ENERNET
Corporation

K20 ENERGY
SURVEY METER/RECORDER

INSTALLATION MANUAL

Connection Diagrams

Rev. Date November 2000

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1.0 INTRODUCTION

The model K20 family of meter/recorders consists of integrated power measurement and data recording instruments. Used extensively by utilities, energy service companies, government and industry to accurately and comprehensively measure and record, AC electrical energy, the K20 is ideal for residential, commercial and industrial electric power metering applications, as well as measuring parameters such as temperature, flow run time, rate and status.

This manual comprises the installation procedures and a basic technical description of the Highland Technology K20 electrical meter/recorder, manufactured and sold by ENERNET Corporation. Please read this manually carefully before making any connections to the K20 meter/recorder.

A PC program called KTOOLS provides a user interface to the K20 energy recorder. KTOOLS is used to configure the recorder's power, analog and digital counter channels to collect data in the specific fashion intended by the user. KTOOLS is available free of charge and can be downloaded from our web site, www.enernetcorp.com. If you do not have Internet access, contact the ENERNET Corporation and a copy of this software can be mailed to you.

All inquiries regarding technical, application and sales of the K20 recorder should be directed to:

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Written questions can be e-mailed to Technical Services or Sales through the ENERNET Corporation web page as well.

2.0 PRODUCT DESCRIPTION

The K20 is intended for use in residential and commercial building electrical end-use survey research projects. The features of the K20 make it well suited to an expanding market in utility load research and demand-side power use verification.

2.1 FEATURES

In order to reduce the K20 programming and processing load and to increase the efficiency of communications, all data averaging operations are performed outside the K20 recorder at the central station computer (PC). The recorder contains enough space in non-volatile memory to COMPLETELY define the nature of the data that it is collecting. A front-end security system ensures that the network is protected against intrusion.

2.1.1 Low Voltage Panels

All signals leaving the Potential Transducer box (PT) connected to the K20 termination panel are less than 30 VAC.

The K20 processor board itself is powered from a 24VAC or 24VDC input. The 24VAC can be supplied by a bell type transformer with primary voltage rating for just about any type of electrical service (15 VA required).

2.1.2 Local Display and Installation Debugging

The K20-3 and the K20-4 have an 8-character vacuum fluorescent display, which can be used for initial installation debugging. Power (KW), line current (AMPS), line voltage (VOLTS), and power factor (PF), ANALOG and DIGITAL channels are displayed in real-time as the channels are connected.

The real-time variables are updated every 9.5 seconds on the K20 display. The power and current variables are signed which, can indicate CT orientation problems. In addition to a reasonableness check on the power, technicians can also use real-time power factor to categorize end uses.

The local display also shows the actual voltage read by the analog subsystem as well as an accumulator on each of the digital channels. Both of these quantities are unscaled, with units of volts or counts. Readings of the AC line voltage potentials are available on the display. Important system parameters such as the system date and time, serial number, and descriptive text are displayed as well.

2.1.3 Power Factor and Voltage Time Series Readings

The K20 is able to store time series apparent power readings (KVA) in addition to real power readings. The quotient of these two gives the average power factor over the interval. Average line voltage and line current are also available for storage in a time series.

The kW variables are signed with zero offsets. This is important for odd service types where net reverse current can be applied to a CT (i.e., corner grounded delta systems or welders on wild leg systems).

2.1.4 Data Compression

The method of data compression used in the K20 necessitates only a minimal requirement for storage space for large signed integer numbers and enhances the speed of data retrieval. The selected format maintains 0.1% of reading resolution for numbers between minus 67 million to plus 67 million.

2.1.5 Binary Data Communication Protocol

A binary packet communications protocol is used for the K20. Each transmission packet has a 16-bit cyclic redundancy check (CRC) code to ensure error-free communications.

2.1.6 System Security

All commands capable of altering the K20 operations are protected from unauthorized execution by the use of a 32-bit binary password. In the unlikely event that the password is compromised, it is possible to download a new operating password by the use of a guarded "master password". The master password is protected by a trapdoor function to prevent its being decipherable by examination of K20 program binary or source code.

2.1.7 Fault Tolerance

All system parameters and time-series data are stored in non-volatile static RAM. In addition, the system is equipped with a battery backed real-time clock. The K20 is able to recover from power failures and continue collecting sequenced time series data.

3.0 THEORY OF OPERATION

The K20 Energy Survey Meter/Recorders are intended to provide accurate acquisition of AC voltage, current, power, and energy levels. The application of modern sampled-data digital signal processing (DSP) technologies to AC measurement requires careful analysis and design to ensure that the reported data is accurate and consistent with the measurements of classical electrodynamic instruments. This section explains the basic measurement techniques used in the Series K20 instruments.

3.1 LOGICAL MEASUREMENT AND POWER CHANNELS

A K20 provides eight or sixteen logical "measurement channels"; each channel is associated with a single current transformer (CT) and a single potential input. The K20 may be connected to one or two 4-lead Potential Transducers, which are connected to the voltage lines to be measured. When a K20 parameter set is defined, each measurement channel is associated with a current transformer and a PAIR of potential leads, one lead being the "high side" of the voltage to be measured, and the other lead the "low side." The K20 allows any CT to be assigned to any of the available logical measurement channels. The four Potential Transducer leads are commonly connected to the A:B:C:N leads of a three-phase power circuit, allowing ANY line-to-neutral or line-to-line potential to be the "measured voltage" associated with a measurement channel. A schematic diagram of the interconnections in a K20 power metering system is shown in Figure 1.

A K20 also provides eight or sixteen logical "power channels", each can be considered a "virtual watt-meter" capable of multiple input circuits. From one to six input measurement channels can be logically "connected" to a power channel. For example, a single measurement channel can drive a single power channel to provide single-phase power measurements, or three separate input channels can drive a single power channel to provide a three-phase power measurement.

This versatile "logical channels" structure allows the K20 to meter a wide variety of source:load situations. For example, a single 3-phase, 4-wire system might be symmetric or unbalanced with respect to neutral, and it may be connected to a mixture of single-phase, delta, and WYE-connected loads. With a single 4-wire potential connection and an appropriate selection of current transformers, the K20 can simultaneously meter all parameters of each of the load branches, providing measurements, which are appropriate to each load type.

3.2 POWER REGISTERS

Each power channel of a K20 has an associated power register (PW). The power register integrates the TRUE RMS POWER real-time variable into the power register. Remember, up to six input measurement channels (CT: voltage pairs) may be summed into any desired power channel, so up to six CT-derived power levels can sum to drive one power register. The power register is "ratcheted" such that it will only count up, and ceases counting if the net power of the related input measurement channels is zero or negative.

Please note that it is possible to separately meter the forward and reverse kWh of a bi-directional inter-tie circuit, using a separate power register for each direction.

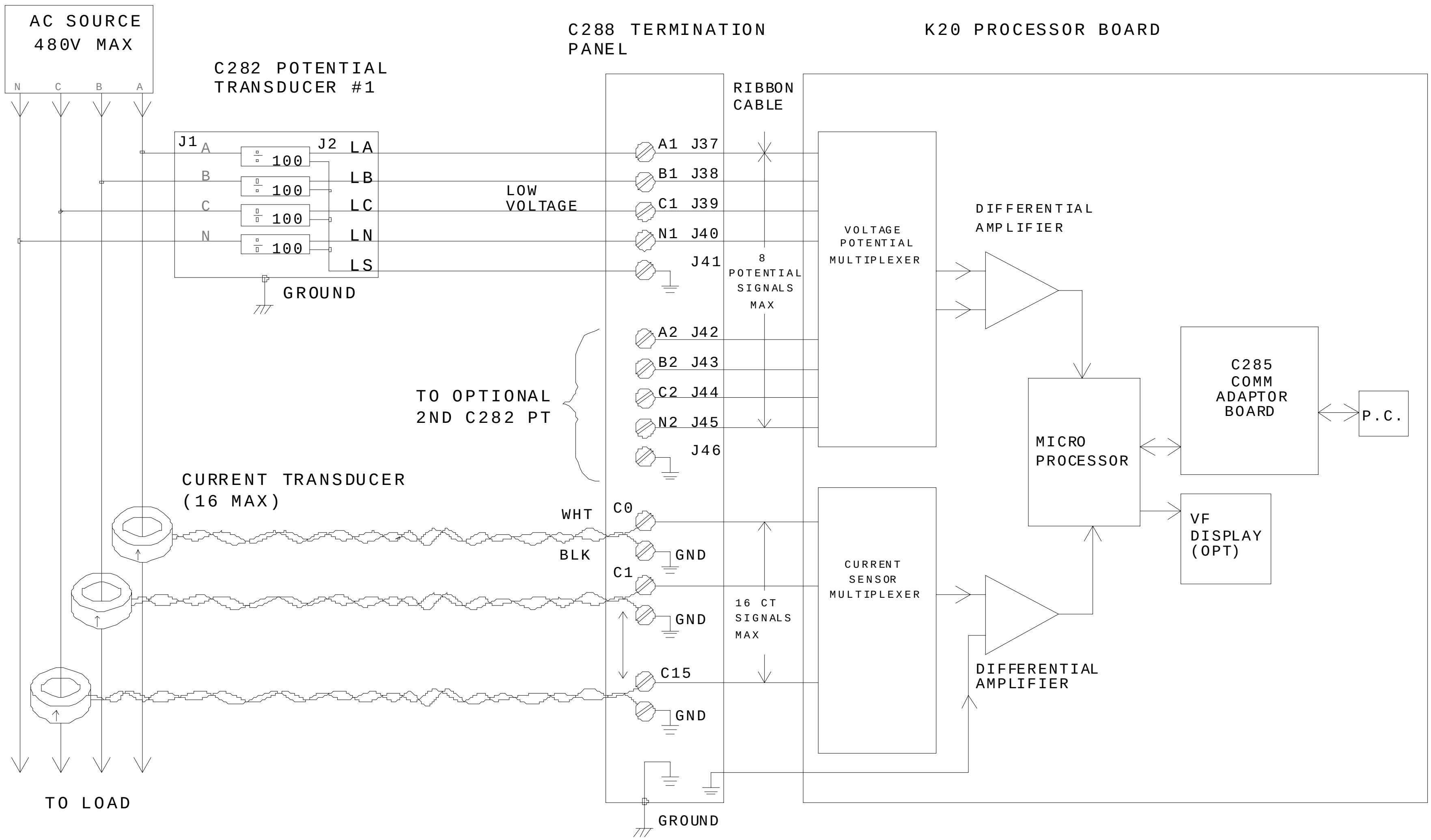


Figure 1 — K20 Interconnection Schematic

3.3 MEASUREMENT ALGORITHMS

The measurement algorithm used by the K20 is as follows:

For each of the defined measurement channels, the selected current transformer signal and the selected potential difference signal are periodically and simultaneously sampled and digitized, giving a pair of “frozen” instantaneous current and voltage values. The sample pair is digitally processed as follows:

Each current sample is squared and summed into the "Sigma I" value.

Each voltage sample is squared and summed into the "Sigma E" value.

Each voltage:current sample pair is multiplied and summed into the "Sigma P" value in the associated power register.

This procedure is repeated until a larger number of samples have been processed. Then...

Sigma I is square rooted to give true RMS amps; this result is posted as the real-time TRUE RMS CURRENT for this measurement channel.

Sigma E is square rooted to give true RMS volts; this result is posted as the real-time TRUE RMS VOLTAGE for this measurement channel.

Sigma P is scaled to give true RMS power; this is posted as the real-time TRUE RMS POWER value for each power channel. The power value is fully bipolar, indicating positive and negative power flows properly.

All Sigmas are cleared for the next set of measurements.

For all input measurement channels which “feed” any given power channel, the apparent power from each channel, TRMS AMPS * TRMS VOLTS, is computed, and all such products are summed to give the APPARENT POWER ("KVA") real-time variable for that power channel.

The POWER FACTOR for each power channel is computed as REAL POWER divided by APPARENT POWER of that channel.

Thus a new set of “real-time” true RMS voltage, current, power, KVA, and PF values is computed periodically. These “fresh” values are immediately available for presentation on the K20 local display panel, and are remotely readable over the serial communications interface using the READ REAL-TIME DATA facility.

The K20 posts a new set of true RMS electrical measurements approximately every 9.5 seconds.

3.4 SAMPLING AND FILTERING

The algorithm described is, on the surface, precisely identical to the processing used by continuous (analog) signal processors to deliver the same results. In fact, it is identical to the “signal processing” used by classic electrodynamic instruments. The only difference is that the input waveforms are sampled and digitally processed, rather than being continuously processed. The K20 sampling rate was chosen to ensure accurate measurement of waveforms containing frequency components up to the 50th line harmonic, and up to an AC line frequency of over 100 Hz. Advanced signal processing and filtering techniques are used in all K20 energy metering products to deliver accurate measurements for the ranges of signals found in real AC power systems.

3.5 TIME-SERIES RECORDS

The K20 may be configured to record data blocks called time-series records (TSR) according to a user-definable schedule. A TSR is a data record which contains a header (tagging the time, date, and reason for posting the TSR) and any number of selected measured values. TSRs are stored in nonvolatile memory, with up to 1 Mbyte of TSR storage available on the K20. Users may enable any number of candidate variables to be included in the TSR records, by selecting any items from the following list:

Input	K20 8 Ch.	K20 16 Ch.
Voltage inputs	0 to 7	0 to 15
Current inputs	0 to 7	0 to 15
Power channels	0 to 7	0 to 15
KVA channels	0 to 7	0 to 15
KWH channels	0 to 7	0 to 15
Analog inputs	0 to 7	0 to 14
Counters	0 to 7	0 to 15

The user merely selects which items are of interest, arranges the TSR time schedule, and then allows the K20 to “trend” the selected items. Power factors are not included in TSRs, but are easily computed from power and KVA values.

3.6 SOURCES OF ERROR

Several sources of error should be considered in applying the K20 meter/recorders. They include:

1. CURRENT SENSOR ERRORS. The standard current sensors provided with the K20 are typically accurate to about 0.5% (amplitude) and 0.5 degrees (phase), so these sensors are the dominant error contributors in a typical system. These sensors, like most current transformers, show increased phase shift at low currents (say, below 10% of full scale). If higher accuracy is needed, special high-precision current sensors are available. Metering grade, 5-amp secondary CTs are available with ANSI ratings to 0.1% accuracy, and these may be used with precision 0.05-ohm burden resistors as current sensors for the K20.

2. STRAY PICKUP. Since K20 current inputs are usually 333.3 mV AC for full-scale current, low current levels correspond to very low signal levels. A current of 1% of full scale corresponds to only 3.333 millivolts, and a 1% error of this voltage is only 33.3 microvolts. The parts-per-million zero offset accuracy of the K20 can be degraded by microvolt-level hum pickups. To avoid microvolt-level errors, the following precautions are suggested:

A. Use toroidal (as opposed to removable-link) current transformers whenever possible. Removable-link CTs can pick up signals from current-carrying conductors that are outside the sense loop. If split-core sensors are used, keep them away from other current-carrying lines or transformers.

B. Ensure that current sensor leads are tightly and uniformly twisted, and that the signal leads are not run near or parallel to current-carrying conductors or near transformers. Additionally, properly sizing CTs to their loads will ensure that the problem of low level noise interference is negligible.

C. To avoid ground loops, do not ground CT leads anywhere except at the C288 termination panel.

D. SENSOR OVERLOAD. Measurement errors can result from overload of current signal inputs. If a current sensor is rated at "N" amps, the instantaneous current level through the sensor should not exceed 2N amps. Since very distorted waveforms may have high peak-to-average ratios, it may be advisable to use a higher-rated CT to measure currents, which may have high peak values.

E. CIRCULATING DC. Current transformers may lose accuracy if the measured current contains a significant DC component, such as might be created by a half-wave rectified load or asymmetric SCR circuits. If DC is suspected to be present in the circuit, it should be measured with a DC ammeter, and CT specifications checked for compatibility. Note that a DC current component contributes no real power so long as the line voltage remains pure AC.

4.0 HARDWARE

The K20 survey recorder consists of the following hardware elements:

1. ENCLOSURE: NEMA 4X polycarbonate enclosure with hinged door and pin lock.
   Approx. Dimensions: 14.5″ h x 12.00″ w x 7.00″ d.
2. PROCESSOR: The K20 central processor is a single-board, microprocessor-based electrical metering unit with the following features and capabilities:
   - A. Motorola 6800 family central microprocessor with comprehensive 8-bit instruction set, hardware 8 x 8 multiply, internal interval timer, internal fast-access RAM, and internal serial interface.
   - B. 16-Kbyte plug in EPROM program storage.
   - C. 32-Kbyte to 1Mbyte CMOS RAM for data storage.
   - D. Hardware real-time clock/calendar with internal crystal oscillator accurate to 30 seconds per month.
   - E. Lithium battery backup for CMOS RAM and clock/calendar. The battery has an operating life of at least 2.5 years and a standby life of 10 years. The battery is socketed and it is possible to replace the battery in the field without loss of date/time or RAM data.
   - F. An electrical metering subsystem with inputs provided for eight or sixteen external current sensors and eight potential inputs. Each current input accepts a voltage from a terminated current transformer or equivalent sensor having full-scale output of 0.333 VRMS at rated current. Logger potential input is capable of direct connection to AC mains ranging from 120 to 480 VRMS through an external Potential Transducer unit. Provision is made for calculating the voltage, current, power, kWh, kVAs, and power factor associated with any current sensor and any combination of two potential input lines (e.g., any CT may be associated with any highside/lowside potential input pair). All measurements are true RMS. Provision is made for aggregation of up to six CT sensors into a single power/energy/PF variable.
   - G. Provision for detection of up to 16 external dry contact closures, with capability to accumulate run time or pulse counts independently for each input. Suitable impulse noise and contact bounce provisions are provided.
   - H. In the K20-3 and the K20-4, an 8-character, fully alphanumeric, internally-lighted display with a four-button membrane switch/bezel. The display is capable of selecting and displaying all major meter variables, with English-language (non-coded) variable identification, in practical engineering units.
   - I. An analog input subsystem, capable of accepting 8 or 15 analog inputs. Analog inputs may be 0-5V, 4-20mA, 1000 ohm 375α or 385α platinum RTD temperature sensors, or other resistive sensors.
   - J. A serial communications interface, to consist of either an RS-232 serial interface to a Hayes-compatible 1200/2400 baud modem, or the multidrop HiLAN™ interface. Units equipped with the HiLAN™ option are capable of operating in a local cluster mode, with up to 100 units connected across a single modem-equipped unit.

K. A high efficiency switching power supply is capable of operating from 24 volts AC or DC. An external bell transformer with 120 or 480 VAC primary can be used to power the K20, or the meter can be powered by a small wall-plug transformer. All wiring in the K20 is low voltage for safety and UL approval purposes.

3. A separate termination board mounted inside the enclosure for connection of field wiring. All current, potential, contact closure, analog, and instrument power inputs are provided with suitably rated wire-clamp screw terminals. All terminals are provided with clearly legible labels which, both number terminals uniquely, and identify terminal functions. Terminal arrangement is such that each input or sensor is provided with separate, easily accessible terminals.

4. All cables, hardware, and accessories necessary to mount and inter-connect all internal components of the K20.

4.2 STANDARD CONFIGURATION

The standard K20 includes the following items:

NEMA-4 enclosure

Processor module with ROM, 128K RAM, RTC, and memory battery backup

Provision for 8 or 16 current, 8 AC voltage, and 8 or 16 contact inputs

Provision for 8 or 15 analog inputs

RS-232 serial interface and HiLAN™ local network connection

Standard power metering termination board

One three-phase Potential Transducer unit (not mounted)

A standard K20 Energy Recorder with display is shown in Figure 2. The internal configuration of the recorder, with serial interface board and optional modem block installed is shown in Figure 3. The Potential Transducer and 120/24vac power transformer is shown mounted inside the enclosure in Figure 4. (Although there is space inside of the K20 enclosure to facilitate mounting the PT and transformer there, it is crowded to do so.) More often, the PT and transformer is mounted under the enclosure or more conveniently mounted at an electrical panel where the potentials are to be sampled. Low voltage wiring is then run from the PT to the logger, avoiding the need to run high voltage wiring long distances. This is particularly important in commercial/industrial applications where all such wiring must be run in conduit. Figure 5 shows the K20 with a 4-Jaw meter collar mounted to the top of the enclosure. This configuration is sometimes an expedient option in large-scale residential metering projects. The existing billing meter is pulled from its socket, the K20 meter collar is plugged into the existing meter socket and the billing meter is plugged into the K20 meter socket. CTs and potential transducer wiring can be preinstalled in the meter collar so that the mains are monitored the moment the K20 meter collar is plugged into the house meter socket.

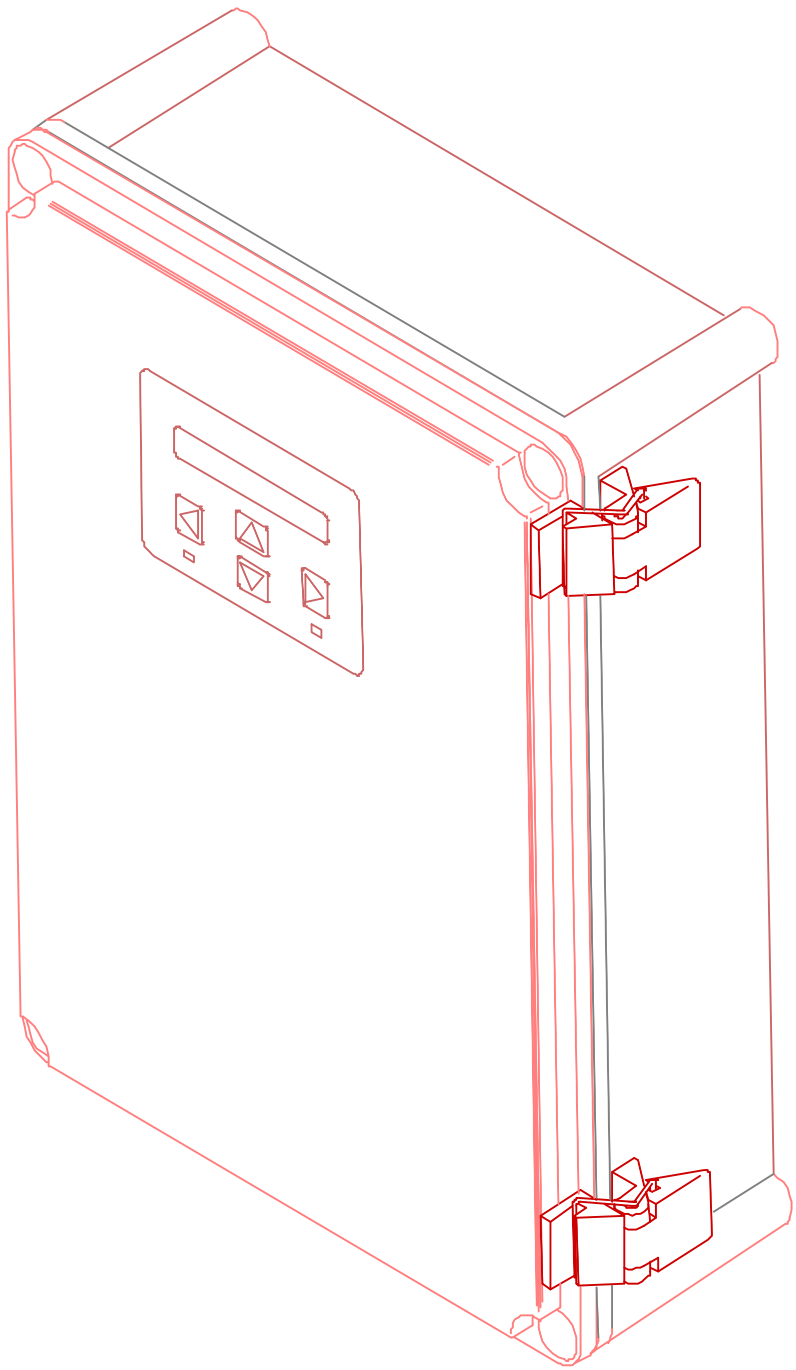


Figure 2 — K20 NEMA 4X Enclosure

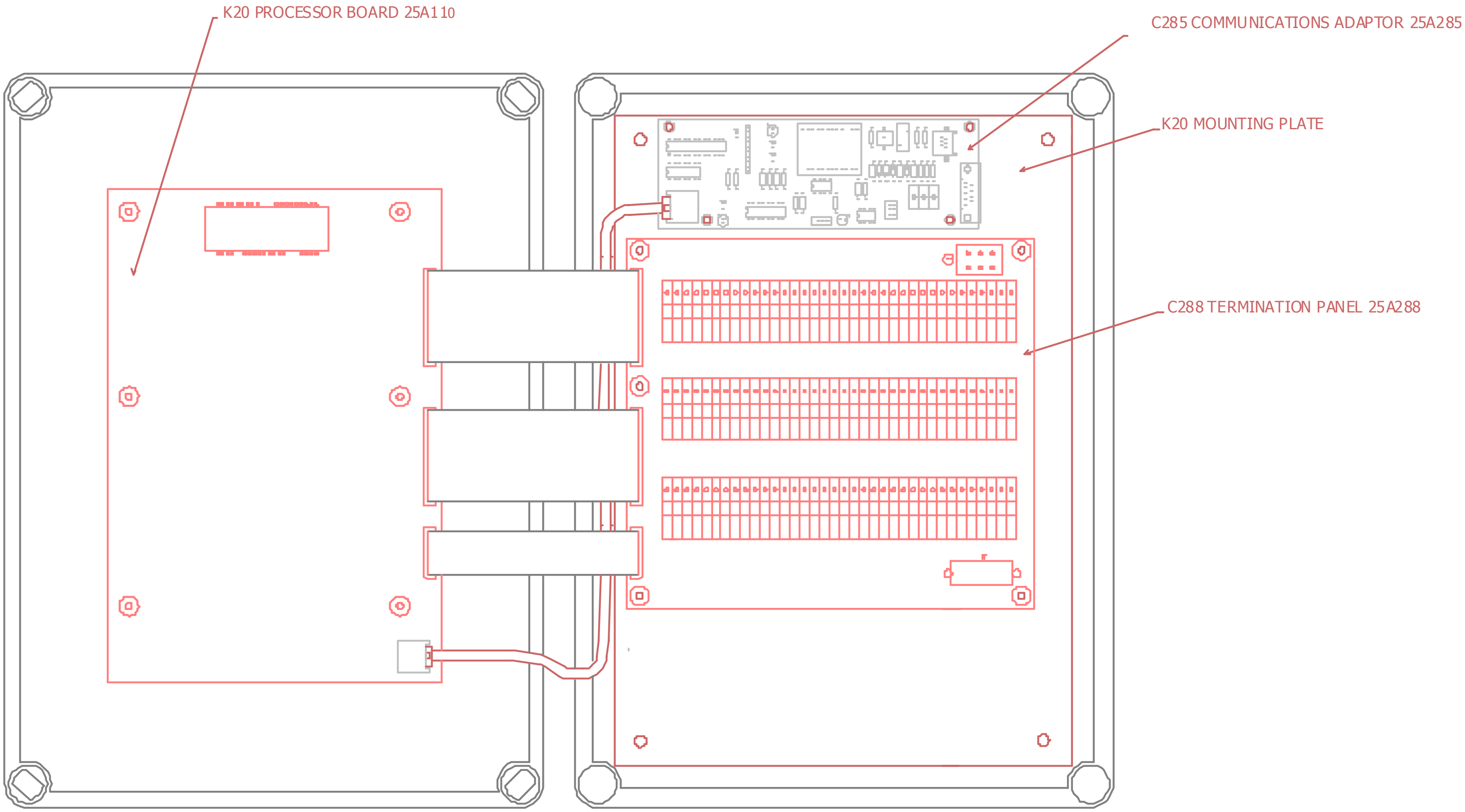


Figure 3 — K20 Standard Architecture

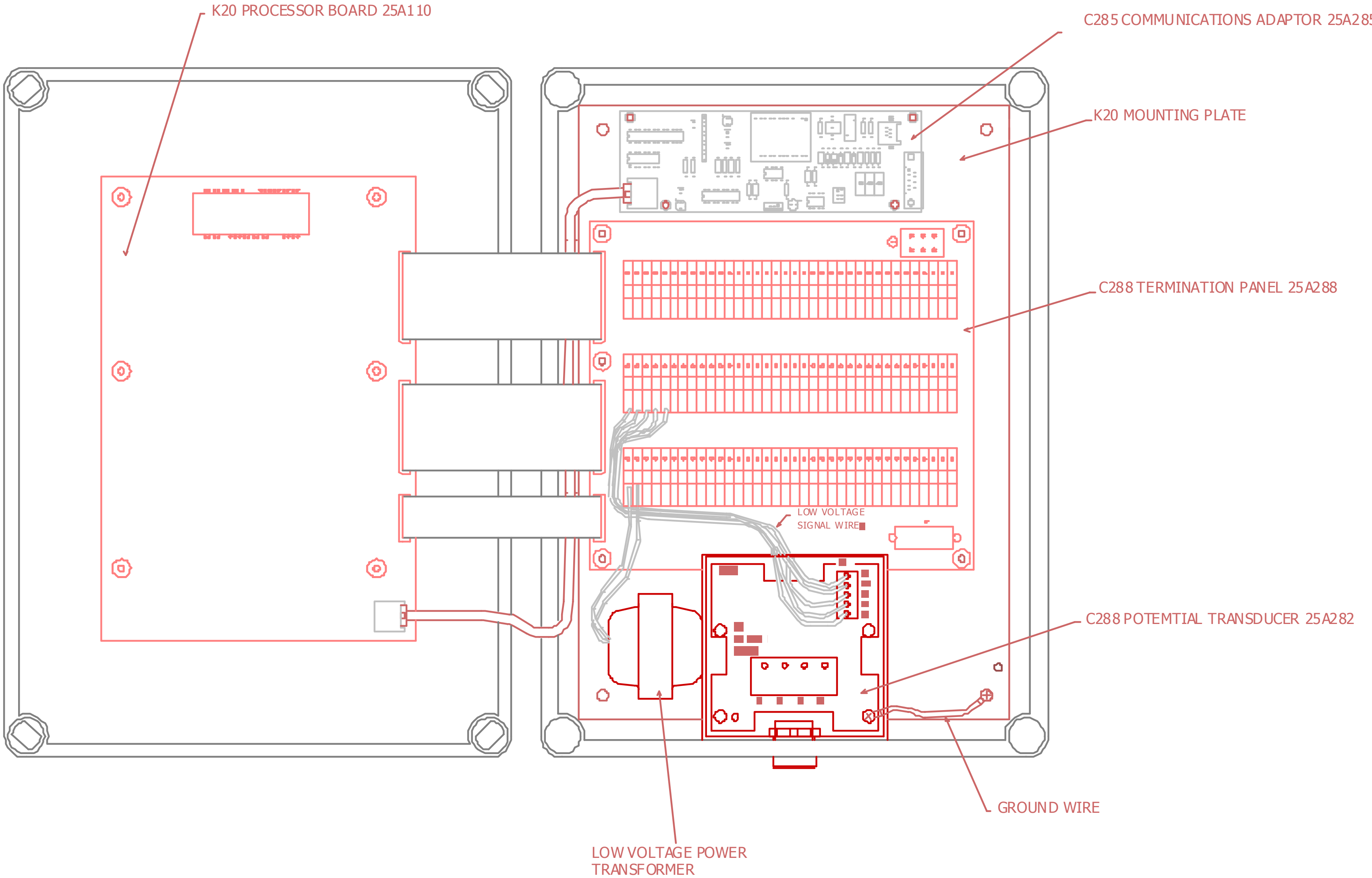


Figure 4 — K20 Optional PT and Power Transformer Mounting

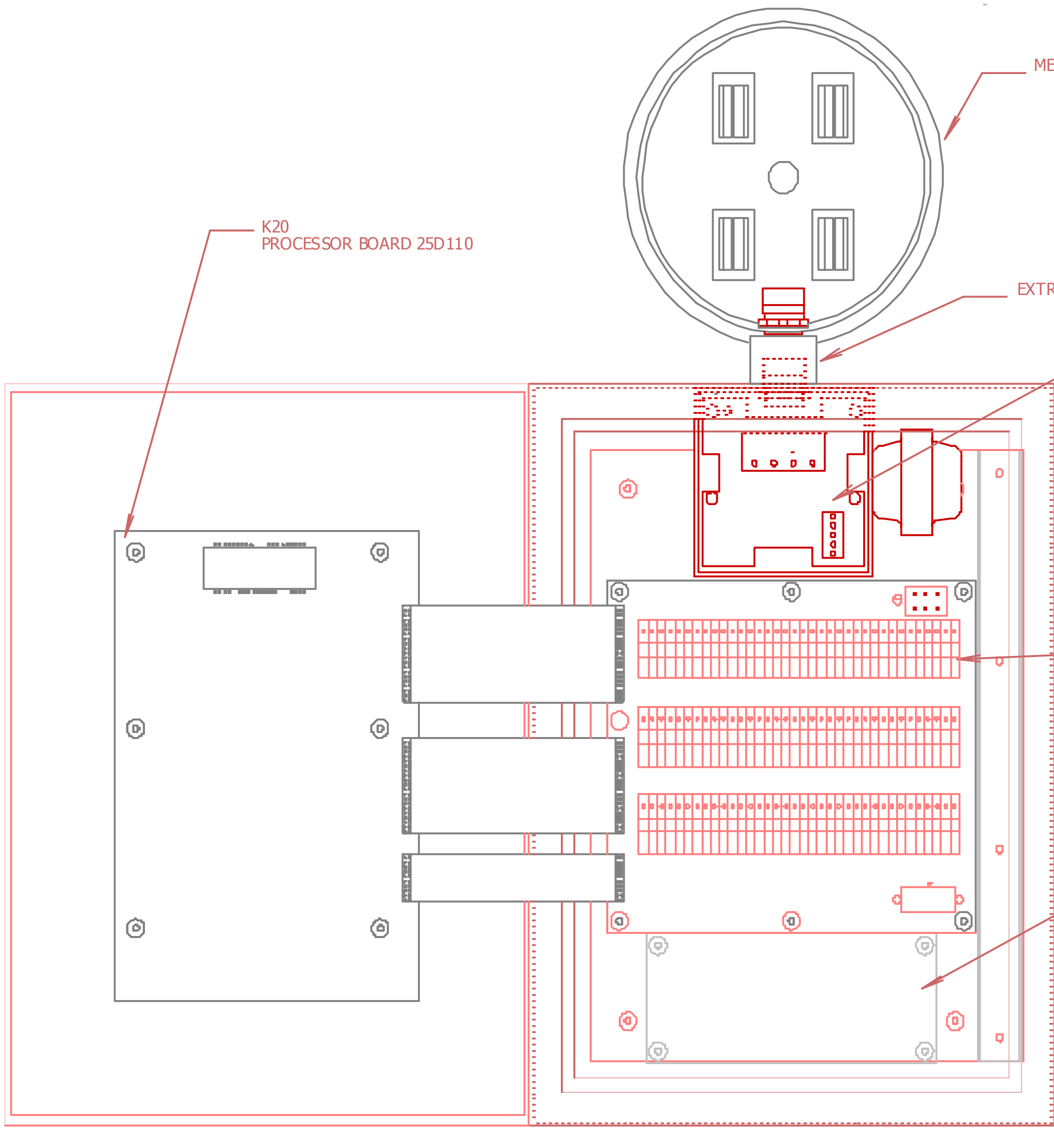


Figure 5 — K20 with Optional Meter Collar

5.0 K20 MOUNTING AND POWERING

As a general rule, we recommend that the K20 not be mounted in an area, which receives prolonged exposure to sunlight or other heat sources. The standard enclosure is rated for outdoor applications; however, proper weather-tight connectors must be used to maintain the enclosures NEMA 4X rating.

5.1 MOUNTING THE K20 RECORDER

The K20 NEMA 4X enclosure has four mounting holes the corners of the enclosure. Typically the K20 is mounted near or adjacent to the distribution panel or switch gear that feeds the loads to be monitored.

The K20 can be mounted on any surface constructed of wood, wallboard, metal, concrete or concrete blocks. The mounting area should have sufficient space to accommodate opening the door of the enclosure and any associated conduit needed to supply power and signal wiring to and from the recorder.

When mounting the recorder to concrete or block wall, as well as other surfaces, it is often advisable to mount a backboard of plywood. The backboard can be mounted with four (4) anchors, minimizing the disruption to the wall and making it far easier to mount the recorder enclosure(s), wiring trough, conduit and other instruments.

Follow all local and national electrical codes that apply to your installation. Please note that we recommend you bring all wiring in through the bottom of the enclosure. Also, the polycarbonate enclosure may crack when using a punch. We therefore recommend drilling, preferably with a sharp unibit.

The K20 is supplied with one C282 Potential Transducer unit as standard. Although sometimes mounted inside the main enclosure, it is more typically mounted with an offset nipple off the bottom of the enclosure or near a panel or in a raceway. Entry into the K20 of the A1, B1, C1, N1, and ground signal wires are made through the bottom of the enclosure. Connect the remote C282 to the K20 as described in Section 5.3.

5.2 POWERING THE K20 RECORDER

Attach all conduit or wiring accessories and pull wires up into K20 enclosure. Refer to the wiring configuration section drawings for proper termination diagrams.

All terminal points on the K20 C288 termination panel are designed for low-voltage only. All high-voltage terminations must be made inside of approved electrical junction enclosures. Only qualified personnel, knowledgeable and familiar with residential/commercial/industrial electrical wiring and associated local and national electrical code should make high-voltage terminations.

CAREFULLY VERIFY HIGH-VOLTAGE AC AND RECORDER SIGNAL WIRING BEFORE APPLYING POWER TO THE K20.

The K20 is powered by a UL listed 24VAC 20VA energy-limited power transformer. It is typically mounted externally from the K20 enclosure on a standard electrical junction box (J-box) with all high-voltage wiring done inside the J-box or through the side of an electrical panel. ENERNET can provide a 120/24vac power transformer. However, power transformers can be obtained from an electrical supplier such as Grainger's, to accommodate different primary voltages from 120 to 480Vac. Stamped or otherwise marked, proper primary voltage will be indicated on the transformer. Take care to provide some form of switched current protection such as a fused disconnect or circuit breaker when powering the K20 power transformer. The 24Vac secondary wires of the transformer are connected to the 24 volt input terminals (J73 and J74) on the K20 C288 termination board (see Figures 4 and 6), which is mounted on the mounting plate inside of the K20 enclosure. The connection is not polarity sensitive.

The optional power transformer the ENERNET supplies is a knockout-mounted bell-type transformer that may be also mounted outside the C282 Potential Transducer J-box, with its primary leads inside the Potential Transducer J-box. If the C282 high-voltage terminal strip potential is compatible with the 24vac primary voltage rating, it can be connected to the appropriate PT terminals, allowing the K20 to be powered from one phase of the measured AC line voltage. (See Figure 7.)

BE SURE THAT THE TRANSFORMER PRIMARY IS CONNECTED TO THE CORRECT AC LINE VOLTAGE. CHECK TRANSFORMER NAMEPLATE FOR VOLTAGE RATING. BE SURE THE C282 PT AND THE K20 LOGGER ARE WELL BONDED TO GROUND. THIS IS IMPORTANT FOR SAFTEY, MEASUREMENT ACCURRACY AND ELECTRICAL INTERFERENCE REASONS.

5.3 POTENTIAL TRANSDUCER WIRING

The model C282 Potential Transducer (PT) is used to interface AC line voltage inputs to the K20 meter/recorder. Each K20 may be wired to one or two C282 transducers through the C288 termination panel. The PT resistively isolates the main electrical service phases from the K20 and reduces the high-voltage of the electrical service to low-voltage signals for use by the K20 processor while preserving phase relationship. This voltage does not provide power to the K20, which is powered through the transformer discussed in Section 4.2 above; however, the voltage to the primary side of the transformer may be picked up at the PT high voltage terminal strip.

The C282 Potential Transducer shown in Figure 6 is packaged in a standard 4″x 4″ J-box. Internally, the box is divided into two halves, a "high voltage" input section and a "low voltage" output section. The function of the PT is to divide-down high-voltage AC line levels to low-voltage AC signals, which can be safely connected to the K20 processor board. Up to one C282 PT may be mounted inside the K20 enclosure, or one or both Potential Transducers may be remotely mounted.

The C282 PT contains four voltage dividers, generally used to divide down the phase A, B, C, and N lines of a polyphase AC system. Each divider can accept up to a 480 volt AC input, measured line-to-line or line-to-ground and provides a proportional low-voltage signal.

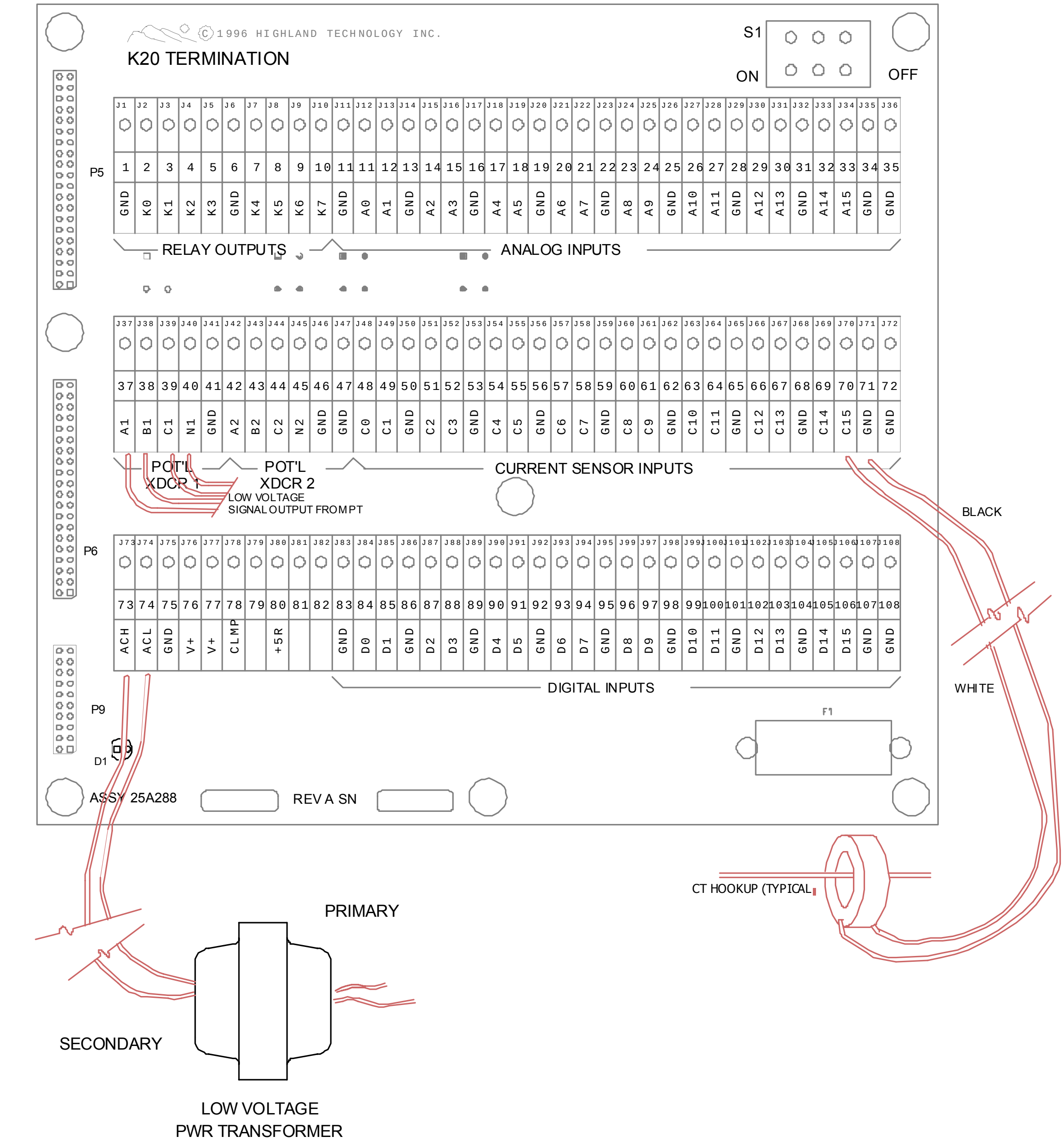
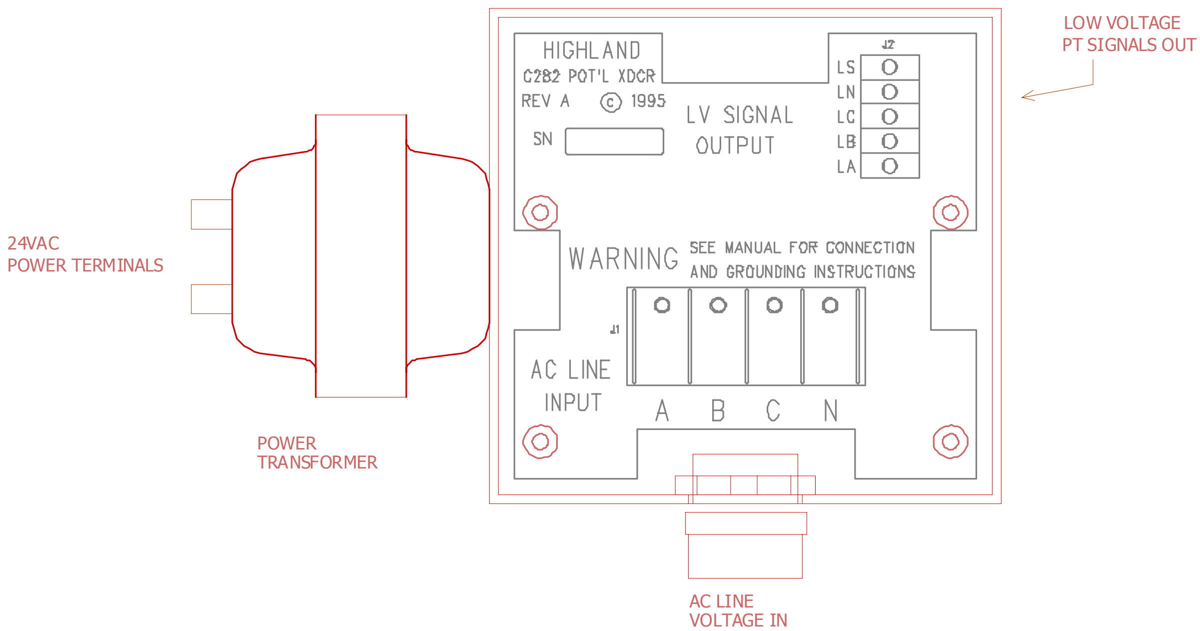


Figure 6 — K20 Termination Board



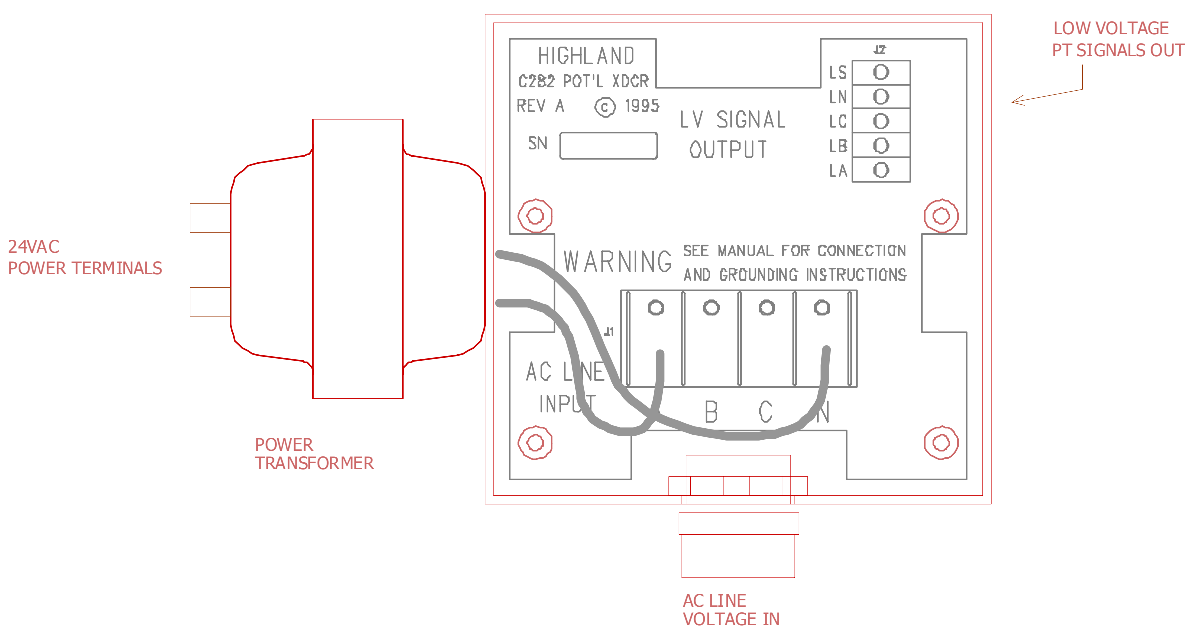


Figure 7 — K20 Potential transducer with Power Transformer

SAFETY WARNINGS

THE K20 C282 POTENTIAL TRANSDUCER MUST BE SECURELY GROUNDED.

THE POTENTIAL TRANSDUCER SHOULD BE CONNECTED TO CIRCUITS WITH LIMITED FAULT CURRENT CAPABILITY. CONNECT TO CIRCUITS WHICH ARE PROTECTED BY LOW-LIMIT CIRCUIT BREAKERS OR LOW CURRENT, HIGH-INTERRUPTING-CAPACITY FUSES.

THE LOW-VOLTAGE OUTPUT WIRING MUST BE ISOLATED FROM AC LINE-VOLTAGE CONDUCTORS.

DO NOT USE THE C282 PT TO MEASURE AC CIRCUITS RATED ABOVE 480 VOLTS AC LINE-TO-LINE OR LINE-TO-GROUND. HIGHER VOLTAGE CIRCUITS MUST USE APPROVED POTENTIAL TRANSFORMERS TO REDUCE THE AC VOLTAGE TO SUITABLE LEVELS.

DURING OPERATION, THE C282 PT COVER MUST BE PROPERLY FASTENED.

The PT has four termination points labeled A, B, C and N on connector J1, for high-voltage AC connection. Five wires leave from the low-voltage terminal strip, J2. The wires from the PT should be color coded to match the industry standard electrical color code as follows:

Black — Phase A
Red — Phase B
Blue — Phase C
White — Neutral
Green — Ground

These wires are connected to the K20 C288 termination board typically in the PT1 location. (See Figures 1 & 6.) Since power measurements are made by the K20 through the relationship between voltage and current, it is imperative that the correct phase relationship be maintained consistently throughout the system installation. High-voltage wiring is connected to A, B, C, and N terminals typically using the color code listed above. The green ground wire must be bonded to the J-box itself. The PT supplied with the K20 can connect directly to any 120/208/240/277/480Vac service. For other types of electrical services (e.g., single-phase, two-phase, etc.), connect the wires to the appropriate termination points (e.g., for two-phase, black or hot to "A," white or neutral to "N" and green or earth-ground to a ground lug on the PT J-box). Single-phase and poly-phase wiring configurations are discussed in more detail in sections 5.4.1 and 5.4.2 below.

A second PT, wired to the C288 termination panel on terminal points 42-46 allows one K20 to make measurements on two separate services. This feature is useful, for example, in commercial buildings where lighting and HVAC is powered from the 277/480 building distribution while receptacle loads are powered from individual step-down transformers. PT1 can sample the potential of the 277/480 services and PT2 can be wired to each phase of the 120/208 step down transformer. Any CT or CT combination can be related to any phase of either PT1 or PT2 inputs.

5.4 PHASE RELATIONSHIP

The measurement of true power in AC circuits requires the measurement instrument to make successive instantaneous readings of voltage and current on each phase used by a load. Current is measured through the use of Current Transducers (CT) which are placed on wires feeding the monitored electrical loads. (Current Transducers are discussed in detail in section 6). Many commercial building loads are three phase. To meter them correctly, it is necessary to know exactly on which phase a CT is installed to ensure that the measured current will be assigned to the correct phase in the K20 recorder. In most cases, phases are color coded as described in Section 5.3 above throughout a building. Even so, care must be taken to see that each CT is on a conductor that is traceable to the same phase at the K20 recorder.

To meter a given AC circuit, each of the associated voltages must be wired to a Potential Transducer input, and the proper number of current transducers must be placed around the appropriate current-carrying conductors and wired to the C288 termination panel. The choice of which CT is wired to which of the sixteen C288 termination panel "C" inputs is arbitrary.

Some common measurement situations are discussed in the following sections.

5.4.1 Single-Phase AC Systems

A single-phase AC load is characterized by the presence of only two wires connecting the AC source to the load. Two wires are commonly a "hot" wire and a "neutral" wire, although a single-phase load may be connected to two hot or phase wires. This is the case with common residential single-phase 240-volt loads such as clothes dryers and electric hot water tanks. A common commercial single-phase load is lighting, sometimes connected between two lines of a 3-phase 120/208 system or one line and neutral of a 480/277 system. In all cases, only two wires enter the load, and only ONE current transducer is needed; if a non-current-carrying safety ground wire is present, it may be ignored for metering purposes. Refer to Figure 8 for a wiring diagram of a single-phase load measurement.

To instrument a single-phase load,...

Make sure that BOTH power conductors are connected to the inputs of a C282 Potential Transducer. It is convenient to connect similarly named PT inputs (say, AC phase A to PT1:A and AC neutral to PT1:N) if possible, but any arbitrary connection will meter properly. In any case, name one of the voltage leads the "highside" lead.

Install the current transducer over the "Highside" current-carrying conductor, properly oriented as noted in Section 6. Wire this CT's low-voltage output to one of the "C" inputs of the termination panel, called "Cn" for this example.

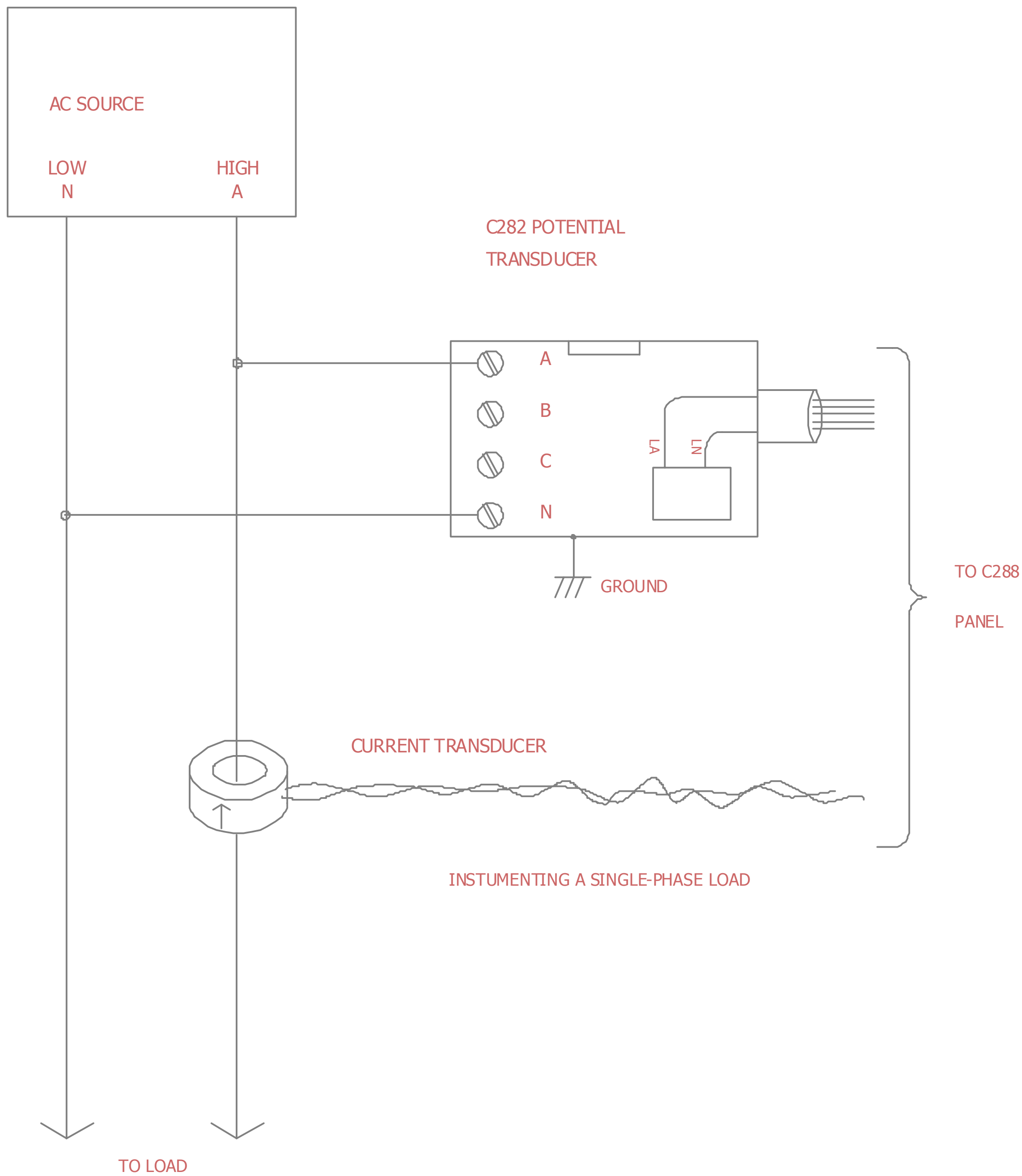


Figure 8 — Single-Phase Connection Diagram

Use the KTOOLS program to configure acquisition channel "n" to be the appropriate current rating, and select the correct highside:lowside potential inputs (i.e., the ones that the voltage leads were wired to, such as "A1" and "N1" for example). Then select a power register that you would like to become the "wattmeter" indicator for this power circuit. The acquisition channel and power register may be assigned names as desired. Once the parameter set is edited for this and any other CT inputs, save it to disk and install it into the K20 meter.

Now the real-time display will show the AC line-to-line voltage (VOLTS), power (kW), line current (AMPS), and power factor (PF) associated with this single-phase load circuit.

5.4.2. Polyphase AC Systems

A polyphase load is a load to which power is delivered over three or more wires. According to Blondel's theorem, an N-wire load needs at least N-1 current transducers for accurate metering. A 3-wire load (say, a 120-0-120 volt split-phase load, a typical residential electrical configuration, or a Delta-connected 3-phase load) will need two CTs, whereas a 4-wire "WYE" load will need three CTs. Refer to Figures 9 and 10 for wiring diagrams of 3-phase measurements.

In either case, wire all involved potential lines to inputs of a C282 Potential Transducer, and install properly oriented CTs on all but one of the current-carrying conductors. If a near-ground neutral conductor is present, make it the "odd" line (e.g., no CT) and reference all voltages to it when the parameter set is configured. Again, non-current-carrying safety ground wires may be ignored for measurement purposes.

Below are a few examples of multi-CT measurement setups in KTOOLS, the K20 logger configuration software. In general, one should follow the methodology of Blondel's theorem to configure the correct number of "virtual watt-meters" required to properly meter any multi-wire circuit.

The examples below assume that one Potential Transducer ("number 1") is used, and that the power system leads are connected to the "most logically named" Potential Transducer inputs. For example, a 4-wire, three-phase system is wired to Potential Transducer No. 1 inputs A, B, C, and N, referred to here as PT inputs A1, B1, C1, and N1. This setup is convenient but arbitrary: ANY set of PT inputs can be used so long as KTOOLS (or Synernet®) is used to configure the proper set of Blondel compatible virtual watt-meters. If two PTs are used, ANY of the eight available voltage inputs can be used arbitrarily to access the various system voltages.

A 4-wire, 3-phase load configuration is instrumented as shown in Figure 9. In this case, one might use KTOOLS to configure the three associated CT acquisition channels as follows :

CH	DESCRIP	AMPS	VH	VL	VMULT ...	DLT	PW
0	VFan A	400	A1	N1	1	OFF	1
1	VFan B	400	B1	N1	1	OFF	1
2	VFan C	400	C1	N1	1	OFF	1

Now POWER REGISTER 1 will indicate the net circuit power.

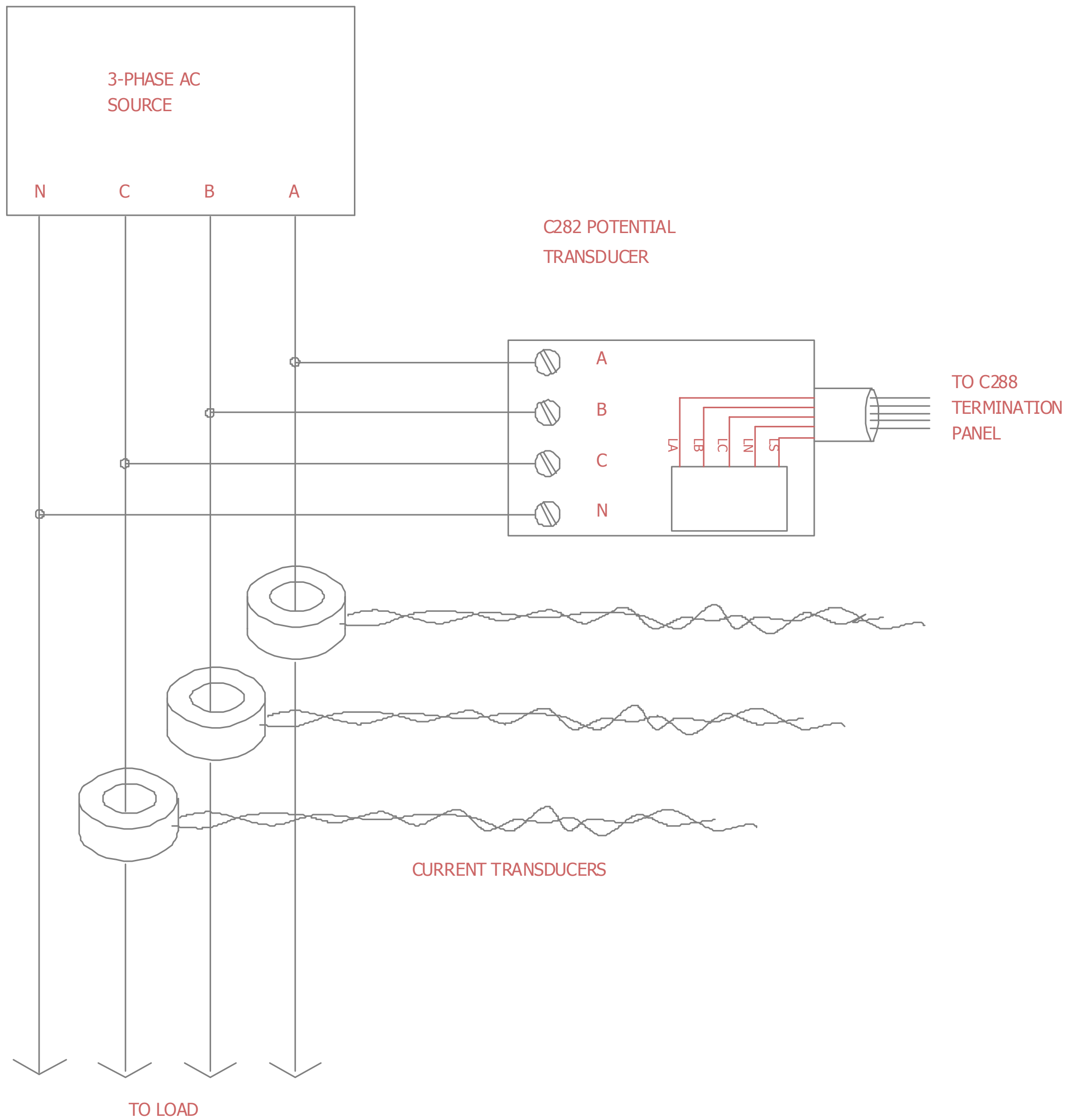


Figure 9 — 3-Phase 4-Wire Connection Diagram

A three-wire, 3-phase "Delta" load configuration is instrumented as shown in Figure 10. In this case, one could use KTOOLS to configure two CT acquisition channels as follows:

CH	DESCRIP	AMPS	VH	VL	VMULT ...	DLT	PW
3	CPump A	200	A1	C1	1	ON	2
4	CPump B	200	B1	C1	1	ON	2

Now POWER REGISTER 2 will indicate the net circuit power.

Since the measured circuit is a 3-phase Delta circuit (i.e., line-to-line loads in a true 3-phase, 120-degree circuit) we must set the DELTA attribute in KTOOLS ON for BOTH of the CT acquisition channels. This will correct for the inherent vector rotations present in such a system and will ensure accurate KVA, KVAH, and power factor displays.

To verify that the system is a true 3-phase circuit, use an AC voltmeter to measure CAREFULLY the three line-to-line voltages A:B, B:C, and A:C. In a three-phase system, all readings will be approximately equal.

In certain cases of unbalanced or non-unity-power factor load, one of the acquisition channel powers may read negative; this is normal and correct, with net power totalization reading the correct sign and magnitude.

A three-wire, split-phase load configuration such as the 120 – 240 volt panel Mains of a typical home in the United States may be instrumented as shown in Figure 10. In this case, KTOOLS might be used to configure two CT acquisition channels as follows:

CH	DESCRIP	AMPS	VH	VL	VMULT ...	DLT	PW
5	Mains A	100	A1	N1	1	OFF	3
6	Mains B	100	B1	N1	1	OFF	3

Now POWER REGISTER 3 will indicate the net circuit power. This configuration will accurately measure both line to line and line to neutral loads. Since the load is not three phase, we do not set the DELTA attribute ON.

To verify that the system is a true split-single-phase circuit, use an AC voltmeter to measure CAREFULLY the three line-to-line voltages A:N, B:N, and A:B. The A:N and B:N voltages should be nominally 120 volts and about equal, while A:B should be about twice as much or approximately 240 volts.

A single-phase 240 volt line to line load in this same typical home, a load such as a dryer, may be instrumented with a single CT. In this case, KTOOLS might be used to configure a single CT acquisition channels as follows :

CH	DESCRIP	AMPS	VH	VL	VMULT ...	DLT	PW
7	Dryer	100	A1	N1	1	OFF	4

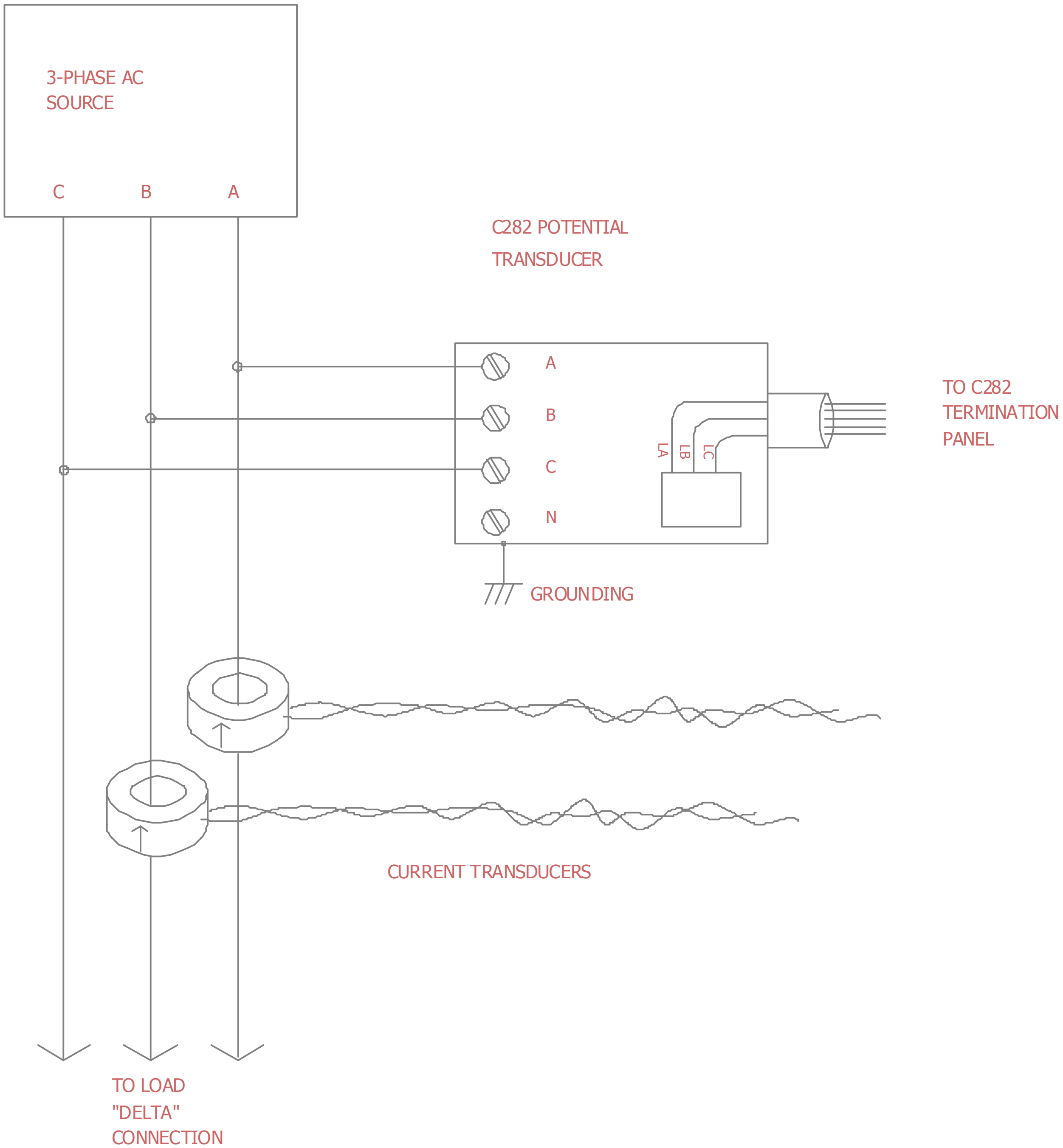


Figure 10 — 3-Phase 3-Wire Connection Diagram

6.0 SELECTING AND INSTALLING CURRENT SENSORS

6.1 4LS-SERIES CURRENT SENSORS

ENERNET Corporation furnishes the series 4LS current sensors for use with the K20. Sensors are UL or ETL Recognized per UL506 Standard and tested per ANSI C57.13. ENERNET's current transformers include internal burden resistors; they provide a safe, low-voltage output (0.3333 volts RMS at rated full-scale line current) suitable for connection to the C288 termination panel.

The 4LS sensors are available in both closed-loop (toroidal, or solid core) and square split-link or split-core styles. The solid core sensors are less expensive, more accurate, and less likely to pick up leakage fields from nearby current-carrying conductors. The split-core CT style is easier to install than the toroids, as they may be installed around an existing (even live) current-carrying conductor without the necessity of breaking the current-carrying circuit.

Do not run more than one wire through the CT core **unless** you specifically intend to sum two in-phase currents as described in Section 7 below. Do not run a multi-wire Romex or similar multi-wire cable through a CT, or place a CT around a conduit.

DO NOT install a CT over a bare live wire. If required, additional nonconductive insulators or spacers may be used between the conductor and the CT.

Either type of CT should be slipped over the insulated, current-carrying conductor at any convenient location. The signal output leads of the CTs should be kept tightly twisted, and routed and secured so as to avoid as much as possible, running near or contacting high current power wiring. Route the signal leads in conformance with wiring codes for LOW VOLTAGE wiring.

Current transducers must be installed in the proper orientation to ensure that the power polarity is correctly measured. Transformers are marked on their faces or sides. A face may be marked “This side toward source,” “HI,” or “H1”; in such cases, the side so-marked should face the AC power source. If the side of the CT is marked with an arrow, the arrow should point in the direction of the source when the CT is installed over the wire. All CTs MUST face in the same direction in a polyphase system. See Figures 11, 12, and 13 for style, wiring, and orientation examples.

The output leads of the current transducers should be routed to the C288 termination panel. Connect the WHITE (highside, or “X1”) lead to the appropriate “Cn” terminal of the panel, and connect the BLACK lead to the adjacent GND terminal. If the CT leads are too short, they may be extended. Attempt to keep CT wire runs less than 200 feet in length and always use twisted-pair cable.

6.2 SIGNAL WIRE

ENERNET recommends 20-gage stranded and shielded wire. Be aware of where this cable will be routed to ensure its insulation is rated for the potential voltage environment it will encounter. If the cable will run through panels and switch gear with 120/208/240 in it, it will need to be 300-volt rated. If the potential voltages are 277/480, its rating must be 600-volts. We further recommend using cable in which the individual signal wires are insulated with a polypropylene material. The overall cable jacket may be PVC or other material.

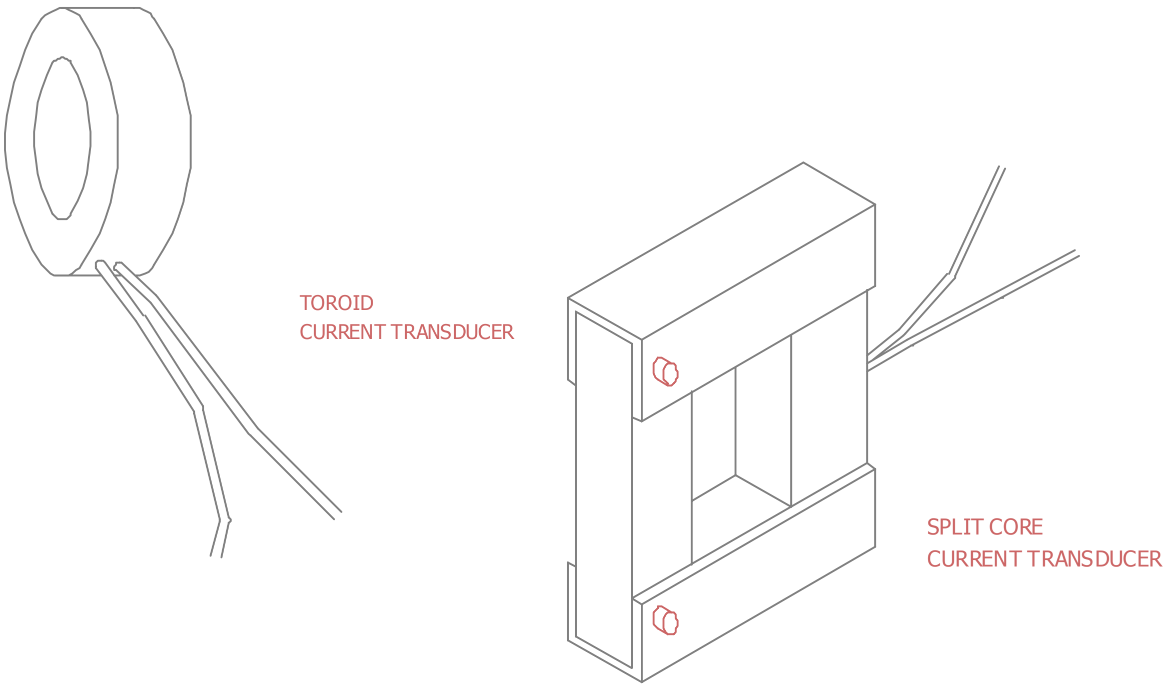


Figure 11 — Current Transducer Styles

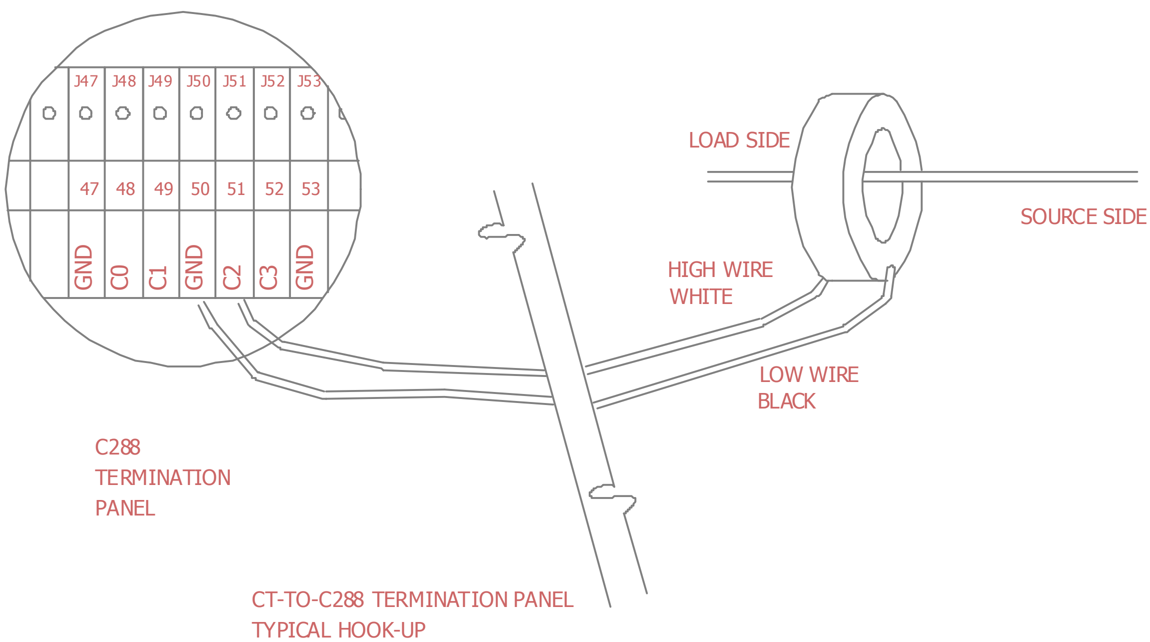


Figure 12 — Current Transducer Termination

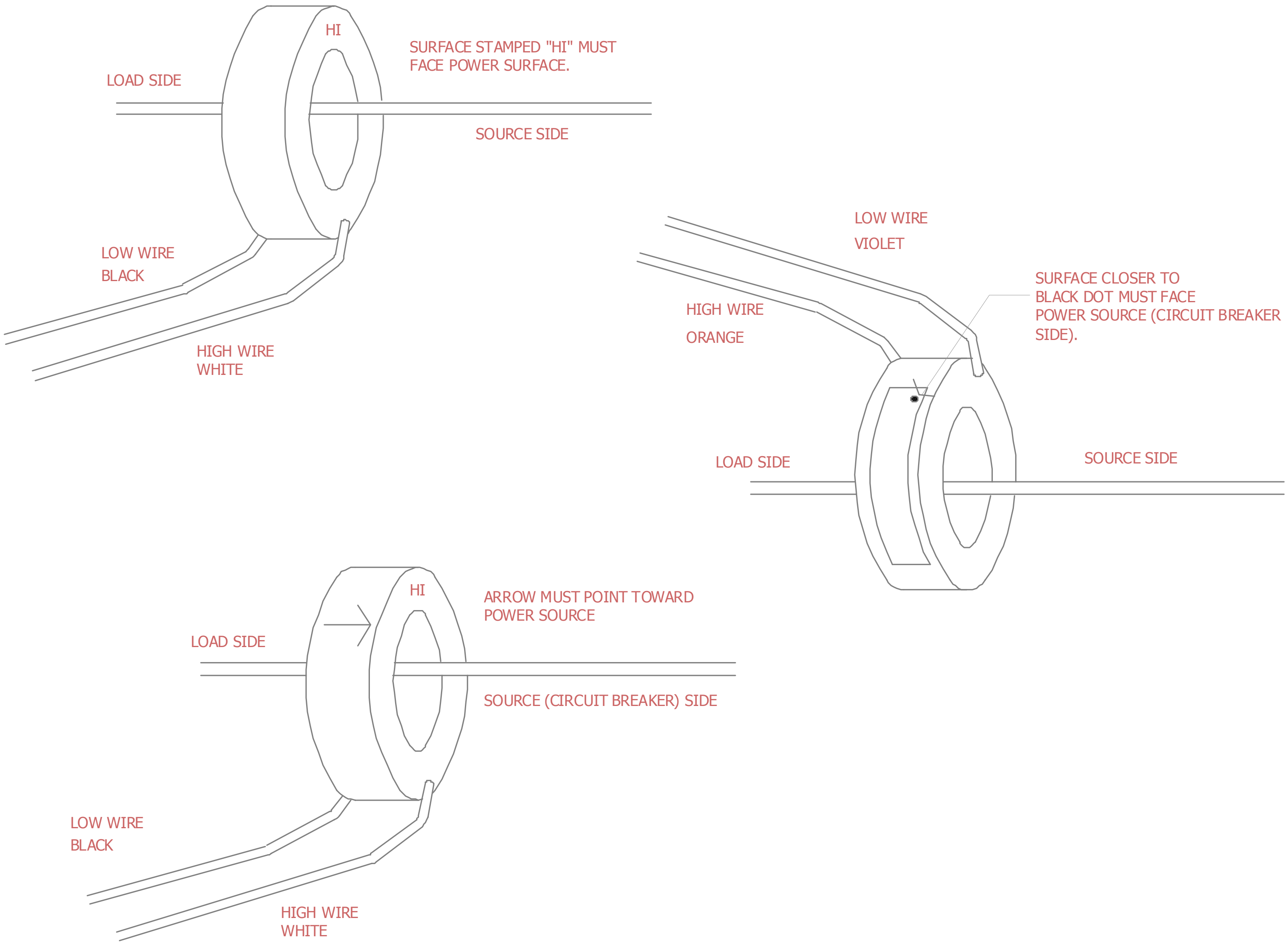


Figure 13 — Current Transducer Orientation Markings

7.0 CT APPLICATION

In order to conserve channels, CTs can be carefully configured to aggregate similar end-use loads through three techniques discussed in this section. Each technique is illustrated in the wiring configuration section of this document. The *like phase/like size* rule applies when applying aggregation techniques. In other words, care must be taken that all combined circuits are on the same electrical phase and that all CTs combined on the same channel are of the same ampacity, e.g., a 50A CT and a 100A CT should not be connected together.

7.1 AGGREGATION TECHNIQUES

7.1.1 Multiple Conductors

Multiple conductors on the same phase can be passed through a single CT. The current flowing through each wire combines in the CT with the CT output reflecting the sum of the currents. It is often practical to do this within an electrical panel. In the typical panel of a commercial building, for example, circuit wiring, from the bottommost circuit to the top, follows up the sides of the panel and out the top. In a panel with mixed end-uses, the like-phase wires feeding the circuits of interest can be gathered towards the top and passed through individual CTs. In a common application, several lighting circuits are picked up in a panel with other non-lighting loads.

7.1.2 CTs in Series

Sometimes the like end-use loads of interest are not all located in the same panel. When this is the case, CTs can be put in series with the output from one CT connected to be additive with that of another. As with two or more batteries, e.g., connecting the positive terminal of one battery to the negative of the next and so on, the black lead of CT1 may be connected to the white lead of CT2 and so on. Once again, the like phase/like size rule applies. As long as each CT is measuring loads on the same phase, this technique will work, keeping in mind that the maximum input signal of the K20 recorder is 333mV. Therefore, the sum of all CTs with their respective loads at full scale must be ≤333mV. For example, if you have four 50A maximum loads you wish to meter, you will need to install 200A CTs on each load to ensure that when they are put in series, the resulting signal, if they are all on at full load, will not exceed 333mV. Obviously, some resolution is sacrificed by using a 200 amp CT to measure a load that cannot exceed 50 amps. Good judgment must be used. If your maximum 50 amp load can also go down below 20 amps, there is a risk of going below the linear range of the CT.

7.1.3 CTs in Parallel

Putting CTs in parallel is another method of load aggregation similar to the series CT technique above. It is in many ways a cleaner technique from a wiring standpoint and does not require attention to the potential of over ranging the input of the recorder. Paralleling CTs does require attention to certain other details.

In connecting wires from multiple CTs in parallel, the like phase/like size rule applies along with one other rule, *like impedance*. This means simply one CT should not present a significantly larger or smaller resistance than any other CT. What does this mean from a practical standpoint? Don't have CT1 with 10 feet of wire connected to CT2 with 100 feet of wire. If each CT is thought of as a resistor, the goal is to have each resistor exactly equal. To do this, keep all CT wiring the same length and type of wire and do not mix CT brands. ("Manufacturer A" will not necessarily use the same size shunt resistor as

"Manufacturer B.") In actual practice, most of the time this is very easy and natural to do. A typical case in which this method might be used is for a large distribution panel from which several like end-use loads using large gauge cable are fed. The CTs are likely to be in close proximity to each other, very often close enough to connect all the leads. A single signal cable, probably with three pairs of wires to accommodate three phases, is pulled to the distribution panel and all CT leads are connected by phase, i.e., white to white leads and black to black. The single cable is then run to the K20 and terminated.

In a few cases, CTs are located in different locations in a building and may have signal wires of different lengths and/or be of different manufactures. The addition of series resistors in the leads of each CT allows them to be wired in parallel despite such nonconformance. For example, assume CT1 & CT2 are identical except for wire length. CT1 signal wiring presents 1 ohm of resistance while CT2 wiring presents 5 ohms. This is a 20% disparity and will adversely effect readings. In this same situation, suppose a 10k ohm resistor is placed in one lead of each CT, now CT1 wiring presents 10,001 ohms of resistance while CT2 presents 10,005 ohms. The disparity is now .04% and is essentially inconsequential to readings. Obviously, these resistors do not need to be precision elements, and can be any appropriate resistance. Also, since there is no load current, they can be any wattage. 1/8 watt resistors are small and will do just fine. If you do need to normalize lead resistance with resistors, take care to make good connections, a crimp-on connector is a good choice. Be sure to strap the resistors to the jacket of their respective cable to provide solid strain relief. The fact is, in most situations, CT signal wire lead length can be kept the same and the use of this particular technique should be limited.

When configuring the K20 power channels through KTOOLS software supplied with your K20, you must specify the CT rating of each CT input. When paralleling CTs, the effective CT value becomes the sum of all CTs put in parallel in a "virtual CT." For example, if four 50A CTs were wired in parallel, they would have a virtual CT rating of 200A and that value should be specified in KTOOLS. If three 50A CTs were in parallel, a CT value of 150A should be specified in KTOOLS.

7.2 CT DISAGGREGATION TECHNIQUES

The same three techniques used to aggregate CT loads can also be used to disaggregate loads. For example, when an entire panel is almost completely powering one end-use type with the exception of a few circuits of another end-use type, the methods described below provide a means of getting rid of the unwanted loads through the CT itself.

7.2.1 Multiple Conductors

As mentioned in 7.1.1 above, multiple conductors on the same phase can be passed through a single CT. The current flowing through each conducting wire induces an output voltage in the CT with the CT output reflecting the sum of the conductor currents. If the direction of current flow in a wire is opposite that of another, the CT is in effect summing a positive and negative signal. This effect can be utilized to eliminate the current from nuisance circuits contained in a monitored breaker panel.

In a typical configuration, a panel is wired with CTs snapped on at the mains feeding the panel. As the circuits feed out of the top of the panel, the wires feeding the unwanted circuits can be looped around and fed back through the appropriately phased CT at the mains; e.g., 'A' phase nuisance circuit to 'A' phase mains CT, etc. Current flowing through the mains is the sum of all the current being fed by all circuits in the panel including the nuisance circuits. By putting the nuisance circuit wires through our CTs in this way, current flowing in those circuits cancels their own contributing *emf* within the mains

CT. The CTs on the mains then produce a signal proportional to the current flowing in all of the other circuits except the nuisance circuits.

It is sometimes necessary to extend a nuisance circuit wire so it can reach the CT and be looped. In accordance with the national electrical code, an electric panel may not be used as a junction box and therefore technically should not have splices or wire-nuts in it. It is usually allowed for short term periods of a year or so; however, with the condition that it will be undone at the completion of a monitoring period. If it is to be a permanent installation, a junction box may be needed on the side of a panel where the circuit wires can be routed and spliced.

7.2.2 CTs in Series

The same effect can be achieved using CTs in series. As explained in section 7.2, multiple CTs can be wired in series like batteries. To subtract the signal of a CT from one or more others, simply orient the CT around the conductor to measure in the opposite direction or reverse the leads in the series chain. This solves the same type of problem as described in the section on multiple conductors above. In many cases, wiring in commercial buildings is too large to allow such manipulation, and additional CTs are used instead.

7.2.3 CTs in Parallel

Reversing the orientation of a CT on a conductor will also affect the desired signal subtraction when wiring CTs in parallel. The leads may also be reversed to obtain the same result. All other rules and tips given in section 7.3 apply to this disaggregation technique.

7.2.4 Conductor Wrapping

When necessary resolution may be improved by wrapping the wire of the circuit to be measured multiple times through the same CT. This technique in effect reduces the CT ratio and can be used essentially to tune the CT to the load or resize the CT if it is inappropriate for the load to be measured. For example, suppose you have a 100A CT on hand and the load you would like to meter is approximately 5 amps. Passing the conductor through the 100A CT four times effectively creates a 25A CT. The signal out with 5 amps flowing in the circuit is exactly what it would be if one pass were made through an actual 25A CT.

8.0 ANALOG CHANNELS

Depending on the model being used, the K20 recorder can provide up to 8 or 15 single-ended analog channels, all referenced to circuit common. These channels are very versatile, directly accepting 0 - 5vdc, 4 - 20mA, 1000Ω platinum RTD, and LM 34/35 IC temperature sensors. Analog inputs may be displayed locally as real-time data items, read remotely, or included in time-series records.

Analog values can be stored in TSRs as time averages or as instantaneous snapshot values. Analogs can also be interlocked with runtime inputs so as to average an analog quantity only during selected intervals, say to measure heat exchanger performance only during the times that a pump is running.

8.1 ANALOG SPECIFICATIONS

RANGE:	-5.00 to +5.00 volts DC
INPUT IMPEDANCE:	10 Mohm minimum
A/D CONVERSION:	Integrating, 100 mSec averaging interval
60 Hz REJECTION:	Normal mode, 40 dB minimum for up to 1 V P-P
ACCURACY:	+0.25% of full scale.
RESOLUTION:	Voltage: 1.0 mV Resistance: 0.3 ohms Temperature: 0.1° C w/ Platinum RTD or LM34/35 IC temperature sensor.
INSTRUMENT POWER :	Unregulated +30 volts nominal, 150 mA for external transducers.

8.2 RTD INPUTS

Any analog channel may be programmed to measure 2-wire resistance sensors, using an internal constant-current source. Linearization is provided for 1000 ohm platinum RTD temperature sensors.

8.3 COUNTERS

The K20 has either eight or sixteen contact-closure inputs, each of which may be configured as either a pulse counter or a runtime meter. Counter values may be included in TSRs and in the K20-3 and the K20-4, are visible on the local display.

8.4 RELAY OUTPUTS

A K20 can have four or eight optional open-collector relay drivers. Five of the outputs generate kWh pulses associated with the first five power channels, two relays are remotely controllable, and one output goes ON whenever a TSR is posted.