BN	277	480	3	4
WNC-3Y-600-BN	347	600	3	4
WNC-3D-240-BN	120*	208–240	3	3–4
WNC-3D-400-BN	230*	400	3	3–4
WNC-3D-480-BN	277*	480	3	3–4

\*Note: the delta models have an optional neutral connection that may be used for measuring wye circuits. In the absence of neutral, voltages are measured with respect to ground. Delta WattNode models use the phase A and phase B connections for power.

**Table 9: WattNode Models**

## Model Options

Any of these models are available with the following options. See the CCS website [WattNode BACnet - Options](#) page for details.

## General Options

**Option CT=xxx:** Pre-assign xxx as the global **CtAmps** value of the attached current transformers.

**Option CT=xxx/yyy/zzz:** Pre-assign xxx to **CtAmpsA**, yyy to **CtAmpsB**, and zzz to **CtAmpsC**. This is used if non-matching CTs are connected to different phases.

## Accuracy

The following accuracy specifications do not include errors caused by the current transformer accuracy or phase angle errors. “Rated current” is the current that generates a CT output voltage of 0.33333 Vac.

### Condition 1 - Normal Operation

**Line voltage:** -20% to +15% of nominal

**Power factor:** 1.0

**Frequency:** 48 - 62 Hz

**Ambient Temperature:** 25°C

**CT Current:** 5% - 100% of rated current

**Accuracy:** ±0.5% of reading

### Condition 2 - Low CT Current

All conditions the same as Condition 1 except:

**CT Current:** 1% - 5% of rated current

**Accuracy:** ±1.0% of reading

### Condition 3 - Very Low CT Current

All conditions the same as Condition 1 except:

**CT Current:** 0.2% - 1% of rated current

**Accuracy:** ±3.0% of reading

#### **Condition 4 - High CT Current**

All conditions the same as Condition 1 except:

**CT Current:** 100% - 120% of rated current

**Accuracy:**  $\pm 1.0\%$  of reading

#### **Condition 5 - Low Power Factor**

All conditions the same as Condition 1 except:

**Power factor:** 0.5 ( $\pm 60$  degree phase shift between current and voltage)

**Additional Error:**  $\pm 0.5\%$  of reading

#### **Condition 6 - Temperature Variation**

All conditions the same as Condition 1 except:

**Ambient Temperature:**  $-30^{\circ}\text{C}$  to  $+55^{\circ}\text{C}$

**Additional Error:**  $\pm 0.75\%$  of reading

## **Measurement**

**Creep Limit:** 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, the output power for the phase will be set to zero. These limits prevent spurious readings due to measurement noise. To customize the creep limit, see **CreepLimit** in **Configuration and Diagnostic Objects**.

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

**Start-Up Time:** Approximately 1.0 second. The meter 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 meter does not respond to BACnet packets during this start-up time.

**Default Current Transformer Phase Angle Correction:** 0.0 degrees The CT phase angle correction can be changed using the **PhaseAdjustA**, **PhaseAdjustB**, **PhaseAdjustC** registers.

**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 meter and void the warranty. See **Line Voltage Too High** (p. 24).

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

## **BACnet Communication**

**Protocol:** BACnet MS/TP

**Baud Rates:** 9600, 19200, 38400, and 76800

**Duplex:** Half (two-wire plus common)

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

**BACnet Buffer:** 512 bytes (480 byte maximum APDU)

**Communication Response Time:** 5 - 25 milliseconds

**EIA RS-485 Interface:**

**RS-485 Output Isolation:** 4500 Vac RMS

**Driver Output Voltage (Open Circuit):**  $\pm 6$  Vdc maximum

**Driver Output Voltage (54  $\Omega$  load):**  $\pm 1.5$  Vdc minimum

**Driver Output Current (54  $\Omega$  load):**  $\pm 60$  mA typical

**Driver Output Rise Time (54  $\Omega$  || 50 pF load):** 900 nS typical

**Receiver Common-Mode Voltage Range:** -7 Vdc to +12 Vdc maximum

**Receiver Sensitivity:** ±200 mV

**Receiver Bus Load:** 1/8 unit load (up to 64 WattNode meters per subnet)

**Receiver Failsafe Modes:** bus open, bus shorted, bus idle

## BACnet Protocol Implementation Conformance Statement (PICS)

**Date:** March 30, 2012

**Vendor Name:** Continental Control Systems, LLC

**Product Name:** WattNode BACnet

**Product Model Number:** WNC-3Y-208-BN, WNC-3Y-400-BN, WNC-3Y-480-BN,  
WNC-3Y-600-BN, WNC-3D-240-BN, WNC-3D-400-BN, WNC-3D-480-BN

**Application Software Version:** 1.0

**Firmware Revision:** 1.03

**BACnet Protocol Revision:** 10

**Product Description:** Three-phase electric power transducer with BACnet MS/TP

### BACnet Standardized Device Profile (Annex L)

**BACnet Application Specific Controller (B-ASC)**

**BACnet Smart Sensor (B-SS)**

The WattNode BACnet is primarily a smart sensor (B-SS), but also includes the characteristics of an application specific controller (B-ASC).

### List all BACnet Interoperability Building Blocks Supported (Annex K)

**DS-RP-B:** Data Sharing - ReadProperty - B

**DS-RPM-B:** Data Sharing - ReadPropertyMultiple - B

**DS-WP-B:** Data Sharing - WriteProperty - B

**DM-DDB-B:** Device Management - Dynamic Device Binding - B (Who-Is, I-Am)

**DM-DOB-B:** Device Management - Dynamic Object Binding - B (Who-Has, I-Have)

### Segmentation Capability

Segmentation not supported

### Standard Object Types Supported

No objects support CreateObject or DeleteObject services.

#### Device

**Optional Properties:** Location (30 characters), Description (30 characters), Max\_Master, Max\_Info\_Frames

**Writable Properties:** Object\_Identifier, Location, Description, Max\_Master, Max\_Info\_Frames

#### Analog Input

**Proprietary Properties:** Integer\_Value (1000); Integer data type; units of 0.1 kilowatt hours; this property appears in all energy objects including reactive and apparent energy.

#### Analog Value

**Proprietary Properties:** Error\_Timestamp (2000); Unsigned data type; units of seconds; this appears in **ErrorStatus** objects and is the value of TotalSecs when the error occurred.

**Writeable Properties:** The Present\_Value property of the objects: ConfigPasscode, CtAmpsA, CtAmpsB, CtAmpsC, DemPerMins, DemSubints, GainAdjustA, GainAdjustB, GainAdjustC, PhaseAdjustA, PhaseAdjustB, PhaseAdjustC, CreepLimit, PtRatio

### Property Range Restrictions:

- The Present\_Value of CtAmpsA, CtAmpsB, and CtAmpsC is limited to 1 to 60000 amps.
- The Present\_Value of DemPerMins is limited to 1 to 720 minutes.
- The Present\_Value of DemSubints is limited to 1 to 10.
- The Present\_Value of GainAdjustA, GainAdjustB, and GainAdjustC is limited to 5000 to 20000.
- The Present\_Value of PhaseAdjustA, PhaseAdjustB, and PhaseAdjustC is limited to -8000 to 8000.
- The Present\_Value of CreepLimit is limited to 100 to 10000.
- The Present\_Value of PtRatio is limited to 0.05 to 300.

### Binary Value

**Writeable Properties:** The Present\_Value property of the objects: InvertCtA, InvertCtB, InvertCtC, ClearErrors, ZeroEnergy, RecallDefaults

### Multi-State Value

**Optional Properties:** State\_Text; array of descriptions of each possible state

**Writeable Properties:** The Present\_Value property of the objects: PhaseOffset, Averaging, ZeroDemand.

## Data Link Layer Options

MS/TP master (Clause 9), baud rate(s): 9600, 19200, 38400, and 76800

## Device Address Binding

Static device binding is not supported

## Networking Options

None

## Character Sets Supported

ANSI X3.4

## Electrical

**Power Consumption:** The following table shows typical power consumption and power factor values with all three phases powered at nominal line voltages. The 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, WattNode meters draw slightly more power at 50 Hz.

Model	Real Power (60 Hz)	Real Power (50 Hz)	Power Factor	Rated VA <sup>(1)</sup>	Power Supply Range (Vac)	Power Supply Terminals
WNC-3Y-208-BN	1.5 W	1.8 W	0.79	4 VA	96 – 138	<b>N</b> and <b>ΦA</b>
WNC-3Y-400-BN	1.6 W	1.8 W	0.73	4 VA	184 – 264	<b>N</b> and <b>ΦA</b>
WNC-3Y-480-BN	1.6 W	2.0 W	0.69	4 VA	222 – 318	<b>N</b> and <b>ΦA</b>
WNC-3Y-600-BN	1.0 W	1.3 W	0.76	4 VA	278 – 399	<b>N</b> and <b>ΦA</b>
WNC-3D-240-BN	1.2 W	1.5 W	0.70	4 VA	166 – 276	<b>ΦA</b> and <b>ΦB</b>
WNC-3D-400-BN	1.1 W	1.4 W	0.67	3 VA	320 – 460	<b>ΦA</b> and <b>ΦB</b>
WNC-3D-480-BN	1.2 W	1.6 W	0.70	3 VA	384 – 552	<b>ΦA</b> and <b>ΦB</b>

**Table 10: Power Supply Characteristics**

<sup>(1)</sup>Note: This is the maximum at 115% of nominal Vac at 50 Hz. This is the same as the value that appears on the front label of the meter.

**Maximum Power Supply Voltage Range:** -20% to +15% of nominal (see table above). For the WNC-3D-240-BN, this is -20% of 208 Vac (166 Vac) to +15% of 240 Vac (276 Vac).

**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 meter are rated for the following CAT III voltages (these ratings also appear on the front label):

Model	CAT III Voltage Rating
WNC-3Y-208-BN WNC-3D-240-BN	240 Vac
WNC-3Y-400-BN WNC-3D-400-BN	400 Vac
WNC-3Y-480-BN WNC-3D-480-BN	480 Vac
WNC-3Y-600-BN	600 Vac

**Table 11: WattNode CAT III Ratings**

**Current Transformer Inputs:**

**Nominal Input Voltage (At CT Rated Current):** 0.33333 Vac RMS

**Absolute Maximum Input Voltage:** 5.0 Vac RMS

**Input Impedance at 50/60 Hz:** 23 k $\Omega$

## Certifications

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

**Immunity:** EN 61326: 2002 (Industrial Locations)

**Electrostatic Discharge:** EN 61000-4-2: 4 kV contact, 8 kV air: (B) Self-Recovering

**Radiated RF Immunity:** EN 61000-4-3: 10 V/m: (A) No Degradation

**Electrical Fast Transient / Burst:** EN 61000-4-4: 2 kV: (B) Self-Recovering

**Surge Immunity:** EN 61000-4-5: 1 kV I/O, 4 kV AC: (B) Self-Recovering

**Conducted RF Immunity:** EN 61000-4-6: 3 V: (A) No Degradation

**Voltage Dips, Interrupts:** EN 61000-4-11: (B) Self-Recovering

**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:** non-condensing, 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 (IP 66).

## Mechanical

**Enclosure:** High impact, ABS and/or ABS/PC plastic

**Flame Resistance Rating:** UL 94V-0, IEC FV-0

**Size:** 153 mm × 85 mm × 38 mm (6.02 in × 3.35 in × 1.50 in)

**Weight:** 314 gm (11.1 oz)

**Connectors:** Euroblock style pluggable terminal blocks

**Green:** up to 12 AWG (2.5 mm<sup>2</sup>), 600 V

**Black:** up to 12 AWG (2.5 mm<sup>2</sup>), 300 V

## Current Transformers

WattNode meters use CTs with built-in burden resistors generating 0.33333 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, but should not harm the meter.

None of these CTs measure DC current and the accuracy can be degraded in the presence of DC currents, as from half-wave rectified loads.

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

### Common CT Specifications

**Type:** voltage output, integral burden resistor

**Output Voltage at Rated Current:** 0.33333 Vac (one-third volt)

**Standard CT Wire Length:** 2.4 m (8 feet)

**Optional CT Wire Length:** up to 30 m (100 feet)

### Split-Core CTs

Also called “opening” current transformers. These are UL recognized under UL file numbers E96927 or E325972: CTM-0360-**xxx**, ACT-0750-**xxx**, CTS-0750-**xxx**, CTS-1250-**xxx**, CTS-2000-**xxx**, where **xxx** indicates the full scale current rating between 0005 and 1500 amps.

The accuracy of the split-core CTs are generally specified from 10% to 100% of rated AC current. The phase angle is specified at 50% of rated current (amps). Some low current split-core CTs have unspecified phase angle errors.

Model	Inside Diameter	Rated Amps (-xxx)	Accuracy / Phase Angle	Maximum Amps
CTM-0360-xxx	0.30" (7.5 mm)	5, 15, 30, 50, 70	±1% / <2°	100
ACT-0750-xxx	0.78" (20.0 mm)	5, 20, 50, 100, 200, 250 <sup>(1)</sup>	±0.75% / ±0.5° <sup>(2,3)</sup>	400
CTS-0750-xxx	0.75" (19.0 mm)	5, 15, 30, 50	±1% / not spec.	200
CTS-0750-xxx	0.75" (19.0 mm)	70, 100, 150, 200	±1% / <2°	200
CTS-1250-xxx	1.25" (31.7 mm)	70, 100	±1% / not spec.	600
CTS-1250-xxx	1.25" (31.7 mm)	150, 200, 250, 300, 400, 600	±1% / <2°	600
CTS-2000-xxx	2.00" (50.8 mm)	600, 800, 1000, 1200, 1500	±1% / <2°	1500

**Table 12: Split-core CTs**

<sup>(1)</sup>Non-stock models are available with 15, 30, 75, and 150 rated amps.

<sup>(2)</sup>The ACT-0750 (Accu-CT™) model accuracy applies from 1% to 100% of rated AC current.

<sup>(3)</sup>Option C0.6 Accuracy: Accuracy ±0.50%, Phase Angle ±0.25°

## Split-Core Bus Bar CTs

These current transformers are 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 (amps).

Model	Opening	Rated Amps	Accuracy / Phase Angle	Maximum Amps
CTB-1.5x3.5-0600	1.5" x 3.5" (38.1 mm x 88.9 mm)	600	±1.5% / <1.5°	750
CTB-4.0x4.0-0800	4.0" x 4.0" (101.6 mm x 101.6 mm)	800	±1.5% / <1.5°	1000
CTB-4.0x4.0-1200	4.0" x 4.0" (101.6 mm x 101.6mm)	1200	±1.5% / <1.5°	1500
CTB-4.0x4.0-2000	4.0" x 4.0" (101.6 mm x 101.6 mm)	2000	±1.5% / <1.5°	2500
CTB-4.5x4.0-3000	4.5" x 4.0" (114.3 mm x 101.6 mm)	3000	±1.5% / <1.5°	3750
CTB- <b>wwwxhhh-xxxx</b>	Custom ( <b>www</b> by <b>hhh</b> inches)	<b>xxxx</b>	±1.5% / <1.5°	4000

**Table 13: 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 100% of rated current. The phase angle error is specified at 50% of rated current. 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 (-xxx)	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 14: Solid-core CTs**

## Warranty

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All products sold by Continental Control Systems, LLC (CCS) are guaranteed against defects in material and workmanship for a period of five years from the original 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, product modifications, alterations 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.**

## Limitation of Liability

In no event shall CCS be liable for any indirect, special, incidental, punitive or consequential damages of any kind or nature arising out of the sale or use of its products whether such liability is asserted on the basis of contract, tort or otherwise, including without limitation, lost profits, even if CCS has been advised of the possibility of such damages.

Customer acknowledges that CCS's aggregate liability to Customer relating to or arising out of the sale or use of CCS's products, whether such liability is asserted on the basis of contract, tort or otherwise, shall not exceed the purchase price paid by Customer for the products in respect of which damages are claimed. Customer specifically acknowledges that CCS's price for the products is based upon the limitations of CCS's liability set forth herein.