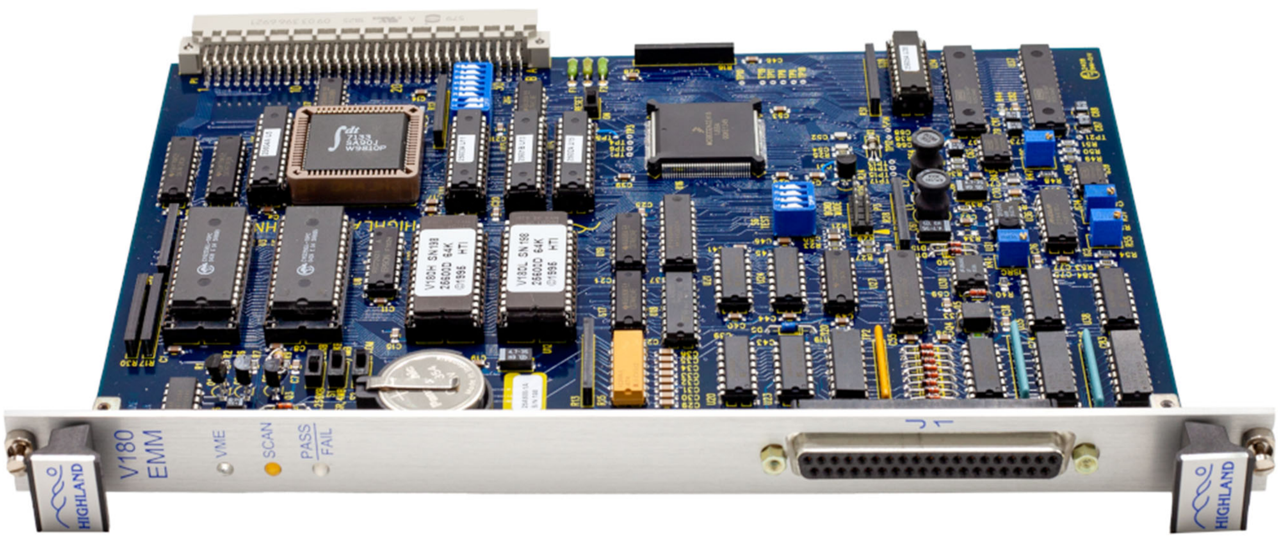
HIGHLAND TECHNOLOGY

V180 & AT180

VME ELECTRICAL

MEASUREMENT MODULE



Technical Manual

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1. Introduction

The AT180 is a plug-in card for PC/AT compatible personal computers. The V180 is a plug-in card for VME computer systems. The module package allows accurate measurement of AC power circuit parameters.

The AT180 and the V180 (AT/VI80) provide 16 “virtual wattmeter” channels, each of which can acquire one AC voltage:current pair and compute true RMS voltage, current, power, and KVAs. Each channel processes one current sensor input associated with an arbitrarily programmable high:low potential input pair.

The 16 AC measurement channels may be aggregated in virtually any combination to form multiple polyphase wattmeters, each providing measurement of total power, total KVAs, positive and negative kilowatt-hours, and KVAHs.

The AT/V180 optionally can acquire one to three sets of voltage:current waveforms, allowing waveform and harmonics analysis of single or 3-phase circuits.

An analog input feature is provided. This allows any of the 16 acquisition channels to measure DC voltages and allows eight of the channel inputs to be used to measure temperature or resistance inputs.

An optional Time-Series-Record (TSR) feature allows the AT/V180 to gather and store time-stamped sequential measurements without continuous PC/AT service.

Features Include:

- Measures up to sixteen AC power circuits
- Measures true RMS amps, volts, watts, KVAs, kilowatt-hours, and power factor
- Interfaces to up to sixteen current transformers and up to two Highland C750 multiphase potential transducers
- Highside: lowside potential inputs freely programmable using any combinations of potential connections
- Pulse counting and KWH pulse output capability
- Analog input capability
- Waveform acquisition option
- Temperature (RTD) measurement option

2. Specifications

2.1 Configuration

An AT/V180 configuration consists of:

The AT180 PC/AT plug-in board or the V180 plug-in module.

One Model C760 Termination Panel with cable.

One (optionally two) Model C750 Potential Transducer. Each C750 permits connection to up to four 120-480 volt power line conductors (typically A, B, C, N in a 3-phase system).

Up to 16 external current sensors. Sensors are closed-ring or split-core current transformers which contain integral burden resistors. Conventional 5-amp secondary CTs may also be used with appropriate external shunt resistor adapters, such as the Highland Model C720.

2.2 Compatibility

The AT180 may be plugged into any standard full-length PC/AT 16-bit slot. A 386DX with math coprocessor is the minimum recommended configuration. The V180 may be installed in any 6U VME card cage.

2.3 Specifications: AT180

Feature	Description
FUNCTION	Acquisition of line voltage, current, true power, volt-amp, power factor, kilowatt-hour for polyphase circuits. General purpose ±5V analog input.
COMPLIANCE	ISA IEEE 996 specification.
SIZE	Full-slot size ISA add-on card, 13.345” x 4.8”.
DEVICE TYPE	16-bit register based slave.
ADDRESSING	256-byte data block in an ISA bus; bus address set by onboard dipswitch.
I/O	Eight voltage (potential) inputs. Eight digital I/Os programmable as pulse counters, as KWH pulse outputs or as general purpose I/O. Sixteen CT inputs. Options included: Eight CT inputs and eight programmable CT/temperature/inputs/Wave form acquisition. CT inputs also double as ±5V analog inputs.
PROCESSOR	High performance Motorola MC68332 32-bit microcontroller.
CONNECTORS	One D37 female connector on front panel.

2.4 Specifications: V180

Feature	Description
FUNCTION	Acquisition of line voltage, current, true power, volt-amp, power factor, kilowatt-hour for polyphase circuits General purpose ±5V analog input
COMPLIANCE	IEEE 1014-1987 VME compliant Meets IEEE-P115/D3 and VXIC 1.4 interim VXI specs for register-based B-format VXI module
SIZE	VME 6U- (160 X 223 mm) size module, B-size VXI module.
DEVICE TYPE	VME/VXI register based slave: A16: D16: D8 (E0) capability.
ADDRESSING	256-byte data block in bus A16 address range C000-FF80 hex: bus address set by onboard dipswitch.
I/O	Eight voltage (potential) inputs. Eight digital I/Os programmable as pulse counters, as KWH pulse outputs or as general purpose I/O. Sixteen CT inputs. Options included: Eight CT inputs and eight programmable CT/temperature/inputs/Wave form acquisition. CT inputs also double as ±5V analog inputs.
PROCESSOR	High performance Motorola MC68332 32-bit microcontroller.
CONNECTORS	One D37 female connector on front panel.

2.5 AT/V180 Performance Specifications

Feature	Description
FUNCTION	The modules contain 16 AC acquisition channels, each an equivalent single-phase wattmeter. Each channel acquires true RMS amps, volts, watts, and volt-amps. Sixteen power totalizers are provided. From one to six acquisition channels may be summed into each totalizer, forming multiphase wattmeters. Each totalizer reports aggregated true RMS power, volt-amperes, positive KWHs, negative KWHs, and KVAHs. Each acquisition channel may be configured as a DC analog input. Eight channels may be used as RTD temperature inputs or resistance sensor inputs. Eight digital channels are provided, each programmable as an input or output. Input functions include pulse counter or runtime counter. Output functions include static outputs, KWH/KVAH/BTU pulse outputs, and TSR pulse flag.
INPUTS	AC voltage inputs: 75 to 500 VRMS line-line or line-neutral using one or two Model C750 potential sensors. Input impedance is 500 Kohm nominal to ground. External potential transformers may be used to measure circuits above 480 VRMS. Current sensor inputs: 0.25 or 0.3333 volts RMS at rated CT current. Input impedance nominal 100 Kohms. Digital inputs: contact closure or open-collector to ground, pulled up to +12 volts through 1K, or configurable for TTL inputs. Analog inputs: range ±5.12 volts, 100 Kohm nom input impedance. Temperature inputs: 1 Kohm, 2-wire platinum RTD, DIN standard (“385”) curve. Resistance inputs: 2-wire, 2047-ohm full scale.

Feature	**Description**
ACCURACY	All accuracy specifications apply over the range of 5% to 105% of full-scale signal range, and 12 to 32 degrees C ambient temperature. Specifications do not include CT or RTD errors. Power/KWH accuracy: ±0.15% of full scale; resolution is at least 0.01% of full scale. Zero offset is below 0.01% FS. Volts/amps/VA/KVAH: ±0.15% of full scale. Analog inputs: ±0.15% of full scale. Temperature: ±0.5 degrees C ±0.25% of reading.
BANDWIDTH	AC RMS measurement bandwidth is 50 KHz minimum at -3 dB.
STEP RESPONSE	Module step response is 400 msec typical 20/80% risetime for realtime data values of measured AC parameters when presented with step change in AC input; 100 msec in fast filter mode. Realtime data is updated 32 times per second.
PULSE OUTPUTS	Pulse outputs are open collector Darlington drivers, saturating to ground to 1.2 V max at 100 mA max. Width, 16 msec nom.
SCALING	Data is presented to the PC/AT bus or to the VME bus as 16- or 32-bit integers. All data scaling is normalized to 100 amp CTs with 1:1 PT ratios. Pulse outputs are scaled to 0.01 KWH or KVAH per pulse. AT/V180 software (B180.EXE) may rescale presented data for other CT ratings or potential transformer ratios. RTD inputs are linearized and scaled to degrees C.
WAVEFORM ACQUISITION	An optional burst acquisition of one to three simultaneously sampled voltage:current sets. Various sample rates and record sizes are available from 128 sample sets over one line cycle to 512 sample sets over 16 line cycles. Equivalent frequency analysis capability ranges from the 64^{th} to 16^{th} line harmonics.

Feature	Description
TIME-SERIES RECORDS	The optional TSR feature allows the AT/V180 to collect and store time-series records of user-selected measurements. TSR data is time/date stamped based on an on-board realtime clock and is stored in battery-backed memory. TSR records may be posted at intervals from one per second to one per day. TSR data represents the average value of selected points over the TSR interval, except for KWHs, KVAHs, and counters, which are saved as end-of-interval values. The AT/V180 will gather TSR records whenever the PC/AT or VME host computer provides power, and will log powerfail/restart events. TSR memory sizes of 256 Kbyte and 1 Mbyte are available. TSRs may be posted based on an internal time schedule, based on an external contact closure, or slaved to another AT/V180 unit.

3. Theory of Operation

The AT180 and V180 electrical measurement modules 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 180 instruments.

3.1 Basics

For each of its 16 "virtual wattmeter" channels, an AT/V180 receives two analog signal inputs from external sensors. One signal is a divided-down differential voltage signal which is proportional to the instantaneous voltage difference between the highside and lowside potential inputs of the "wattmeter," and the other is a low-voltage signal proportional to the instantaneous current flow in the associated current-carrying conductor. Using these two signals, the unit will compute the true RMS voltage, true RMS current, true power (watts), apparent power (volt-amps), integrated energy (kilowatt-hours), and apparent energy (KVA-hours) of each channel.

In brief, the signal processing sequence is as follows:

1. Both the voltage and current signals are periodically (and simultaneously) sampled and digitized, yielding numeric instantaneous voltage and current sample values.

2. The voltage samples are squared and lowpass filtered to yield a smoothed, mean-square voltage value. The square root of this filtered value is periodically computed and presented as the realtime RMS voltage value.

3. The current samples are squared and lowpass filtered to yield a smoothed, mean-square current value. The square root of this filtered value is periodically computed and presented as the realtime RMS current value.

4. The instantaneous voltage and current samples are independently multiplied to yield a signed instantaneous power product. The power-product samples are lowpass filtered, and the output of this filter is periodically posted as the realtime true power value.

5. The realtime power value from the "power" lowpass filter is time-integrated into a kilowatt-hour (energy) register.

6. The realtime RMS voltage and current values (the output signals of steps 2 and 3 above) are multiplied and presented as the realtime apparent-power (KVA) value.

7. The realtime KVA value is time-integrated into the KVAH register.

This algorithm is accurate without regard to the signal frequency, phase angles, or waveforms.

3.2 Samples 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 and, in fact, 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 AT/V180 sampling rate was chosen to ensure accurate measurement of waveforms containing frequency components up to the 50^{th} line harmonic, up to an AC line frequency of over 100 Hz. Advanced signal processing and filtering techniques are used in the Series 180 products to deliver accurate measurements for the ranges of signals found in real AC power systems.

Although Series 180 units are normally used to measure 50 or 60 Hz AC circuits, the units are capable of accurate measurement of power circuits from DC to over 100 Hz, if suitable current transducers are provided.

All acquired data is lowpass filtered to smooth instantaneous samples into averaged RMS volts, amps, watts, and KVAs. The digital filters used in the AT/V180 have a normal bandwidth of 1 Hertz. The filters have a “transitional” transfer function, a compromise between good high-frequency noise rejection and clean, damped step response. For a step change of voltage or current, the realtime RMS values reported by the AT/V180 will transition (20-80% levels) in about 400 milliseconds, and will settle cleanly without ringing or over-shoot; this behavior is well suited for both measurement and closed-loop control applications, and has response similar to the dynamics of mechanical meter movements. In the selectable “fast filter” mode, filter bandwidth is increased to 4 Hz, with 0.1-second step response. Fast filter mode is useful for recording envelope transients (say, motor starts) and for use in fast control loops, but will inherently display “noisier” data in a system connected to a real-life AC line and load.

Filtered volts, amps, watts, and other measured parameters are updated to the computer bus (ISA or VME busses for the AT180 and V180 respectively) at a rate of 32 times per second.

One advantage of digital processing is the wide dynamic range of power measurement that it makes possible. Whereas electromechanical instruments are limited by friction, and analog-multiplier-based electronic wattmeters have inherent offset and drift errors, a digital wattmeter can use autozero and correlation techniques to eliminate offsets, and can use statistical techniques to improve ADC linearity and remove digital quantization effects. The Series 180 products demonstrate power measurement linearity of better than 1 part in 5000, and have virtually immeasurable “zero power” offsets—below 1 part in 100,000. This means that a Series 180 instrument can accurately measure power levels that are a small fraction of the full-scale power of the instrumented circuit. The AT/V180 achieves this wide dynamic range without scale or gain switching, thus avoiding the bizarre behavior that some electronic power instruments display when they are presented with low- and mid-range signal levels.

3.3 Sources of Error

Several sources of error should be considered in applying the V180 and AT180 products. They include:

1. **CURRENT SENSOR ERRORS**. The standard current sensors provided with the Series 180 products are typically accurate to about 0.5% (amplitude) and 0.5 degrees (phase), so these sensors are the dominant error contributor 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 Series 180 instruments.

2. **STRAY PICKUP**. Since Series 180 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 Series 180 modules 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. Removable-link CTs can pick up signals from current-carrying conductors which 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.

c. To avoid ground loops, do not ground CT leads anywhere except at the C760 Termination Panel.

d. Ensure that the module mainframe (PC/AT computer or VME crate) is properly grounded, and that the C760 Termination Panel is securely grounded to the same ground system.

e. Route the D37 cable (from the termination panel to the module) away from current-carrying conductors.

3. **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.

4. **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 circuit. 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: A DC current component contributes no real power so long as the line voltage remains pure AC.

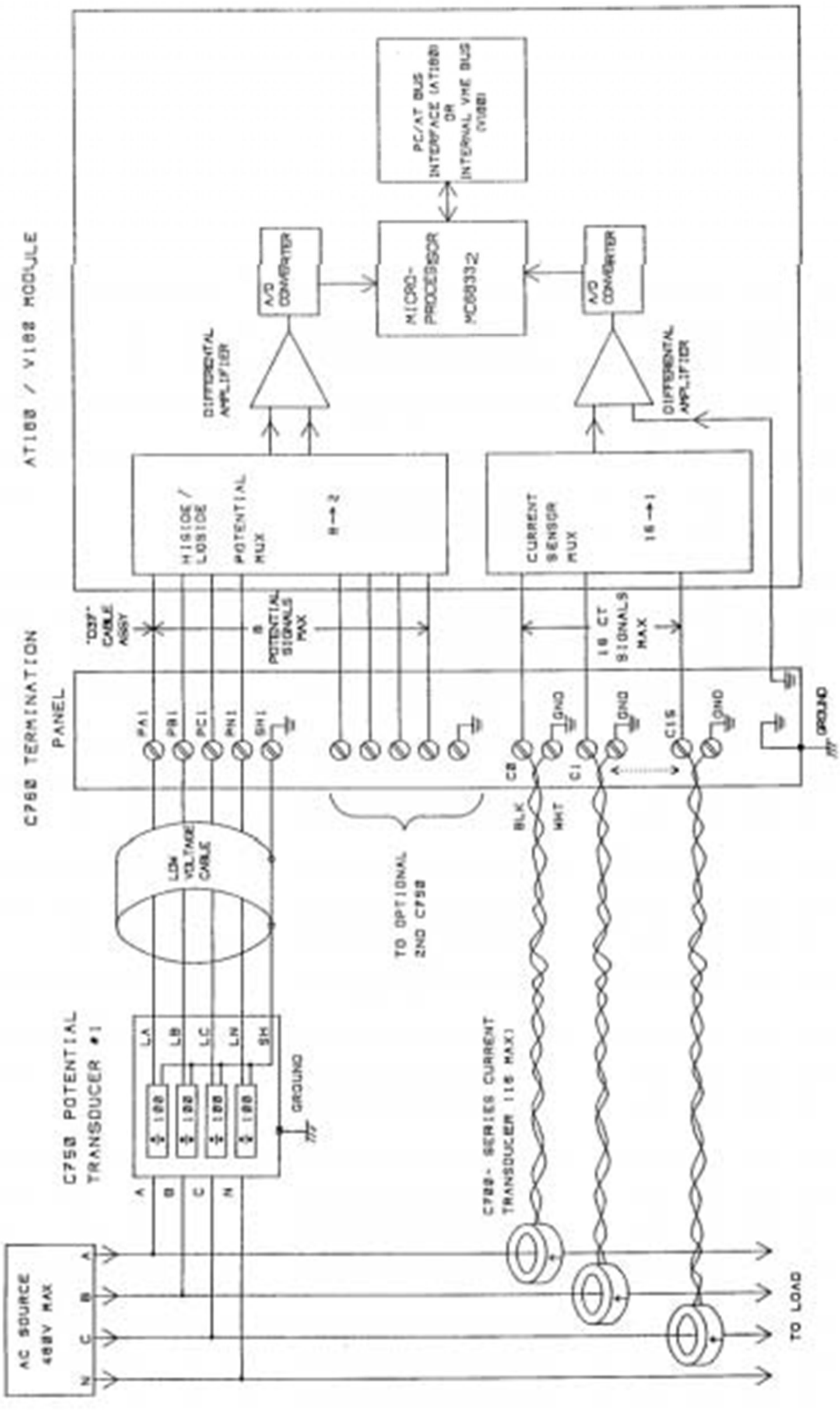

Figure 1. AT/V180 Hook-Up Block Diagram

4. Hardware Installation

4.1 Installing the AT180 in a PC

The AT180 may be installed in any full-length, 16-bit slot in any ISA architecture (IBM PC/AT compatible) computer. A 16-bit slot will have motherboard mating connectors for both sections of the gold-plated edge connector on the side of the AT180 module. Before installing the module, read and follow the steps below.

1. If a battery protector is installed (a strip of blue plastic under the upper leaf of the battery holder), remove it.

2. Set all four sections of the maintenance DIPswitch (“S4 TEST”) to the OFF position; press the lower sides of the switch rockers (near the word “OFF”) with a straightened paper clip or toothpick, NOT a pen or pencil.

3. Set the port address DIPswitch (“S6 ADDRESS”) to the desired PC/AT I/O port address. To do this, you must know the I/O address of all devices on your computer’s bus and select an unused block of four bytes of I/O space for the AT180 to use. The CONFIG.180 file furnished with the PowerView software lists the hex addresses which we suggest for up to eight AT180 modules, beginning with 2E0 hex for the first AT180 board. The ADDRESS DIPswitch can be used to select any address from 000 to 3FC hex. Each of the eight switch sections selects one bit for the address comparator, as shown in the following table:

S6 Section	Address Bit	Hex Value When “ON”
1	9	200
2	8	100
3	7	80
4	6	40
5	5	20
6	4	10
7	3	8
8	2	4

To select the standard address 2E0 hex, turn ON Sections 1, 3, 4, and 5.

Once set up, the AT180 module may be plugged into an available 16-bit motherboard slot. Be sure to secure the mounting bracket to the PC's frame to ensure proper grounding of the panel and connector shell.

The system file CONFIG.180 must be edited to declare the selected PC/AT I/O port addresses. (See Section 5.)

4.2 Installing the V180 in a VME System

The V180 may be installed in any 6U VME card cage. Before installing the module, read and follow the steps below.

1. If a battery protector is installed (a strip of blue plastic under the upper leaf of the battery holder), remove it.

2. Set all four sections of the maintenance DIPswitch ("S4 TEST") to the OFF position; press the lower sides of the switch rockers (near the word "OFF") with a straightened paper clip or toothpick, NOT a pen or pencil.

3. Set the port address DIPswitch ("S6 ADD") to the desired VME short I/O VME Space (address modifiers 29H and 2DH) base address. Before setting this switch, determine the I/O addresses of all devices on your computer's bus and select an unused block of 2KB space for the V180 to use. The ADDRESS DIPswitch can be used to select any address from 000 to F800 hex. The first five of the eight switch sections are functional, and they select one bit for the address comparator, as shown in the following table:

S6 Section	Address Bit	Hex Value When "ON"
1	15	8000
2	14	4000
3	13	2000
4	12	1000
5	11	8000
6	not used	
7	not used	
8	not used	

To select the standard address C000 hex, turn ON Sections 1 and 2. The V180 may be inserted into any standard VME crate or VME-compliant programmable logic controller.

⚠ **CAUTION: Always turn off crate power before installing or removing the module. Always secure the front-panel hold-down screws.**

After securing the module, connect and secure the front-palen I/O cable and connect the other cable end to the termination panel.

⚠ **CAUTION: The termination panel and the VME card cage must both be securely grounded.**

When the VME crate is powered up, the front-panel PASS/FAIL LED should initially illuminate red and, after the self-test sequence passes (in about one second), should turn green. The SCAN LED should then blink once per second, and the blue VME LED should light whenever the module is addressed by the VME bus.

If you are using the PV software (i.e., you are operating in a XYCOM XVME-674 or through a BIT3 Model 406), the CONFIG.180 file should be edited to identify the device as a V180, to indicate its base address, and to include comments on its function. (See Section 5.)

4.3 Installing the C760 Termination Panel

The C760 Termination Panel provides screw terminals for terminating field wiring from potential transducers, current sensors, and digital I/O signals.

The C760 should be secured to a flat mounting surface using the Z-brackets furnished, or bolted to a Model C765 rackmount bracket if used.

⚠ **CAUTION: To ensure personal safety and proper operation, the C760 Termination Panel must be securely grounded to an approved ground circuit.**

The following grounding means are suggested, but MUST be verified for compliance with applicable electrical codes:

1. **GROUND WIRE**. A suitable ground wire may be used to connect the Z-shaped mounting bracket to an approved ground. Secure the ground wire through one of the bracket mounting holes, using a 10-32 or larger machine screw or other fastener that complies with electrical codes. The ground wire should be at least as large as the largest signal-carrying wire connected to the C760 or to any of the associated C750 Potential Transducers, but no smaller than size 12 AWG.

2. **SURFACE GROUND**. The C760 may be grounded by bolting it securely to a properly grounded metallic mounting surface, using approved machine screws and locking devices. A redundant ground wire is recommended.

3. **RACK GROUND**. The C760 may be properly bolted into a Model C765 rack mounting bracket which is in turn securely bolted into a properly grounded relay rack. A redundant ground wire is recommended.

Once installed and grounded, grounding should be verified with a suitable test instrument.

Once mounted and grounded, all field wiring should be installed and checked BEFORE connecting the D37 signal cable from the C760 to the AT180 located in the PC or in the VME system. Wiring to specific sensors is discussed in the following sections.

⚠ **CAUTION: It is intended that only low voltage, low current signals be connected to the C760 Termination Panel. Before connecting the C760 to the computer, use an AC+DC responding voltmeter to verify that all field wiring inputs are at safe (12 volts or less) potentials to ground.**

4.4 Installing the C750 Potential Transducer

The Highland Model C750 Potential Transducer is used to interface AC line voltage inputs to the AT180 and the V180 Electrical Measurement Modules. Each AT/V180 may be wired to one or two C750 transducers through the C760 field-wiring termination panel.

The C750 is a small (5” x 3.25” x 2”) diecast NEMA-4 rated aluminum box having a gasket-sealed top cover and two 7/8” cutout holes, one on each end. Internally, the box is divided into two halves, a “high voltage” input section and a “low voltage” output section. The function of the C750 is to divide down high-voltage AC line levels to low-voltage AC signals which can be safely connected to an electronic measurement module.

The C750 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 and including a 480-volt AC input, measured line-to-line or line-to-ground.

⚠ **CAUTION: The C750 must be securely grounded. Refer to the “Grounding” section.**

The C750 Potential Transducer should be connected to circuits with limited fault current capability. Whenever possible, 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; see the section entitled "C750 Wiring: Low Voltage Outputs."

Do not use the C750 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 C750 cover must be properly fastened.

4.4.1 C750 Physical Mounting

The C750 may be mounted in any of the following ways:

1. The unit may be bolted to a flat surface. Remove the top cover and note the two through-mounting holes. The unit may be mounted using 8-32 machine screws and nuts, or (if mounted to a wood or similar insulating surface) with "wood bullet"-type screws.

2. The C750 may be mounted to the side of an existing electrical junction or equipment box, using an available 7/8" knockout hole. A standard 7/8" metallic bushing and locknut can be used to secure the C750 to either the outside or inside of the box.

   If the C750 is mounted INSIDE a bigger box, the mounting bushing must be used to secure the LOW VOLTAGE side of the C750 to the sidewall of the bigger box. In this case, the LOW VOLTAGE wiring of the C750 will feed through the side of the bigger box.

   If the C750 is to be attached to the OUTSIDE of an equipment or junction box, the HIGH VOLTAGE side of the C750 must be secured to the junction box using the bushing, and the HIGH VOLTAGE wiring will enter the C750 through this bushing.

3. The C750 may be suspended in a rigid conduit run, using suitable conduit fastener bushings.

If the C750 is mounted in an outdoor location or is subject to water drips or splashes, the two 7/8" wiring holes must be sealed with suitable fittings to protect against water entry. If conduits are used, ensure that any interior or exterior conduit condensation will not drip into the C750 enclosure.

4.4.2 Grounding Requirements

Three grounding methods may be used, in conformance with local electrical codes:

1. **CONDUIT**. Grounding may be accomplished by using suitable 7/8” conduit fittings to secure the C750 to properly grounded conduits.

2. **MOUNTING SURFACE**. If the mounting surface of the C750 is properly grounded, the C750 may be securely fastened to this surface to achieve grounding with installation per applicable codes.

3. **GROUND WIRE**. Two copper-colored grounding screws are provided inside the C750 NEMA-rated metallic enclosure. Run a suitable grounding wire through an inlet bushing and secure it to either screw, in conformance with local electrical codes. This wire must be suited to the fault current capability of the AC circuits connected to the C750.

CAUTION: The C750 enclosure must be securely grounded, using ground wiring and a ground suited to the type and fault-current capacity of the AC line voltage circuits being measured.

Use suitable test equipment to confirm ground integrity before applying AC line voltage inputs to the C750.

4.4.3 C750 Wiring: High Voltage Inputs

AC voltage inputs to be measured are connected to the large screw terminals in the HIGH VOLTAGE side of the C750. Wiring should be 12 through 18 gage, solid or stranded, insulated for the voltage present and in conformance with local electrical codes. A suitable wire bushing or conduit fitting and cut-through protections must be used. Connect the phase A, B, C, and N (neutral) wires to the marked A, B, C, and N terminals, or wire per the measurement project wiring diagram if appropriate.

4.4.4 C750 Wiring: Low Voltage Outputs

The low-voltage output of the C750 should be connected to the C760 Termination Panel using a 4-conductor cable with overall foil shield and drain wire; the maximum recommended cable run length is 200 feet. A UL-2094 type cable is recommended, such as Alpha 2404C or Belden 8729. Connect the four signal wires to the LA, LB, LC, and LN terminals, and connect the shield wire to the LS terminal. These terminals are located in the LOW VOLTAGE side of the enclosure. Refer to the project wiring diagram for color-code connections.

Do not allow the shield lead to touch the chassis of the C750, as this may cause measurement errors.

The low-voltage cable must pass through a suitable cable bushing or conduit fitting.

⚠ **CAUTION: The low-voltage cable must be isolated from any AC line voltage conductors, in conformance with local electrical codes.**

4.5 Selecting and Installing Current Sensors

4.5.1 C700-Series Current Sensors

Highland furnishes the series C700 current sensors for use with the AT/V180. Sensors are UL-listed current transformers which 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 C760 Termination Panel.

The C700 sensors are available in both closed-loop (toroidal, or doughnut form) and square split-link styles. The doughnut sensors are less expensive, more accurate, and less likely to pick up leakage fields from nearby current-carrying conductors. The split-link conductors are 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. Do not run a multiwire Romex or similar multiwire 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 running near or contacting power-level wiring. Route the signal leads in conformance with wiring codes for LOW VOLTAGE wiring.

Current transducers must be installed in the proper orientation to insure 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 the same direction in a polyphase system.

The output leads of the current transducers should be routed to the C760 Termination Panel. Connect the BLACK (highside, or “X1”) lead to the appropriate “Cn” terminal of the panel, and connect the WHITE lead to the adjacent GND terminal; refer to the project wiring diagram if available. If the CT leads are too short, they may be extended up to 200 feet using twisted-pair, 20-gage or larger stranded wiring. It is not necessary to shield this wiring.

4.5.2 Using 5-amp Secondary CTs

If the user of the AT/V180 chooses to use a simple 5-amp secondary current transformer rather than one of Highland Technology's current transducers (C701 through C706) to sense current, then a suitable burden resistor should be installed in parallel with the current transformer. This is because Highland Technology's current transducers have an in-built burden resistor.

The AT180 only works with current transducers that produce 0.25 or 0.333 volts RMS at full-scale current. Therefore the burden resistor must be chosen to output one or the other of these maximum voltages.

Highland Technology furnishes the C720, 0.05-ohm Current Transformer Load Resistor to fulfill this role. The C720 is a PC-board assembly consisting of a 4-lead, 0.05-ohm, 0.1%, 5-watt resistor and barrier-strip connectors. The C720 is provided with mounting holes.

When using the AT/V180 with the C720, a Type CT2 current sensor must be declared in the AT/V180 PARAMETER SET to permit proper scaling of the current data.

⚠ **CAUTION: The C720 should be installed in parallel with the current transformer before power is applied in the wire through which the measured current will flow. Otherwise, a lethal voltage may develop across the leads of the current transformer.**

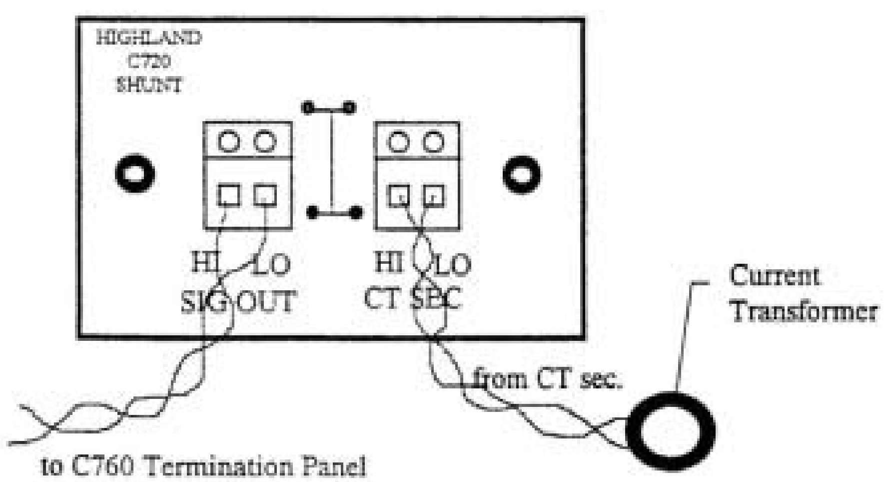

Figure 2. Connecting a C720 to a 5-amp Secondary Current Transformer

4.6 Installing the AT/V180 Signal Cable

Once the C760 Termination Panel is properly mounted, grounded, and wired, and ALL inputs have been verified to be safe low-voltage potentials, the D37 cable assembly may be connected between the termination panel and the AT/V180 module installed in the PC or in the VME system. Secure both ends with the jackscrew hardware provided. If the cable is too short, it may be extended with a standard shielded one-for-one D37 cable assembly or, alternatively, longer assemblies can be ordered from Highland. The D37 cable assembly may be up to 100 feet long; this cable length will not adversely affect measurement accuracy EXCEPT resistance inputs and RTD-measured temperatures. Each additional ohm of cable resistance will cause a temperature measurement error of about 0.25 degrees C.

5. Software Installation

The PowerView software is furnished on a DOS-format floppy disk, normally a 1.44 Mbyte, 3.5” disk. To install the software, insert the disk into a floppy drive (A or B) and, at the DOS prompt, type

`A:INSTALL` or `B:INSTALL`

The INSTALL.EXE program will run; you may use the indicated single-letter commands to change the program defaults if suitable, then type “`I`” to install the software. The installation program will create a directory on your hard disk (default C:\AT180) and install all programs and files. Your system files AUTOEXEC.BAT and CONFIG.SYS will not be altered. The PowerView software requires about 600 Kbytes of hard disk space.

The PowerView software includes the following programs:

PV.EXE	the overall system shell
PARSET.EXE	creates, edits, and manages Parameter Sets, AT180 setup files
B180.EXE	the realtime data display and logging program
TSRMAN.EXE	the optional time-series-record manager

All programs include extensive HELP facilities, and PV includes an electrical measurement tutorial and an introduction to the Series 180 modules.

The system file CONFIG.180 should be checked to verify that it lists all present AT180 and V180 cards correctly, including the selected hex I/O port addresses. If this file is incorrect, edit it using the DOS EDIT.EXE program or other flat ASCII editor, keeping edited data in the fields indicated by the “=====” field header line.

If the PowerView software includes a file named DEMO.ON, rename the file DEMO.OFF.

6. Measurement Configurations

To instrument an AC power circuit, the following items are required:

An AT180 module installed in a suitable PC, with the PowerView software, or a V180 module installed in a VME computer system.

One C760 Termination Panel, properly connected and grounded.

One or two C750 Potential Transducers; each PT can be connected to up to four AC potential (voltage) inputs.

From one to 16 C700-Series Current Transducers, one per current-carrying wire to be measured. Each CT should be sized to have a rated current somewhat higher than the maximum current to be measured. For circuits which may have high peak-to-average current ratios (typical of electronic loads) CT ratings may need to be higher.

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 C760 Termination Panel. The choice of which CT is wired to which of the 16 C760 "C" inputs is arbitrary.

Some common measurement situations are discussed in the following sections.

6.1 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. The two wires are commonly a "hot" wire and a "neutral" wire, although a single-phase load may be connected to two "hot" wires, as in a common single-phase, 240-volt (say, a clothes dryer) situation, or a case in which a single-phase load is connected between two lines of a 3-phase 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.

To instrument a single-phase load:

Make sure that BOTH power conductors are connected to the inputs of a C750 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.

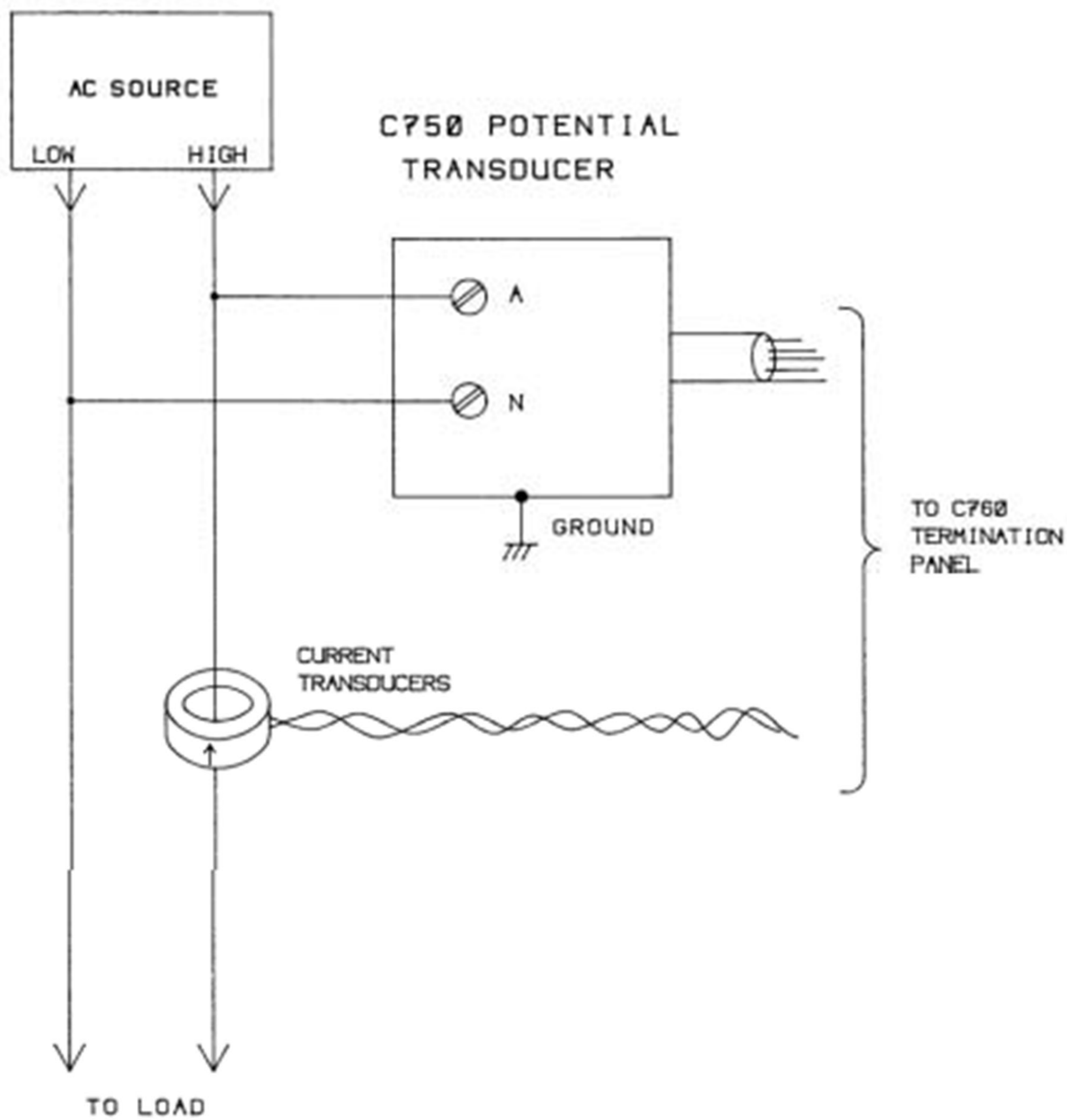

Figure 3. Instrumenting a Single-Phase Load

Install the current transducer over the "highside" current-carrying conductor, properly oriented as noted in Section 4.5.1. Wire this CT's low-voltage outputs to one of the "C" inputs of the termination panel, called "Cn" for this example.

Use the PARSET program to configure Acquisition Channel "n" to be the appropriate type (CT3 for a standard current transducer) and current rating, and select the correct highside:lowside potential inputs (e.g., the ones that the voltage leads were wired to, such as "A1" and "N1"). Then select a totalizer channel that you would like to become the "wattmeter" indicator for this power circuit. The acquisition channel and totalizer 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 AT/V180 module, as described in Section 5.

Now the B180 realtime display program will show the AC line-to-line voltage, power, KVAs, kilowatt-hours, and KVA-hours associated with this single-phase load circuit.

6.2 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 or a Delta-connected 3-phase load) will need two CTs, whereas a 4-wire "Wye" load will need three CTs.

In either case, wire all involved potential lines to inputs of a C750 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 general, you should follow the methodology of Blondel's theorem to configure the correct number of "virtual wattmeters" required to properly meter any multiwire circuit. Refer to the Electrical Measurement Tutorial for a summary of Blondel's theorem.

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, 3-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 PARSET.EXE is used to configure the proper set of Blondel-compatible virtual wattmeters. 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 4. In this case, you might use PARSET.EXE to configure the three associated CT acquisition channels as follows:

```
CT1:    type CT3    400 Amps    A1:N1    totalizer 1
CT2:    type CT3    400 Amps    B1:N1    totalizer 1
CT3:    type CT3    400 Amps    C1:N1    totalizer 1
```

Now TOTALIZER 1 will indicate the net circuit power.

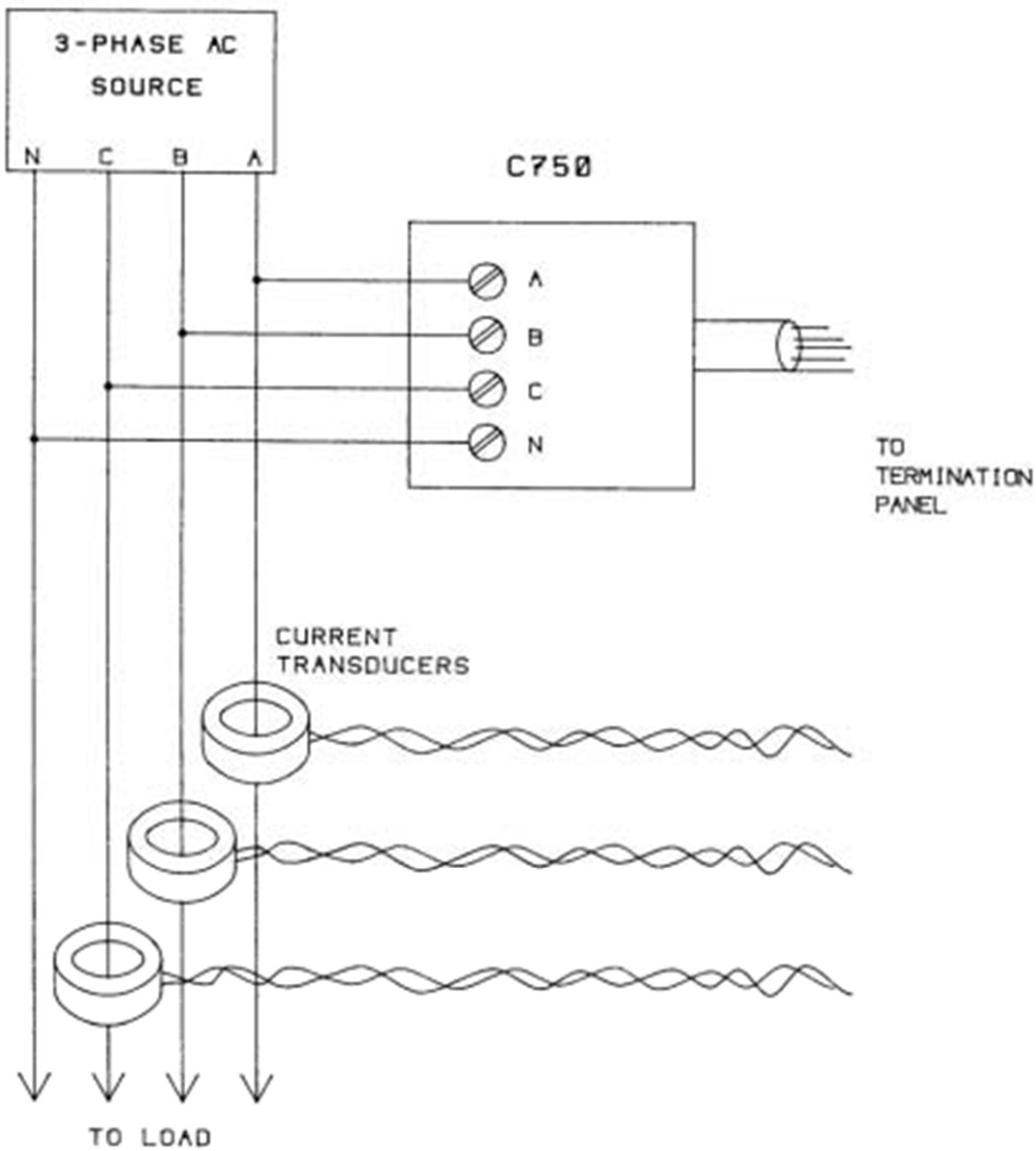

Figure 4. Instrumenting a 4-Wire Polyphase Load

A 3-wire, 3-phase “Delta” load configuration is instrumented as shown in Figure 5. In this case, you could use PARSET.EXE to configure two CT acquisition channels as follows:

```
CT4:   type CT3    200 Amps    A1:C1    totalizer 2   DELTA
CT5:   type CT3    200 Amps    B1:C1    totalizer 2   DELTA
```

Now TOTALIZER 2 will indicate the net circuit power.

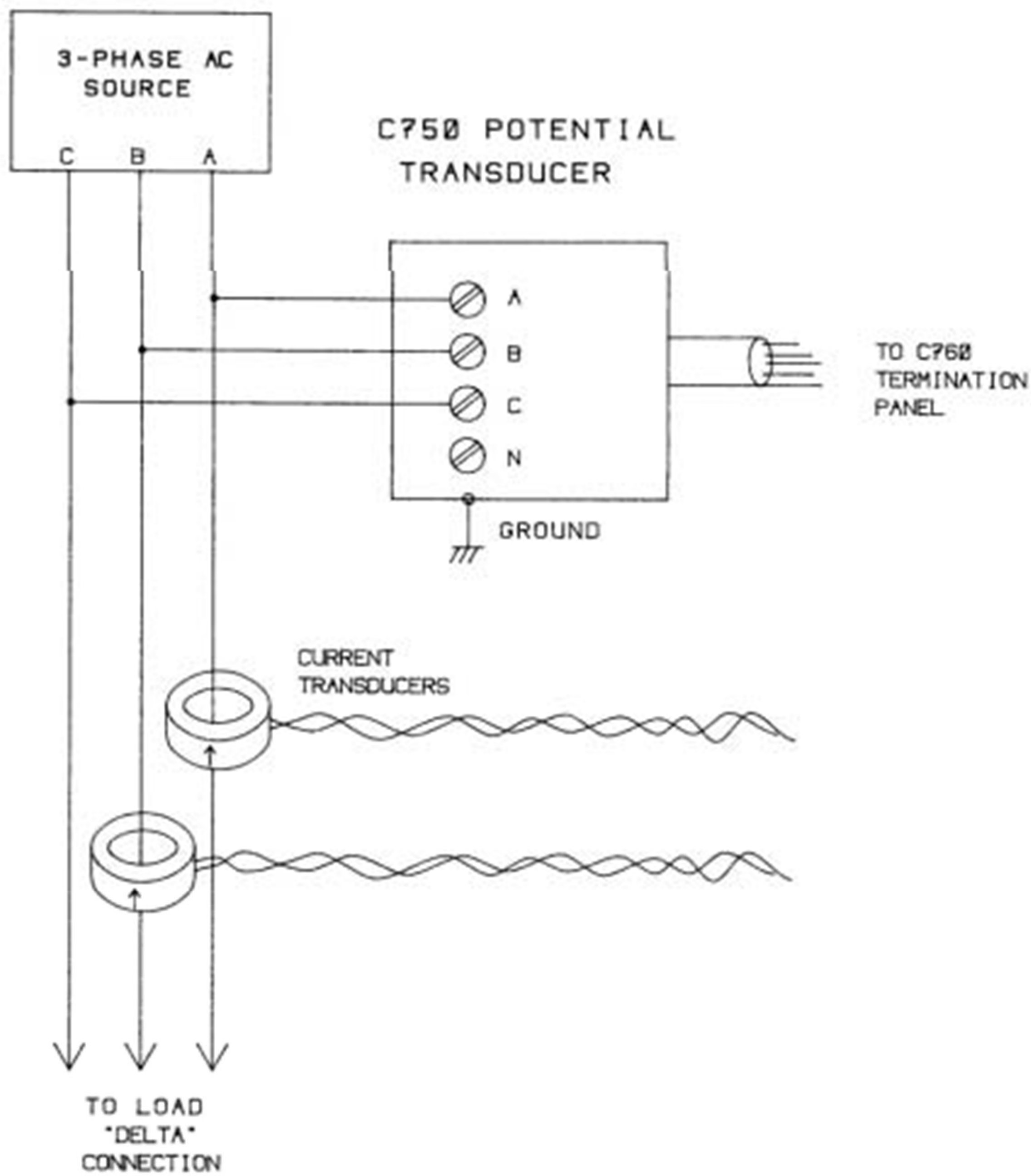

Figure 5. Instrumenting a 3-Wire “Delta” Load

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

To verify that the system is a true 3-phase circuit, use an AC voltmeter to CAREFULLY measure the three line-to-line voltages A:B, B:C, and A:C. In a 3-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 totalized power still reading the correct sign and magnitude.

A 3-wire, split single-phase load configuration may be instrumented as shown in Figure 6. In this case, you could use PARSET.EXE to configure two CT acquisition channels as follows:

```
CT6:    type CT3    100 Amps    A1:N1    totalizer 3
CT7:    type CT3    100 Amps    B1:N1    totalizer 3
```

Now TOTALIZER 3 will indicate the net circuit power. Since the load is not truly three phases, we do not set the DELTA attribute.

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

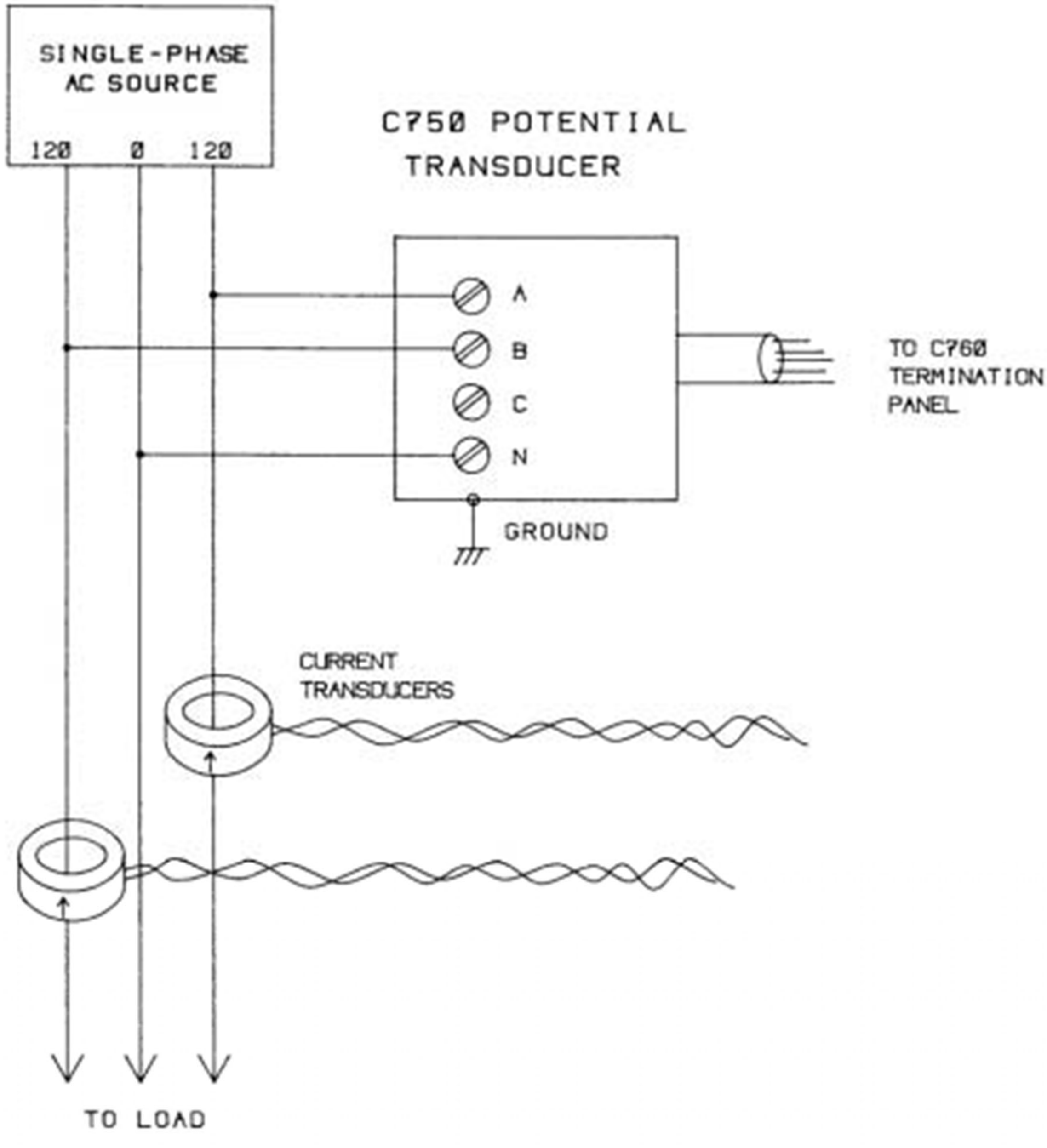

Figure 6. Instrumenting a 3-Wire Split-Phase Load

6.3 DC Analog Inputs

Simple DC analog signals in the range of ±5.12 volts may be acquired using any one of the 16 available acquisition channels. Connect the signal to one of the “Cn” terminals of the C760 Termination Panel, and connect the return side of the signal to the adjacent GND terminal. Note that the C760 does indeed GROUND the return side of the analog signal source.

Use PARSET.EXE to configure Channel “n” to be an ANA type, and enter any desired analog offset and scaling values needed to convert the analog voltage to engineering units if appropriate.

4-20-milliampere transducer signals will require an external precision load resistor, such as the Model C725. The AT/V180 may be damaged by analog inputs above ±12 volts.

6.4 RTD Temperature Inputs

AT/V180 Acquisition Channels 0 through 7 may be used to measure temperatures, using a 1000-ohm, DIN-standard platinum RTD sensor. Connect the RTD to the C760 “Cn” input and its adjacent ground, and use PARSET.EXE to configure Channel “n" to be an "RTD" channel type.

Since the AT/V180 conditions only 2-wire RTDs, any wire resistance in series with the RTD will contribute temperature error. Each ohm of total loop resistance increases indicated temperature by approximately 0.25 degrees C.

6.5 Resistance Inputs

Resistance up to 2047 ohms may be read, using Acquisition Channels 0 to 7. Setup is identical to that for RTDs, but use PARSET to declare the channel type to be "RES."

6.6 Digital Inputs

The AT/V180 has eight digital inputs. Each may be connected to a contact closure, open-collector signal, or optoisolator output. Connect such a device between one of the "Dn" inputs and the adjacent GND. PARSET.EXE may be used to configure this digital channel to be a pulse counter or a runtime input. As a pulse counter, the AT/V180 counts each contact closure, and the B180 program will display counts and optional scaled engineering units.

If a digital input is configured to be a runtime counter, it will count accumulated contact closure time in seconds. If the REVERSE attribute is programmed, contact OPEN time will be accumulated, again in seconds.

All AT/V180 digital input/outputs are pulled up to +12 volts through a 1K resistor. Inputs are conditioned by an R-C lowpass filter which prevents spurious counts caused by contact bounce and electrical noise. The input filter limits the count rate to 20 Hz max. A plug-in resistor package may be replaced if required, extending the count rate to 150 Hz max.

6.7 Digital Outputs

Each of the eight digital channels may be programmed to be an open-collector (with pullups to +12) digital output referenced to ground. Selectable digital output types are:

PLS: A 16-msec closure pulse is generated when an associated KWH or KVAH register increments.

TSR: A 16-msec pulse is made when a time-series record is posted.

OUT: The open-collector output is controlled directly by supplied software.

7. Grounding and Safety Considerations

The AT/V180 is normally used to measure circuits having potentially lethal voltages and potentially explosive current capacities. Users should always observe the following precautions:

CAUTION: All power wiring should be done by a licensed electrician in conformance to applicable electrical codes.

CAUTION: The C750 Potential Transducer must be properly grounded and wired: see Section 4.4. Connection to current-limited (fused) circuits in strongly recommended.

The C760 Termination Panel must be properly grounded and wires: see Section 4.3.

Current transducers must be properly sized and installed: see Section 4.5.

All wiring and grounding should be electrically tested for safety before connecting the D37 cable from the C760 Termination Panel to the AT/V180 module in the PC: see Section 4.6.

The PC used must be plugged directly into a securely grounded AC outlet. The use of extension cords, power centers, or surge suppressors is not recommended.

8. Application Notes

The following is a list of the AT/V180 application notes that can be found on the floppy disk accompanying this manual:

AN1	Online Datalogging vs. Time-Series-Records for the AT180
AN2	Theory of Operation: AT180/V180 Electrical Measurement Modules
AN3	Reading Realtime Data from the AT180 and V180 (Register-level Programming of the AT180 and V180 Modules)
AN6	Mounting and Connecting the C750 Potential Transducer
AN8	Instrumenting DC Power Systems with the AT180 and V180
AN10	The AT180/V180 Parameter Set: Functions and Structure
AN14	Online Datalogging vs. Time-Series Records for the AT180 and V180
AN15	Using the V180 in VME-based Systems
AN20	Endian Considerations for the AT180/V180

9. Connector Pinout

Pin #	Pin name
1	PTC2
2	PTB2
3	PTA2
4	PTN2
5	PTC1
6	PTB1
7	PTA1
8	PTN1
9	DIO2
10	DIO3
11	DIO4
12	DIO5
13	DIO6

Pin #	Pin name
14	DIO7
15	VGND
16	VGND
17	CT7
18	CT6
19	CT5
20	CT4
21	CT3
22	CT2
23	CT1
24	CT0
25	CT15
26	CT14

Pin #	Pin name
27	CT13
28	CT12
29	CT11
30	CT10
31	CT9
32	CT8
33	CTCOM
34	DIO0
35	DIO1
36	SPARE
37	EXT+12V