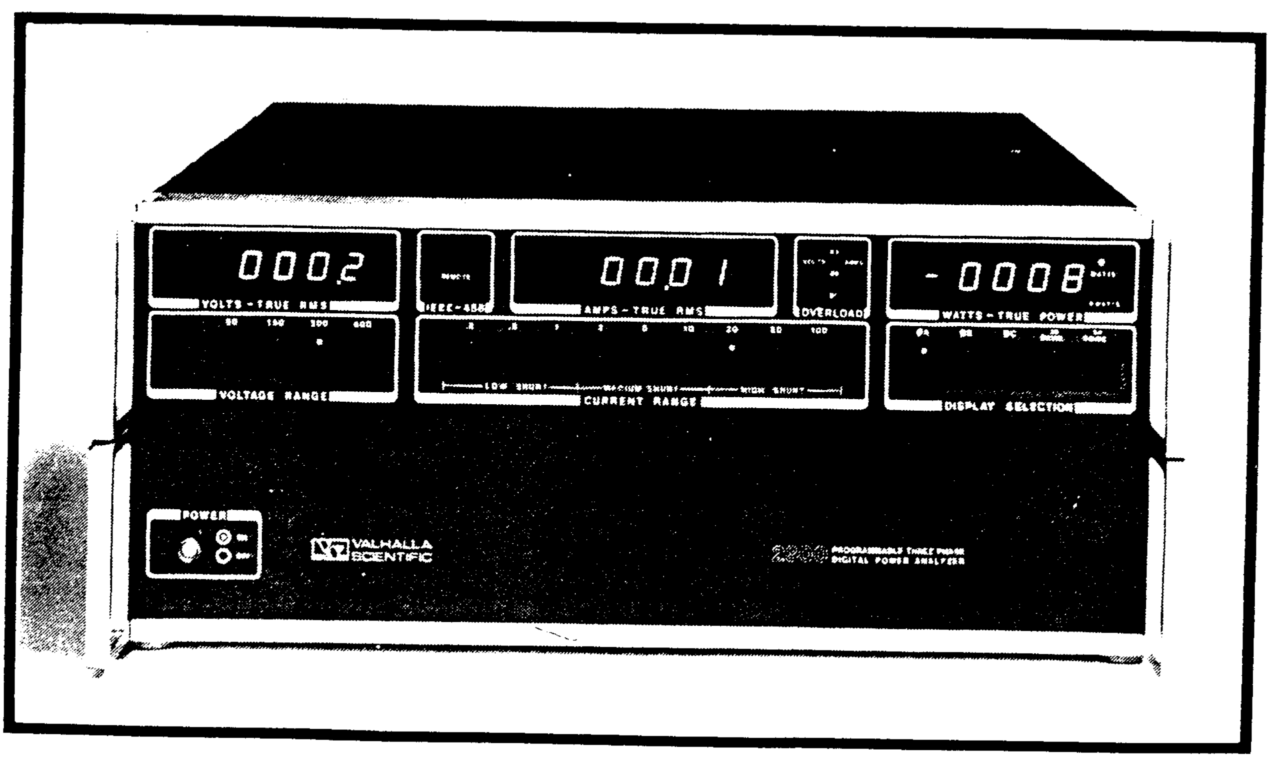
2300 SERIES

Digital Power Analyzers

OPERATING MANUAL



MODEL 2300 THREE PHASE WATTMETER

REVISED 3/84

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NOTICE

The information in this manual covers the following Power Analyzers:

Models 2300, 2300L, 2301 and 2301L

All voltage and power data referred to in this manual should be reduced by a factor of 10 for Models 2300L and 2301L.

All references to ØB, ØC, three-wire and four-wire operation should be ignored for Models 2301 and 2301L.

WARNING

Although this unit does not produce high voltages, potentially lethal voltages and currents may be present at the inputs. Therefore,

DEATH

on contact may result if personnel fail to observe safety precautions. The individual phase signal processing boards are floating with respect to each other and ground. Therefore, avoid contact with the input terminals and the signal processing boards.

SECTION I - UNPACKING AND INSTALLATION

1.1 UNPACKING AND INSPECTION

If the shipping carton is damaged, request that the carrier's agent be present when the unit is unpacked. If, when unpacked, the unit shows external damage, the carrier's agent should authorize repairs before the unit is returned to the factory. If the shipping carton is damaged, the unit may have suffered internal damage in transit that may not be evident until the unit is operated or tested to verify conformance with its specifications. If the unit fails to perform or fails to meet the performance specifications of Section II, notify the carrier's agent and the nearest Valhalla Sales Office. Retain the shipping carton for the carrier's inspection. DO NOT return equipment to Valhalla Scientific or any of its sales offices prior to obtaining authorization to do so.

1.2 INITIAL ADJUSTMENTS

The only adjustments required before placing the unit in operation are to set the rear panel switch to the local power voltage and verify that the proper fuse is installed as listed in Table 1-1.

Table 1-1. Voltage Switch Settings and Fuse Ratings.

SUPPLY VOLTAGE	SWITCH SETTING	FUSE RATING
100 - 130V	115	1 Amp Slo Blo
200 - 260V	230	1/2 Amp Slo Blo

1.3 INSTRUCTIONS FOR BENCH USE

The unit is delivered with all required hardware for bench use installed. Instructions for use in that manner are not necessary. However, before connecting the unit to the local power source, verify that the power cord is equipped with a three-terminal connector (see the Safety Precautions of paragraph 1.5).

1.4 INSTRUCTIONS FOR RACK MOUNTING

Optional brackets are available for mounting the Model 2300 in an equipment rack. These are listed in Section VII. The size of the unit and the location of its center of gravity dictate that it should be supported on both sides along its entire length through the use of trays or slides. If it is to be transported while mounted in a rack, it should be supported in a manner that prevents movement in any direction.

Note that the specifications listed in Section II indicate that accuracy of the unit is degraded at abnormally high temperatures. Therefore, it is recommended that spacer panels at least 1.75 inches high be installed between this and any other air flow. Under no circumstances should the ambient air temperature around the unit exceed 50° C while the unit is in operation or 70° C when power is removed.

1.5 SAFETY PRECAUTIONS

The power plug should be a three-contact device and should be inserted only in a three-contact mating socket where the third contact provides a ground connection. If an extension cable is used, the ground connection must be continuous. Any discontinuity in the ground lead may render the unit unsafe for use.

SECTION II - SPECIFICATIONS

2.1 GENERAL

Performance specifications for the Model 2300 Programmable Three-Phase Digital Power Analyzer are listed in this section as are its environmental limits. Accuracy will be degraded if environmental conditions are not within the specified limits.

2.2 ENVIRONMENTAL LIMITS

The environmental limits for operation of the Model 2300 are listed in Table 2-1.

2.3 PHYSICAL SPECIFICATIONS

The physical specifications of the Model 2300 are listed in Table 2-2.

2.4 OPERATING SPECIFICATIONS

The operating specifications for the Model 2300 are listed in Tables 2-3 through 2-8.

Table 2-1. Environmental Limits.

Operating Temperature Range:	0 to 50 degrees Celsius
Temperature Coefficient:	+0.025% of range per degree Celsius
Power:	115/230 volts ±10%, 40 VA
Warm-up Time:	30 minutes to specifications

Table 2-2. Physical Specifications.

Height:	178mm (7")
Width:	432mm (17")
Depth:	483mm (19")
Weight:	15Kg (33 lbs)

Table 2-3. Input Current Specifications

Accuracy:	(25 C ±5 C for one year) ±0.25% reading ±0.25% range
Crest Factor:	2.5:1 at full scale
Minimum Input:	5% of range
Shunt Compliance Voltage:	100mV at full scale on highest range
Peak Indicator:	2 X range

Table 2-4. AC Current Range Versus Resolution, Bandwidth and Overload Current.

Ranges	0.2A, 0.5A, 1.0A	1.0A, 5.0A, 10.0A	20.0A, 50.0A, 100.0
Resolution Shunt Bandwidth Overload	100 uA 0.1Ω (1A Shunt) 20 Hz - 10 KHz 2A continuous, 5A 100 mSec	1mA 0.01Ω (10A Shunt) 20 Hz - 5 KHz 20A continuous, 50A 100 mSec	10 mA 0.001Ω (100A Shunt) 20 Hz - 1 KHz 150A continuous, 500A 100 mSec

Table 2-5. Input Voltage Specifications.

Accuracy:	(25 C ±5 C for 1 year) ±0.25% reading ±0.25% range from 20 Hz to 10 KHz
Crest Factor:	2.5:1 at full scale
Minimum Input:	5% of range
Peak Indicator:	2 X range

Table 2-6. Voltage Range Versus Resolution.

Ranges	50.00	150.00V	300.0V	600.0V
Resolution	10 mV	10 mV	100 mV	100 mV

Table 2-7. Power Specifications.

Accuracy:	(25 C ±5 C for one year) ±0.25% reading ±0.25% range		
Bandwidth:	1 Amp Shunt	10 Amp Shunt	100 Amp Shunt
	20 Hz - 10 KHz	20 Hz - 4 KHz	20 Hz - 1 KHz

Table 2-8. Instrument Range Versus Power Display Resolution, Single-Phase Measurements.

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 2.0A	5.0A	10.0A	100 Amp Shunt 20.0A	50.0A	100.0A
50V	10.000	25.00	50.00	100.00	250.0	500.0	1000.0	2500	5000
150V	30.00	75.00	150.0	300.0	750.0	1500.0	3000	7500	15000
300V	60.00	150.00	300.0	600.0	1500.0	3000	6000	15000	30.00 kW
600V	120.00	300.0	600.0	1200.0	3000	6000	12000	30.00 kW	60.00kW

Table 2-9. Three-Phase Three-Wire

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 2A	5A	10A	100 Amp Shunt 20A	50A	100A
50V	20.00	50.00	100.00	200.0	500.0	1000.0	2000	5000	10000
150V	60.00	150.00	300.0	600.0	1500.0	3000	6000	15000	30.00 kW
300V	120.00	300.0	600.0	1200.0	3000	6000	12000	30.00kW	60.00 kW
600V	240.0	600.0	1200.0	2400	6000	12000	24.00kW	60.00kW	120.00 kW

Table 2-10. Three-Phase Four-Wire

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 2A	5A	10A	100 Amp Shunt 20A	50A	100A
50V	30.00	75.00	150.00	300.0	750.0	1500.0	3000	7500	15000
150V	90.00	225.00	450.0	900.0	2250.0	4500	9000	22.50kW	45.00 kW
300V	180.00	450.0	900.0	1800.0	4500	9000	18000	45.00kW	90.00 kW
600V	360.0	900.0	1800.0	3600	9000	18000	36.00kW	90.00kW	180.00 kW

Table 2-11. 2300L Single Phase Measurements

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 0.2A	0.5A	1.0A	100 Amp Shunt 2.0A	5.0A	10.0A
5V	1.0000	2.500	5.000	10.000	25.00	50.00	100.00	250.0	500.0
15V	3.000	7.500	15.00	30.00	75.00	150.0	300.0	750.0	1500.0
30V	6.000	15.000	30.00	60.00	150.0	300.0	600.0	1500.0	3000
60V	12.000	30.00	60.00	120.00	300.0	600.0	1200.0	3000	6000

Table 2-12. 2300L Three-Phase Three-Wire

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 2A	5A	10A	100 Amp Shunt 20A	50A	100A
5V	2.000	5.000	10.000	20.00	50.00	100.00	200.0	500.0	1000.0
15V	6.000	15.000	30.00	60.00	150.00	300.0	600.0	1500.0	3000
30V	12.000	30.00	60.00	120.00	300.0	600.0	1200.0	3000	6000
60V	24.00	60.00	120.00	240.0	600.0	1200.0	2400	6000	12000

Table 2-13. 2300L Three-Phase Four-Wire

Ranges	1 Amp Shunt 0.2A	0.5A	1.0A	10 Amp Shunt 2A	5A	10A	100 Amp Shunt 20A	50A	100A
5V	3.000	7.500	15.000	30.00	75.00	150.00	300.0	750.0	1500.0
15V	9.000	22.50	45.00	90.00	225.0	450.0	900.0	2250	4500
30V	18.000	45.00	90.00	180.00	450.0	900.0	1800.0	4500	9000
60V	36.00	90.00	180.00	360.0	900.0	1800.0	3600	9000	18000

SECTION III - MANUAL OPERATION

3.1 GENERAL

The Model 2300 is equipped with the following front panel controls:

Power Switch/Indicator:

The Power Switch is an illuminated alternate action switch which lights when the power is on.

The following are multi-section pushbutton switches:

Power Display Selector:

ØA
ØB
ØC
3Ø 3-Wire
3Ø 4-Wire

Current Range Selector:

0.2 Amperes
0.5 Amperes
1.0 Amperes
2.0 Amperes
5.0 Amperes
10 Amperes
20 Amperes
50 Amperes
100 Amperes

Voltage Range Selector:

50 Volts
150 Volts
300 Volts
600 Volts

Above the three pushbutton switch sets are three digital displays. On the right, above the Power Display Selector switch, is a 5-digit Watts display. Two LED lamps at the right of the Watts display indicate whether the display is in watts or kilowatts. In the center, above the Current Range Selector switch, is a 5-digit Amps display. Three pairs of LED lamps at the right of the Amps display indicate an instrument overload condition on any of the three phases. On the left, above the Voltage Range Selector switch, is a 5-digit Volts display. At the right of the Volts display, a single LED lamp indicates that the instrument is being remotely controlled through the optional IEEE-488 interface.

3.2 CONNECTIONS

The Model 2300 has a separate cluster of terminals for each of the three phases. Each phase has three current terminals, whose use depends on the range of current to be measured. The three current terminals are internally connected to the 1 ampere, 10 ampere and 100 ampere shunts. The opposite end of the three shunts are connected together to the CURRENT COMMON-VOLTS HIGH terminal which serves for all voltage ranges.

Connections to the Model 2300 are outlined in the following paragraphs. The single phase connections are shown using phase C of the Model 2300. Any of the three phases, A, B, or C may be used equally.

CAUTION

In normal use, the terminals of the Model 2300 are connected to lethal voltage sources. Do not attach or remove wires without first ascertaining that all sources have been disabled.

3.2.1 SINGLE-PHASE TWO-WIRE LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.1. Caution! Do not run the neutral current through the volts common terminal. Tap off the neutral wire to connect the volts common terminal.

3.2.2. SINGLE-PHASE TWO-WIRE CT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.2. Observe the polarities of the current transformer. Caution! Do not run the load current through the VOLTS COMMON terminal. Tap off the neutral wire to connect the VOLTS COMMON terminal.

3.2.3 SINGLE-PHASE TWO-WIRE PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.3. Observe the polarity of the potential transformer. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.4 SINGLE-PHASE TWO-WIRE CT-PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.4. Observe the polarities of the current and potential transformers. The current common terminal should be grounded for best performance.

3.2.5 SINGLE-PHASE TWO-WIRE SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.5. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Caution! Do not run the neutral current through the VOLTS COMMON terminal. Tap off the neutral wire to connect the VOLTS COMMON terminal.

3.2.6 SINGLE-PHASE TWO-WIRE CT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.6. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarity of the current transformer. Caution! Do not run the neutral current through the VOLTS COMMON terminal. Tap off the neutral wire to connect the VOLTS COMMON terminal.

3.2.7 SINGLE-PHASE TWO-WIRE PT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.7. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarity of the current transformer. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.8 SINGLE-PHASE TWO-WIRE CT-PT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.8. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarities of the current and potential transformers. For best performance the CURRENT COMMON terminal should be grounded.

3.2.9 THREE-PHASE THREE-WIRE LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.9. Caution! Do not run phase B current through the VOLTS COMMON terminals. Tap off the phase B wire to connect the VOLTS COMMON terminals.

3.2.10 THREE-PHASE THREE-WIRE CT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.10. Observe the polarities of the current transformers. Caution! Do not run the line current through the CURRENT OR VOLTS COMMON terminals. Tap off the line wires to connect the CURRENT AND VOLTS COMMON terminals.

3.2.11 THREE-PHASE THREE-WIRE PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.11. Observe the polarities of the potential transformers. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.12 THREE-PHASE THREE-WIRE CT-PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.12. Observe the polarities of the current and potential transformers. For best performance ground the CURRENT COMMON terminals.

3.2.13 THREE-PHASE THREE-WIRE SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.13. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Caution! Do not run the phase B current through the VOLTS COMMON terminals. Tap off the phase B wire to connect the VOLTS COMMON terminals.

3.2.14 THREE-PHASE THREE-WIRE CT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.14. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarity of the current transformer. Caution! Do not run the line current through the CURRENT OR VOLTS COMMON terminal. Tap off the line wires to connect the CURRENT AND VOLTS COMMON terminals.

3.2.15 THREE-PHASE THREE-WIRE PT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into a load. These connections are shown in Figure 3.15. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarities of the potential transformers. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.16 THREE-PHASE THREE-WIRE CT-PT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into the load. These connections are shown in Figure 3.16. When the Model 2300 is connected in this manner, the watts reading should be multiplied by minus one. Observe the polarities of the current and potential transformers. For best performance, the CURRENT COMMON terminals should be grounded.

3.2.17 THREE-PHASE FOUR-WIRE LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.17. Caution! Do not run the neutral current through the VOLTS COMMON terminals. Tap off the neutral wire to connect the VOLTS COMMON terminals.

3.2.18 THREE-PHASE FOUR-WIRE CT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.18. Observe the polarities of the current transformers. Caution! Do not run the line or neutral currents through the CURRENT OR VOLTS COMMON terminals.

3.2.19 THREE-PHASE FOUR-WIRE PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.19. Observe the polarities of the potential transformers. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.20 THREE-PHASE FOUR-WIRE PT LOAD POWER CONNECTIONS

Connect the wattmeter as shown in Figure 3.20. Observe the polarities of the current and potential transformers. For best performance, ground the CURRENT COMMON terminals.

3.2.21 THREE-PHASE FOUR-WIRE SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into a load. These connections are shown in Figure 3.21. When the Model 2300 is used in this manner, the watts reading should be multiplied by minus one. Caution! Do not run the neutral current through the VOLTS COMMON terminals.

3.2.22 THREE-PHASE FOUR-WIRE CT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into a load. These connections are shown in Figure 3.22. When the Model 2300 is used in this manner, the watts reading should be multiplied by minus one. Observe the polarities of the current transformers. Caution! Do not run the line or neutral currents through the CURRENT OR VOLTS COMMON terminals. Tap off the line and neutral wires to connect the CURRENT AND VOLTS COMMON terminals.

3.2.23 THREE-PHASE FOUR-WIRE PT SOURCE POWER CONNECTIONS

Some applications require measuring the power from a source rather than the power into a load. These connections are shown in Figure 3.23. When the Model 2300 is used in this manner, the watts reading shoud be multiplied by minus one. Observe the polarities of the potential transformers. Caution! Do not exceed the common mode specification of the Model 2300.

3.2.24 THREE-PHASE FOUR-WIRE CT-PT SOURCE POWER CONNECTIONS

Some applications require measuring power from a source rather than power into a load. These connections are shown in Figure 3.24. When the Model 2300 is used in this manner, the watts reading should be multiplied by minus one. Observe the polarity of the current and potential transformers. For best performance the CURRENT COMMON terminals should be grounded.

WARNING!

DO NOT OPEN CIRCUIT THE SECONDARY WINDINGS OF CURRENT TRANSFORMERS WHEN THEY ARE ENERGIZED! LETHAL POTENTIALS MAY EXIST WHICH MAY DAMAGE THE TRANSFORMER AND/OR THE OPERATOR.

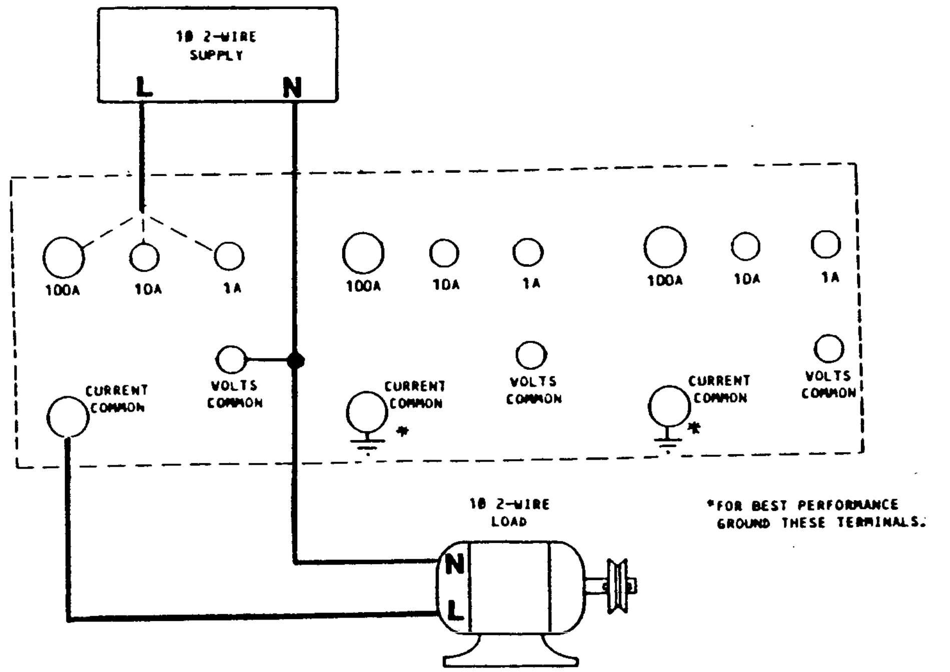

Figure 3-1 Single-PHASE Two-Wire Load Power Connections

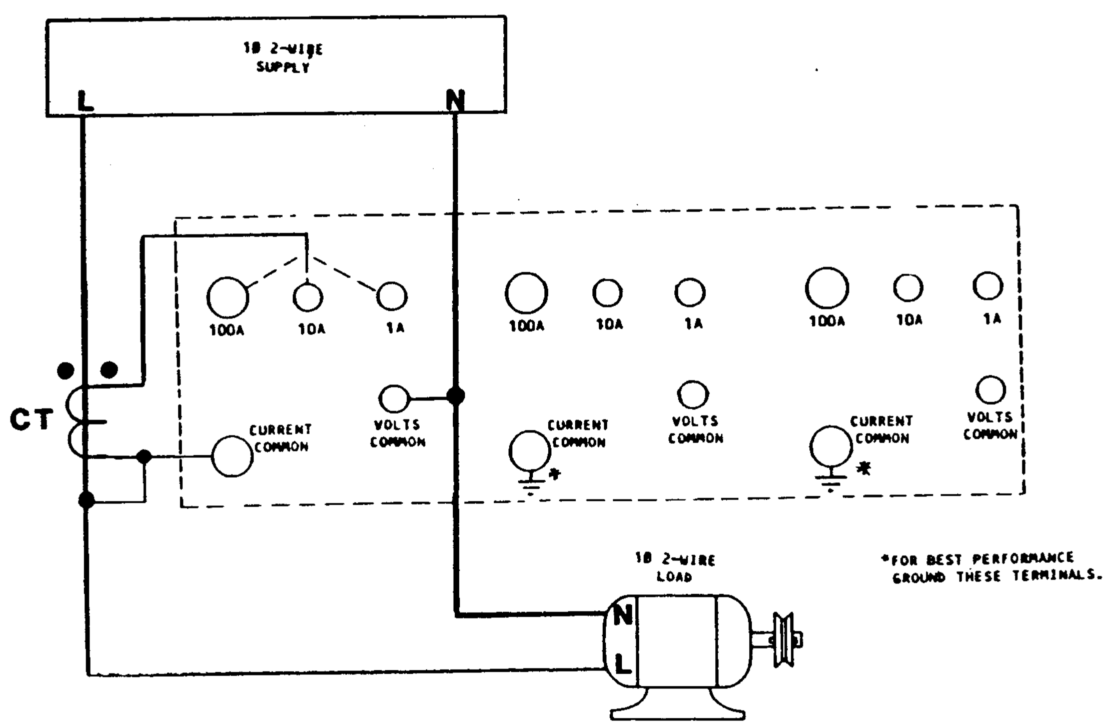

Figure 3-2 Single-Phase Two-Wire CT Load Power Connections

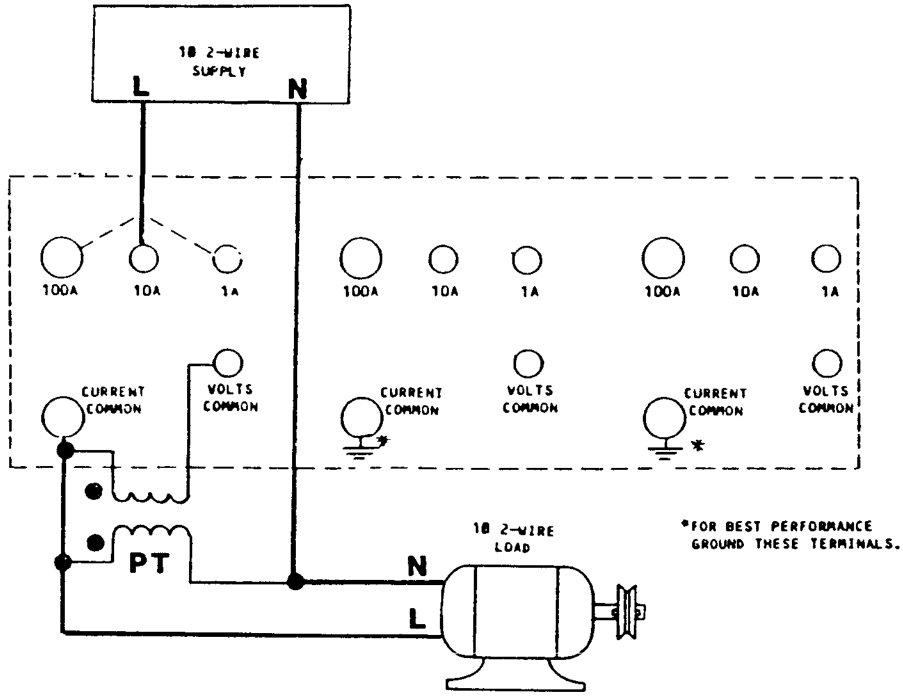

Figure 3-3 Single-Phase Two-Wire PT Load Power Connections

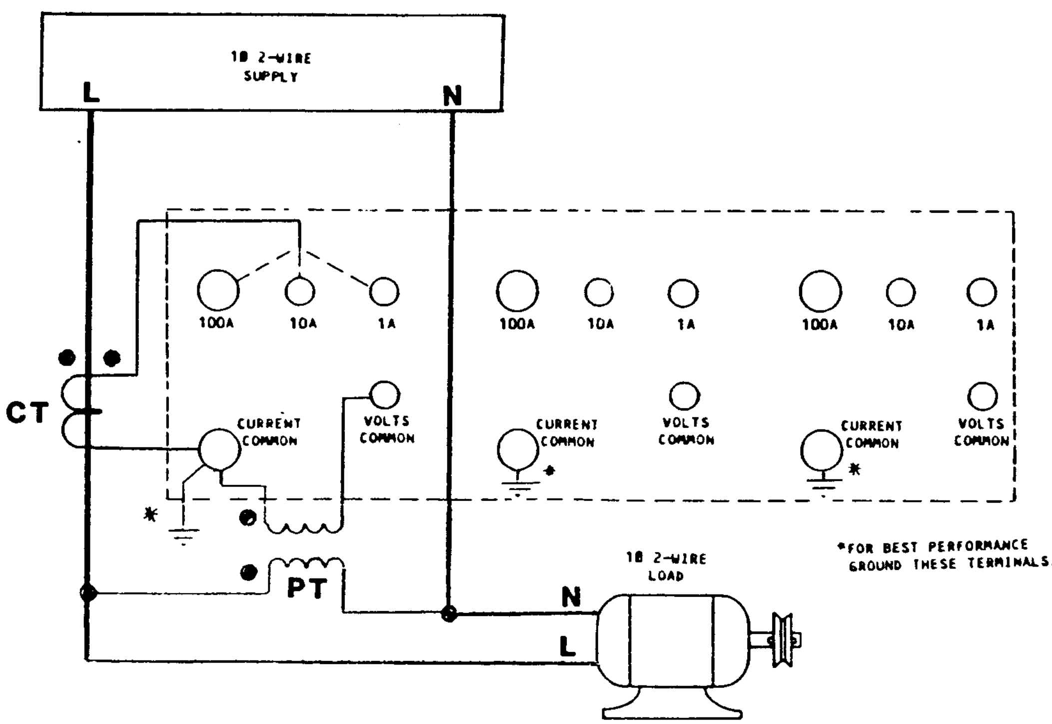

Figure 3-4 Single-Phase Two-Wire CT-PT Load Power Connections

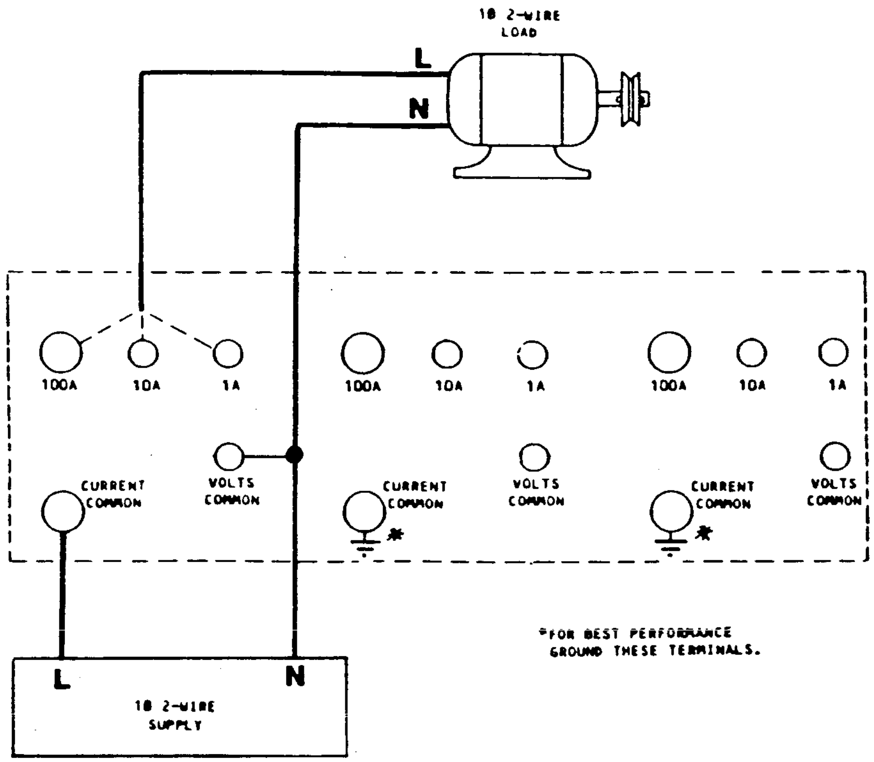

Figure 3-5 Single-Phase Two-Wire Source Power Connections

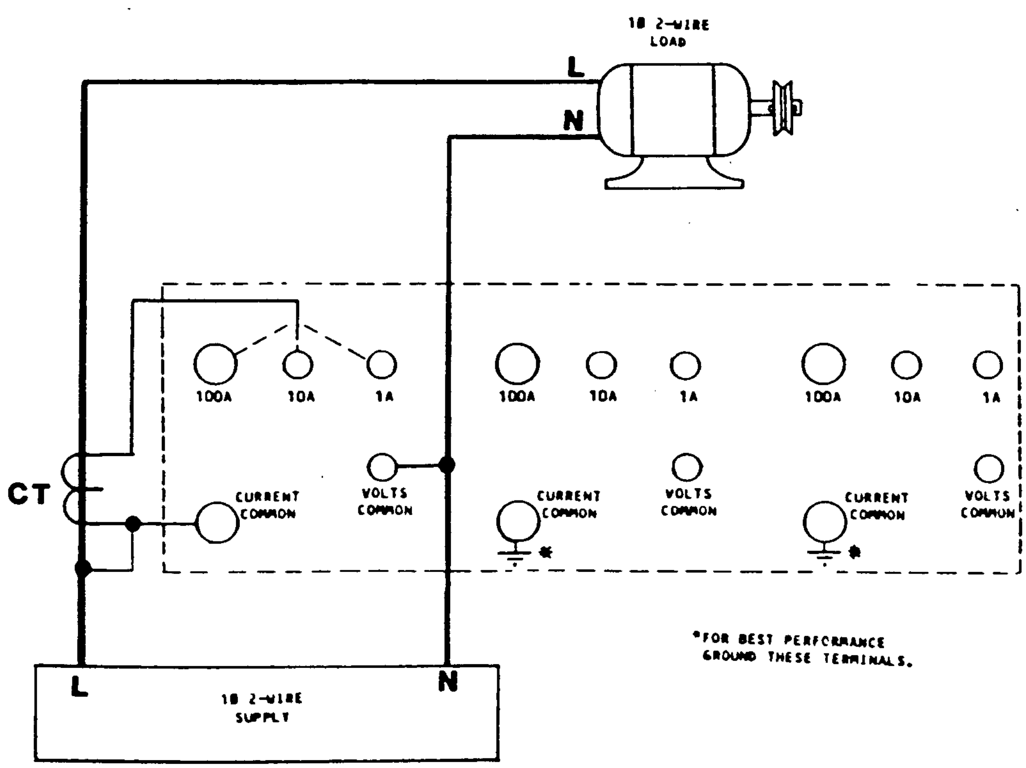

Figure 3-6 Single-Phase Two-Wire CT Source Power Connections

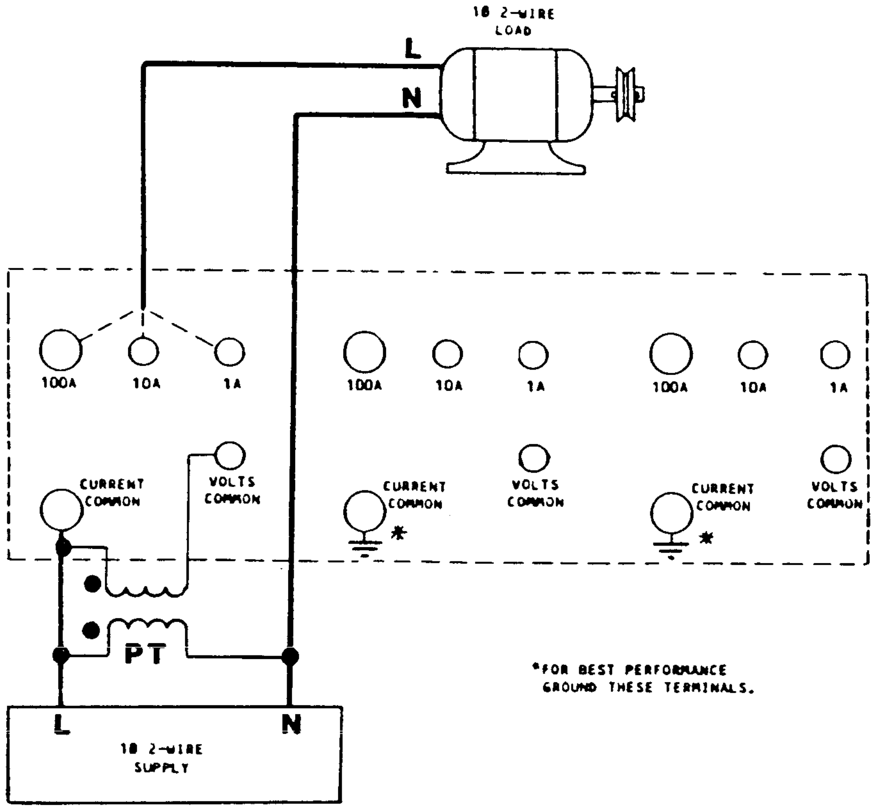

Figure 3-7 Single-Phase Two-Wire PT Source Power Connections

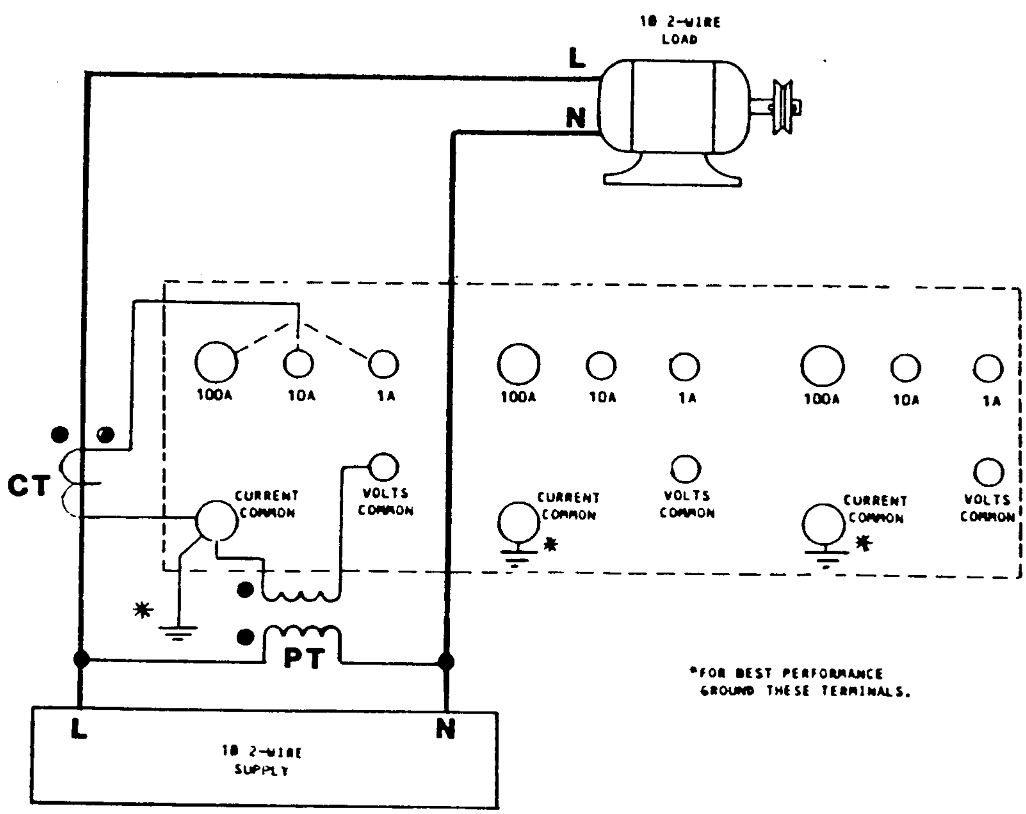

Figure 3-8 Single-Phase Two-Wire CT-PT Source Power Connections

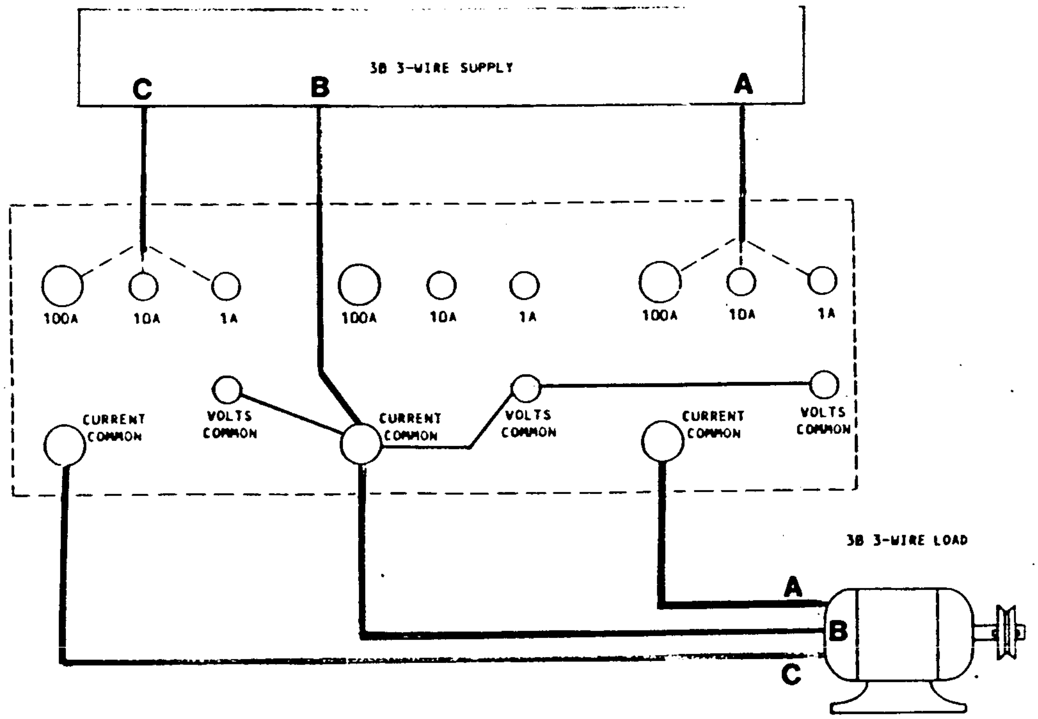

Figure 3-9 Three-Phase Three-Wire Load Power Connections

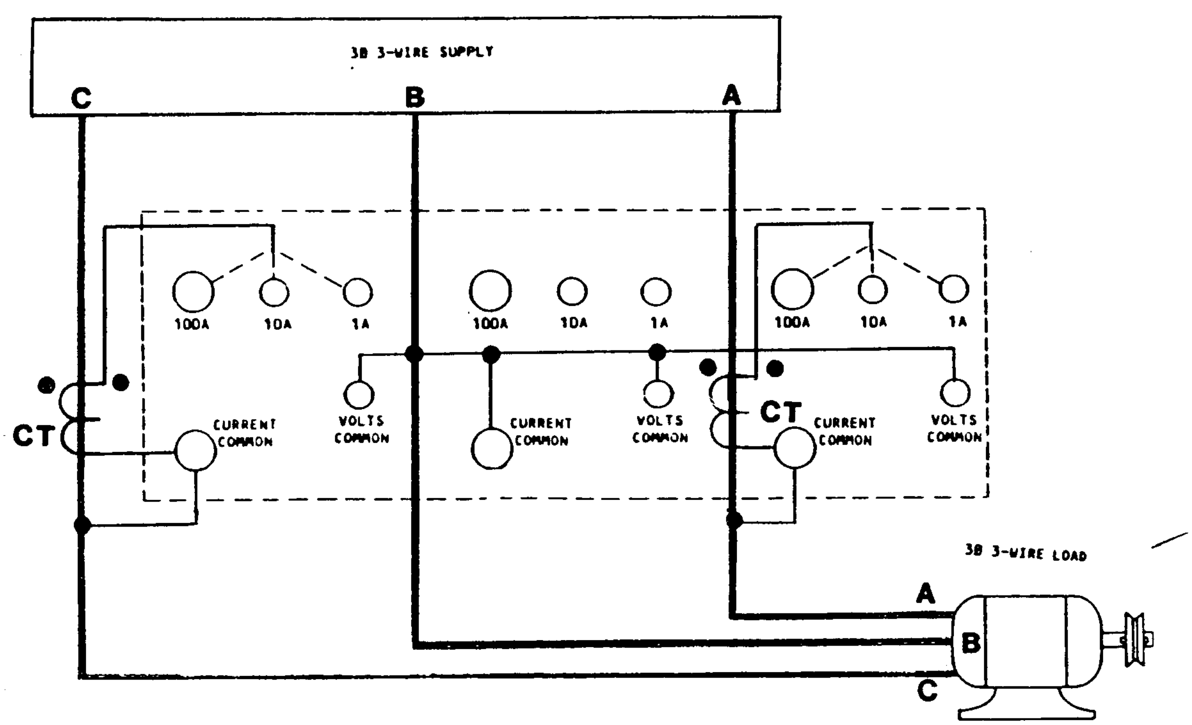

Figure 3-10 Three-Phase Three-Wire CT Load Power Connections

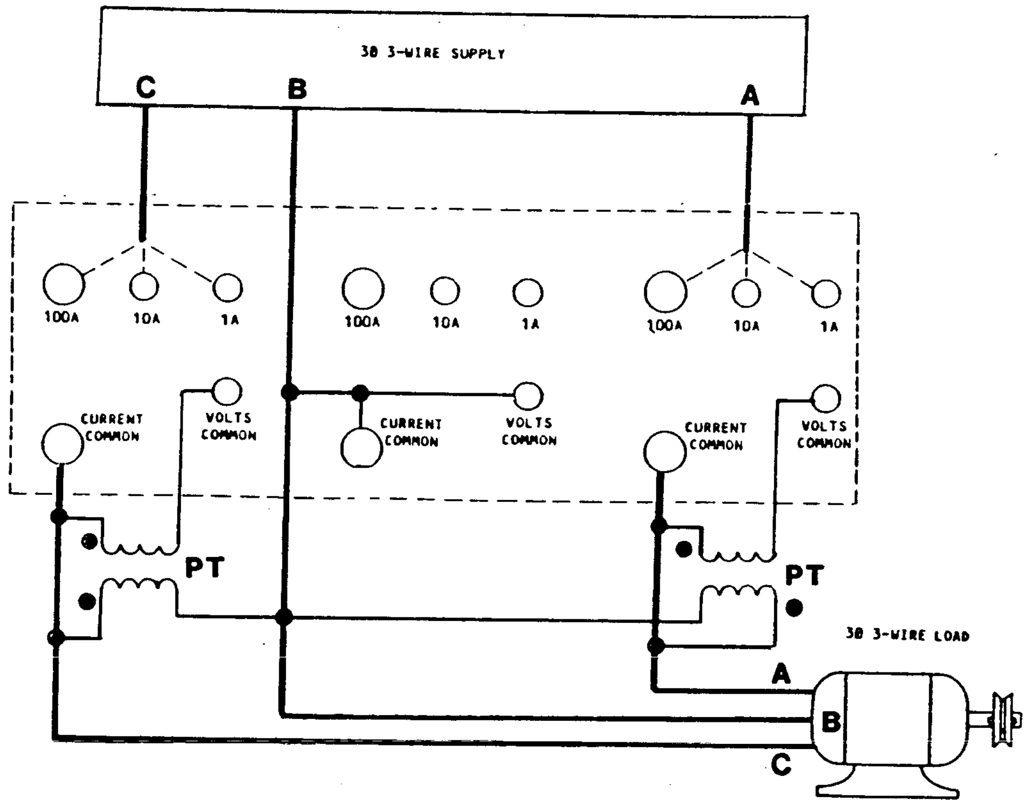

Figure 3-11 Three-Phase Three-Wire PT Load Power Connections

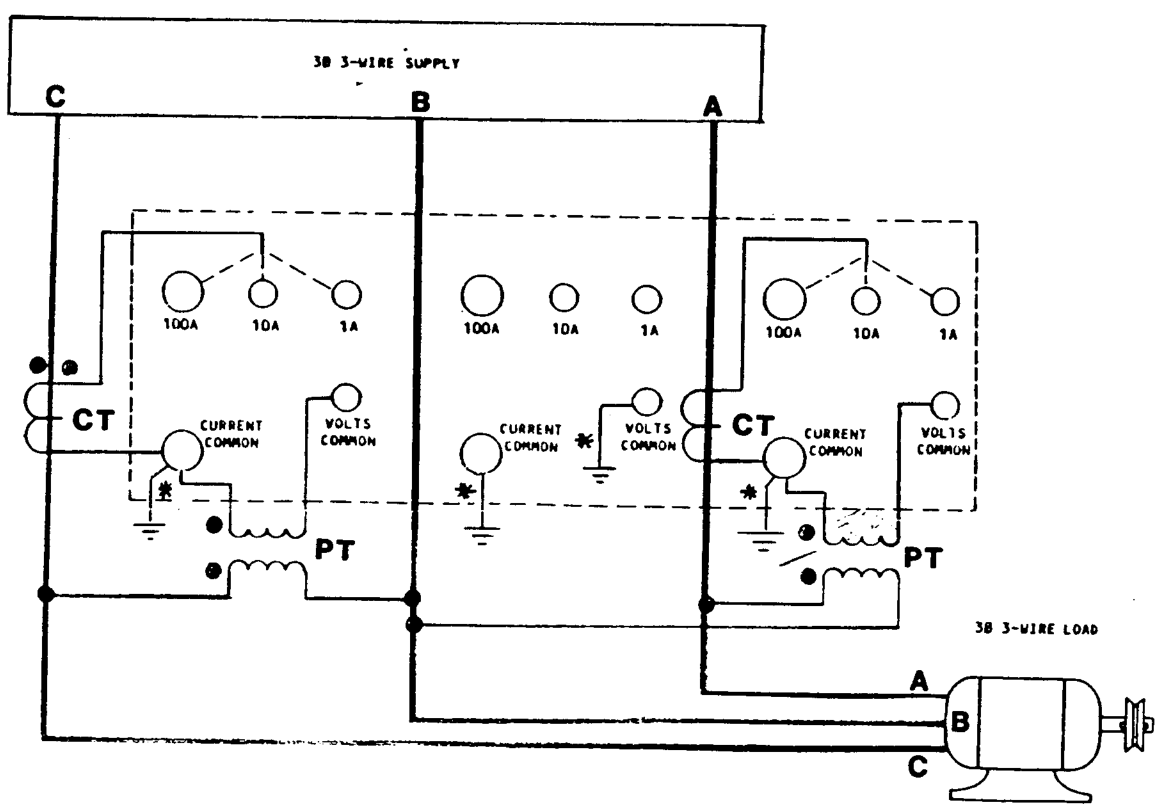

Figure 3-12 Three-Phase Three-Wire CT-PT Load Power Connections

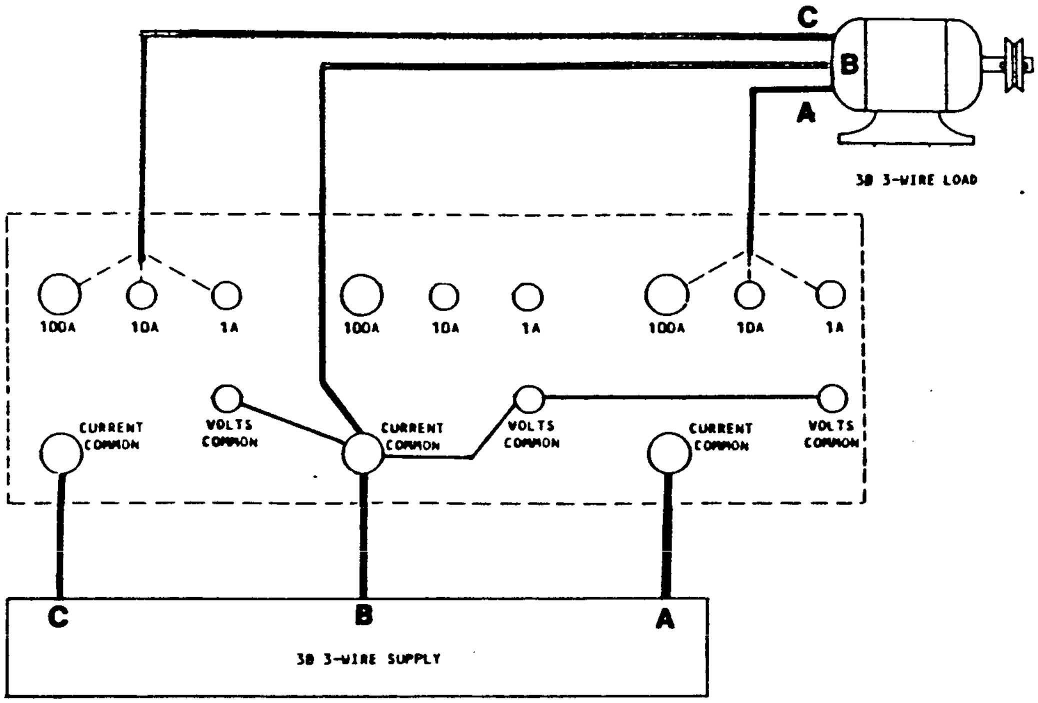

Figure 3-13 Three-Phase Three-Wire Source Power Connections

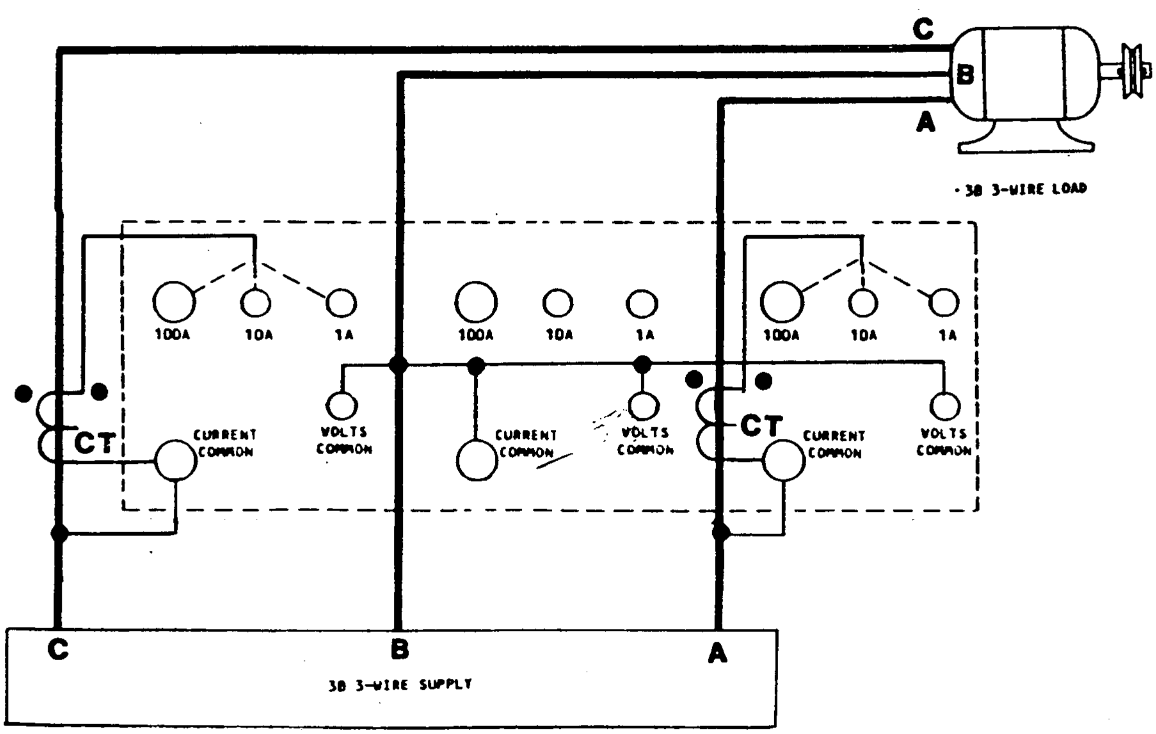

Figure 3-14 Three-Phase. Three-Wire CT Source Power Connections

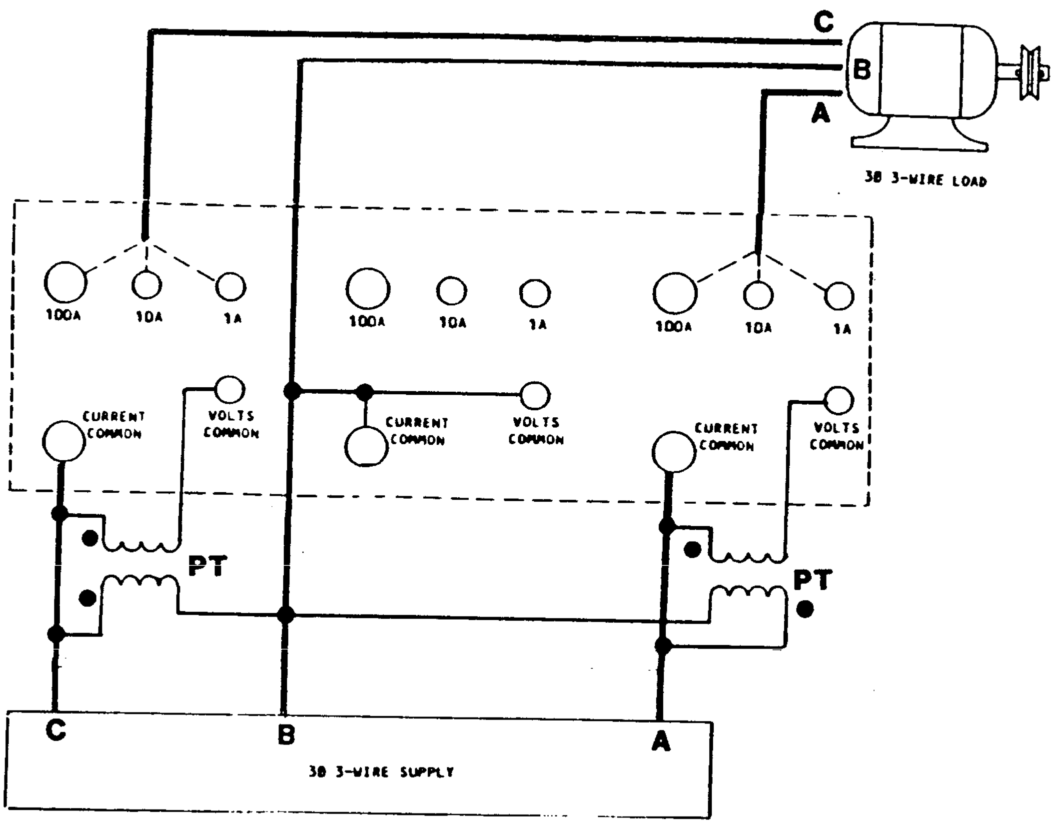

Figure 3-15 Three-Phase Three-Wire PT Source Power Connections

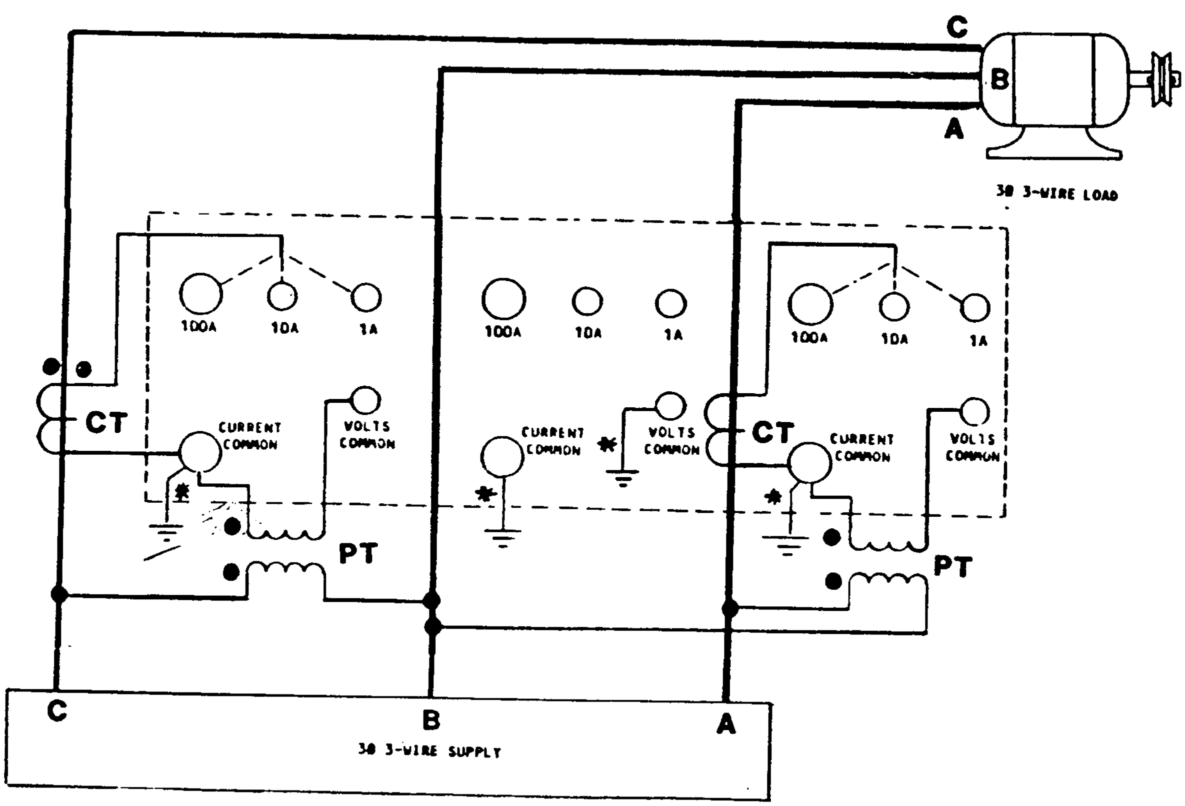

Figure 3-16 Three-Phase Three-Wire CT-PT Source Power Connections

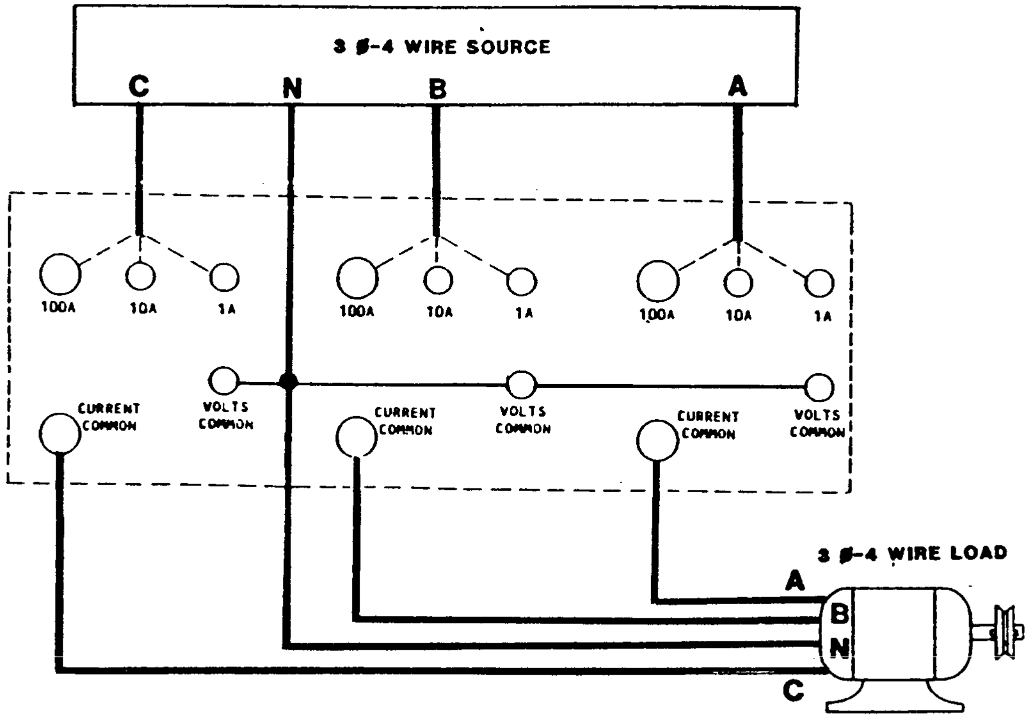

Figure 3-17 Three-Phase Four-Wire Load Power Connections

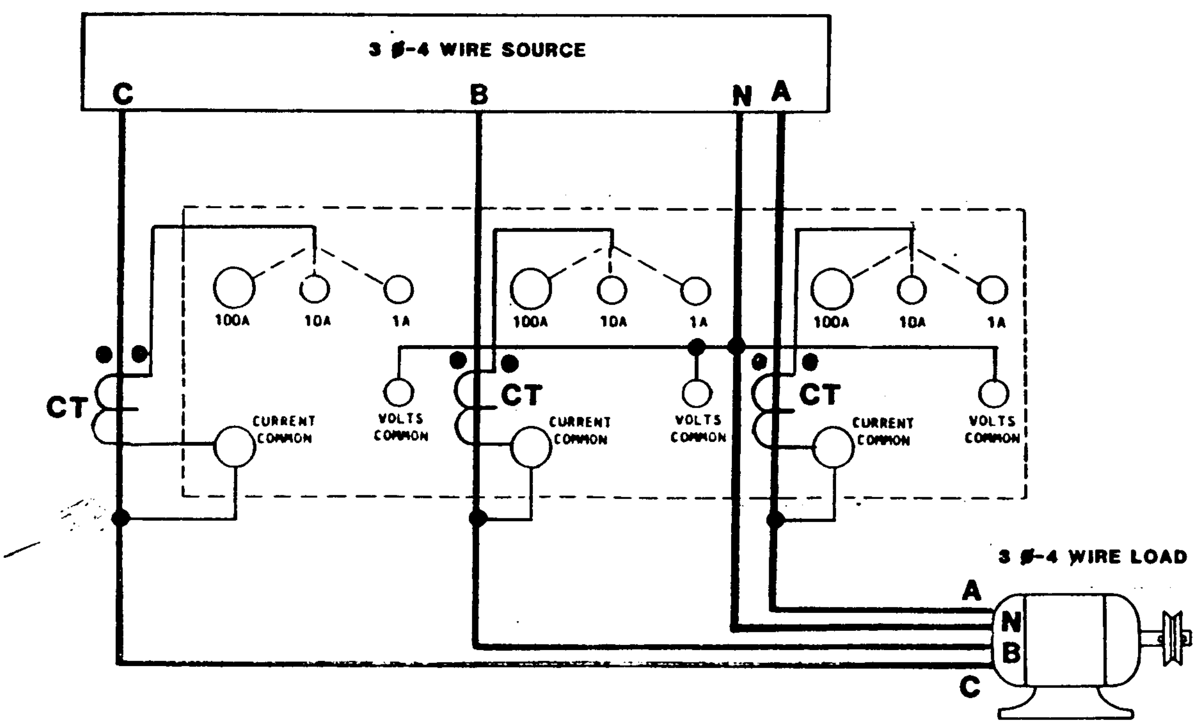

Figure 3-18 Three-Phase Four-Wire CT Load Power Connections

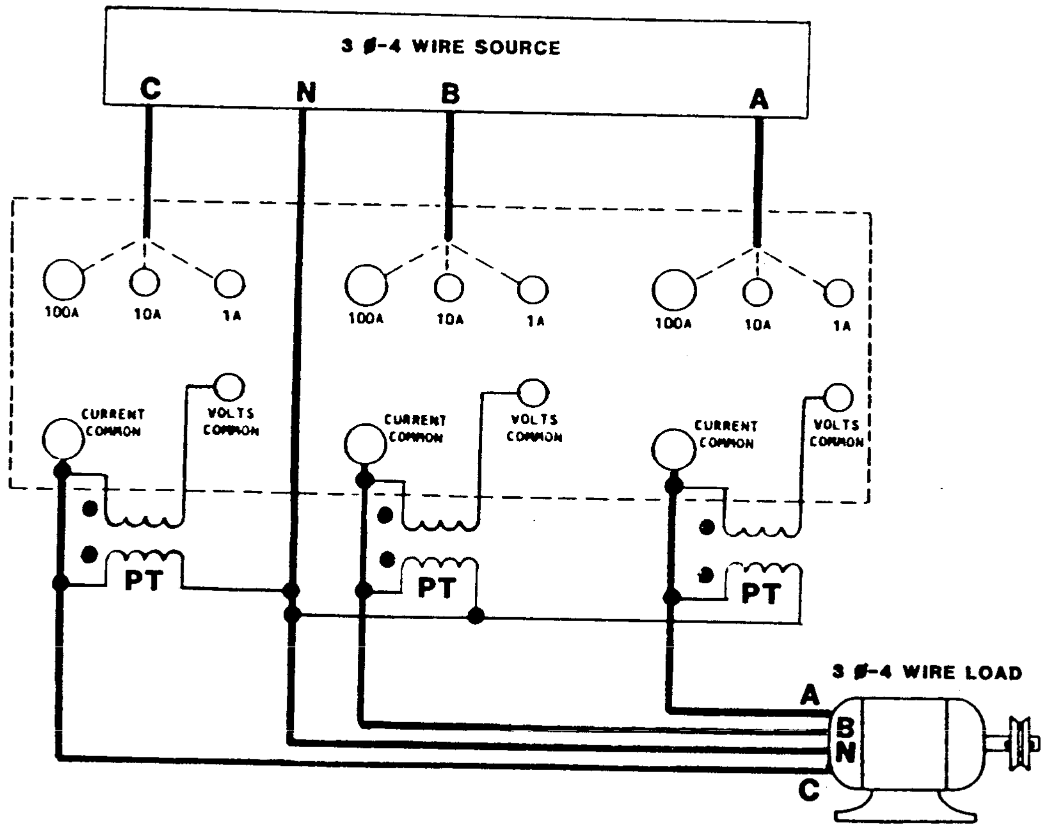

Figure 3-19 Three-Phase Four-Wire PT Load Power Connections

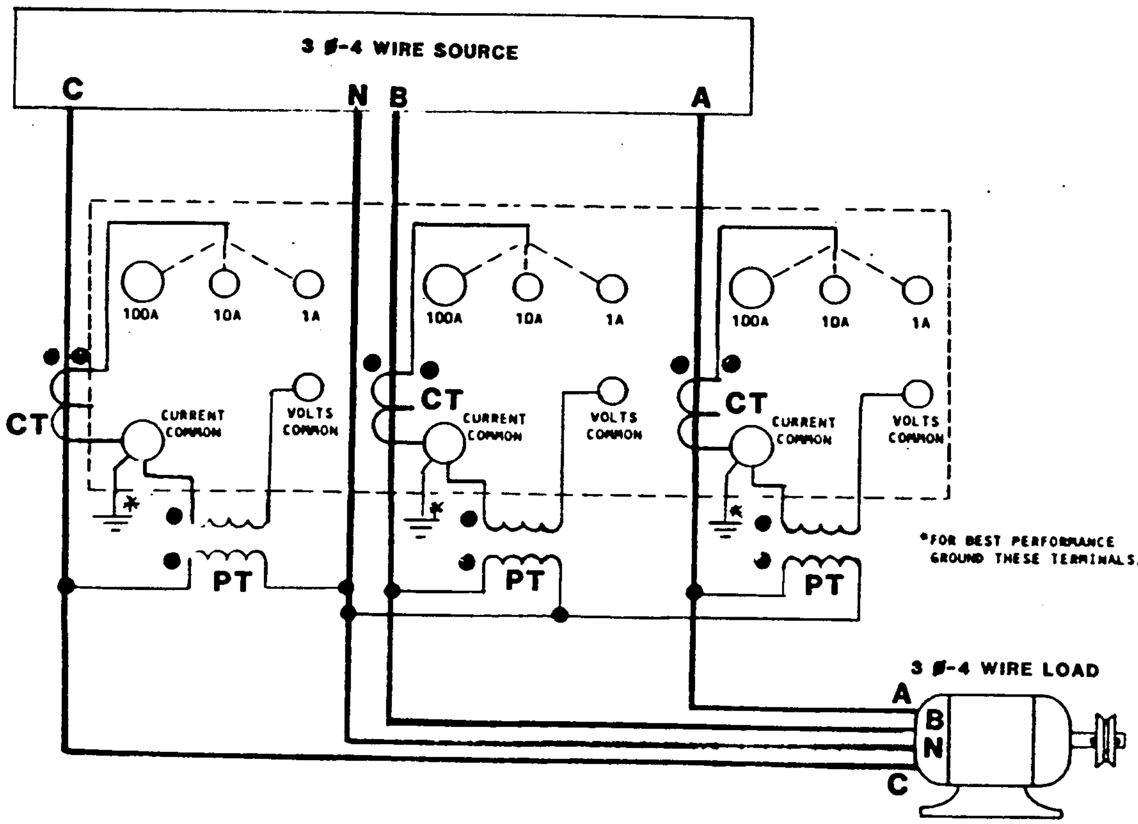

Figure 3-20 Three-Phase Four-Wire CT-PT Load Power Connections

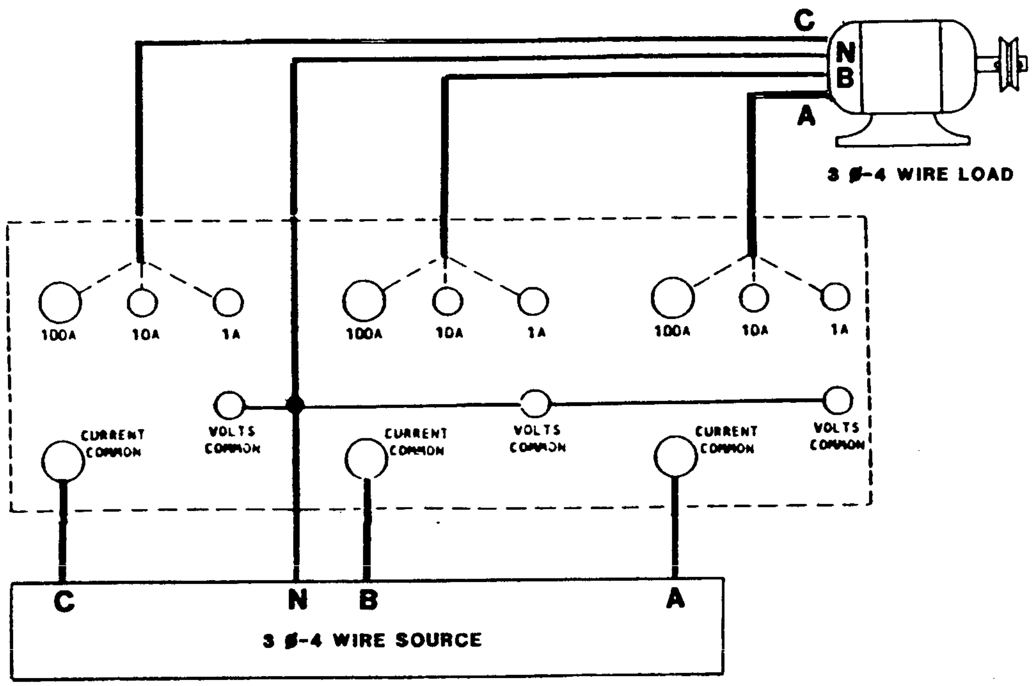

Figure 3-21 Three-Phase Four-Wire Source Power Connections

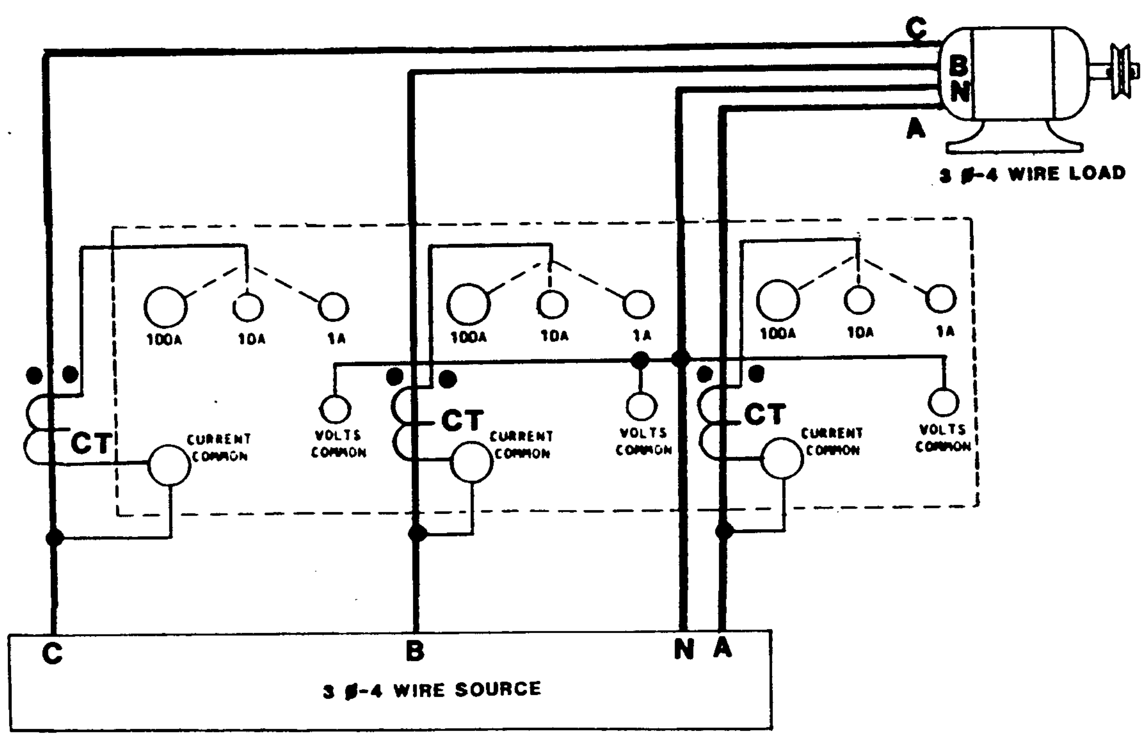

Figure 3-22 Three-Phase Four-Wire CT Source Power Connections

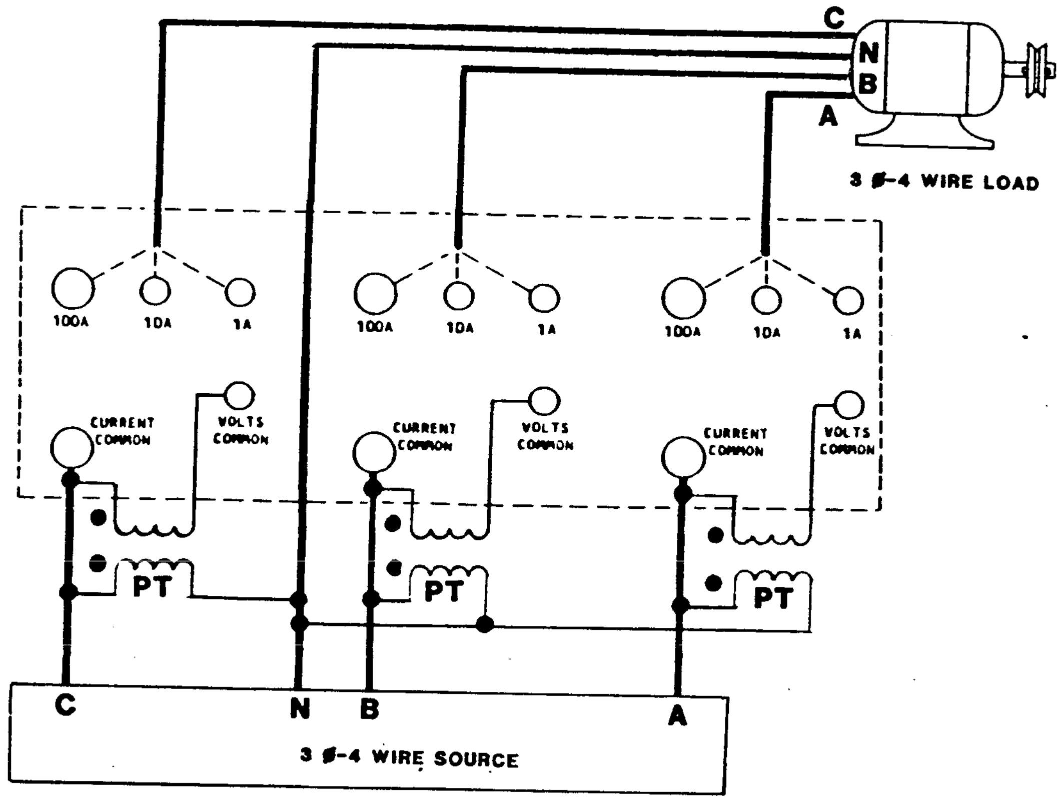

Figure 3-23 Three-Phase Four-Wire PT Source Power Connections

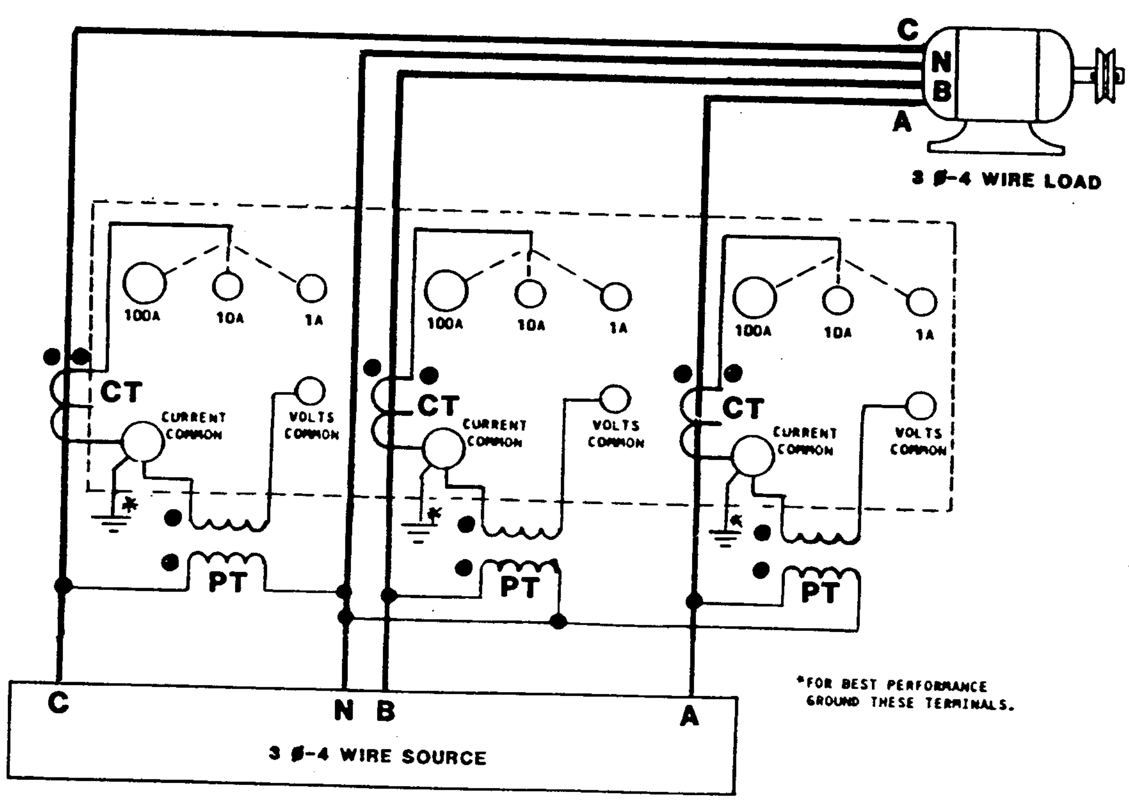

Figure 3-24 Three-Phase Four-Wire CT-PT Source Power Connections

SECTION IV - IEEE-488 INTERFACE OPERATION

4.1 IEEE-488, AN EXPLANATION OF THE BUS

The reader that is not familiar with the requirements of IEEE Standard 488 (1978) (IEEE-488) will want to review the following paragraphs which provide explanations of terms, commands and some examples of commands. Refer to the IEEE-488 Standard for a complete explanation of the requirements.

4.2 DEFINITIONS

The following are definitions of the terms used in describing the IEEE-488 interface:

Bus -- A data link which is usually a set of several parallel wires within a multi-wire cable.

Bi-Directional Bus -- A 'highway' used for two-way communication, with input and output data being carried on the same lines.

Bit Parallel -- A data transmission method in which all of the bits comprising an item of data are present simultaneously on a group of wires in a bus.

Byte -- A group of data bits (usually 8) which are treated as a single item of data.

Byte Serial -- A data transmission method in which information, in bit-parallel bytes, in transferred sequentially between devices.

Device Dependent Message -- A message containing commands/data intended for a specific device.

Handshake -- An exchange of signals between two devices which is used to control the transfer of data between them.

Interface -- The part of an instrument or system which enables it to be connected to another via a bus.

Interface Message -- A message intended for interface management.

Local Operation -- Operation of a device by its front panel controls (also referred to as Manual Control).

4.3 BUS DESCRIPTION

The IEEE-488 Interfacing Standard (also known as IEC DTC66(WG3), ANSI MC1-1, GP-IB, HP-IB, etc.,) defines a bi-directional bus for interconnecting programmable instrumentation in a bit-parallel, byte serial fashion. It defines limitations as follows:

1. A maximum of fifteen devices may be interconnected by a single bus.
2. The total bus length may not exceed 20 meters, or the number of devices divided-by-two, whichever is the shorter.
3. Maximum transmission rate is 1 megabyte per second.
4. All bus data is digital.

Of the devices on the bus, only one may be a controller, exercising control over all other devices and also capable of operating as a talker or listener. The other devices may be listeners (only able to receive data), talkers (only able to transmit data) or both. The Model 2300 is capable of talking and listening. The controller may address other devices and command them to listen or talk. Only one device may talk at any one time.

The interconnecting cable consists of sixteen signal wires and eight ground returns linking devices into a complete system. Each cable connector is a plug/socket combination to permit "daisy-chaining" of units. The sixteen signal wires are:

1. Eight data wires (DIO-0 through DIO-7).
2. Five management wires (ATN, EOI, SRO, IFC and REN).
3. Three "handshake" wires (DAV, NRFD and NDAC).

It should be noted that these wires use "inverse logic". That is to say that a low level indicates the true (asserted) state and a high level indicates a false (non-asserted) state.

4.4 DETAILED DESCRIPTION

The five management wires are described as follows:

ATN -- Asserted by the controller whenever an address or a command is present on the bus.

EOI -- May be asserted by the controller or any talker. With ATN true, EOI indicates that the controller is polling devices. With ATN false, EOI is asserted by the talker to indicate the end of data.

SRQ -- May be asserted by any device. This indicates that the device requires attention (e.g., a fault has occurred). Normally, the controller will respond by polling to determine which device requires service.

IFC -- May be asserted only by the controller. This line initializes the bus to a reset state.

REN -- May be asserted only by the controller. This signal, when asserted, places the addressed device into the Remote mode.

The three handshake wires are described as follows:

DAV -- May be asserted by any talker. Indicates that a valid data byte is present on the data wires.

NRFD -- May be asserted by any listener. Indicates that the listener is not ready to receive data.

NDAC -- May be asserted by any listener. Indicates that the listener has not yet finished reading the data byte.

The transfer of data on the bus is controlled by these three handshake wires. It is important to note that the drivers for the handshake wires are all connected for wired-OR operation. That is, as long as any of the devices on the bus asserts a handshake line, it will remain true. Thus, there must be complete consensus among the devices for any handshake wire to be high (false).

The talker first waits for all devices to be ready to accept data (checks that NRFD is false) then puts one byte of data on the bus and asserts DAV. It then waits for all devices to indicate that the data has been accepted (that is for NDAC to become false) before starting to transfer the next byte of data. This handshake protocol assures that data on the bus is transferred at the speed of the slowest device on the bus.

Data is sent in 8-bytes on the DIO wires, usually (as in the 2300) using the ISO-7 standard ASCII characters. Table 4-1 lists each ASCII character and the bus messages applicable to each. Note that the table is divided into two main groups; the primary command group and the secondary command group. The secondary command group is not utilized in the 2300.

The primary command group is further divided into four sub-groups as follows:

Table 4-1. ASCII Character Codes.

ISO BIT & DIO LINE NUMBER 7 6 5 4 3 2 1	0		1		2		3		4		5		6		7		COLUMN / ROW
7 6 5	0 0 0		0 0 1		0 1 0		0 1 1		1 0 0		1 0 1		1 1 0		1 1 1		
4 3 2 1	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	ASCII	MSG	
0 0 0 0	NUL		DLE		SP	00	0	16	@	00	P	16			p		0
0 0 0 1	SOH	GTL	DC1	LLO	!	01	1	17	A	01	Q	17	a		q		1
0 0 1 0	STX		DC2		"	02	2	18	B	02	R	18	b		r		2
0 0 1 1	ETX		DC3		#	03	3	19	C	03	S	19	c		s		3
0 1 0 0	EOT	SDC	DC4	DCL	$	04	4	20	D	04	T	20	d		t		4
0 1 0 1	ENQ	PPC[1]	NAK	PPU	%	05	5	21	E	05	U	21	e		u		5
0 1 1 0	ACK		SYN		&	06	6	22	F	06	V	22	f		v		6
0 1 1 1	BEL		ETB		'	07	7	23	G	07	W	23	g		w		7
1 0 0 0	BS	GET	CAN	SPE	(	08	8	24	H	08	X	24	h		x		8
1 0 0 1	HT	TCT	EM	SPD	)	09	9	25	I	09	Y	25	i		y		9
1 0 1 0	LF		SUB		*	10	:	26	J	10	Z	26	j		z		10
1 0 1 1	VT		ESC		+	11	;	27	K	11	[	27	k				11
1 1 0 0	FF		FS		,	12	<	28	L	12	\	28	l		|		12
1 1 0 1	CR		GS		-	13	=	29	M	13	]	29	m				13
1 1 1 0	SO		RS		.	14	>	30	N	14		30	n		~		14
1 1 1 1	SI		US		/	15	?	UNL	O	15		UNT	o		DEL		15
	ADDRESSED COMMAND GROUP (ACG)		UNIVERSAL COMMAND GROUP (UCG)		LISTEN ADDRESS GROUP (LAG)				TALK ADDRESS GROUP (TAG)				SECONDARY COMMAND GROUP (SCG)				

PRIMARY COMMAND GROUP (PCG)

STANDARD ISO 7 CHARACTERS

[1] Requires Secondary Command

Notes

1 Device Address messages shown in decimal

2 Message codes are

DCL	Device Clear	LLO	Local Lockout	SDC	Selected Device Clear
GET	Device Trigger	PPC	Parallel Poll Configure	SPD	Serial Poll Disable
GTL	Go to Local	PPU	Parallel Poll Unconfigure	SPE	Serial Poll Enable.

1. The Addressed Command Group - applied only to addressed devices.
2. The Universal Command Group - applied to all devices.
3. The Listen Address Group - set of device listen addresses.
4. The Talk Address Group - set of device talk addresses.

Data in the above command groups is sent with ATN true. It is "device dependent" when data is sent with ATN false.

4.5 GENERAL

ALL IEEE-488 device dependent activity with the 2300 takes place via input and output buffers.

Input Buffer -- Incoming data is placed in the input buffer as it is received. It is not acted upon until any one of the valid input delimiters is received. Then the commands are decoded and the input buffer contents erased. Input data is held off until the previous data is decoded and actioned. Should an invalid character be found in the input buffer, then the buffer is only decoded up to the error, the rest being discarded. An SRQ can be asserted, if required, should this occur.

The valid input delimiters are:

CR (Carriage Return) or

EOI with the last character.

Output Buffer -- With every display update (except fault messages), the output buffer is filled with the contents of the display. This data may be read by the controller any number of times.

The address of the 2300 is set by means of a five-pole switch on the rear of the unit.

At power-up, the 2300 will be in the Local mode (i.e., the unit will respond to commands entered with the front panel key-board). In order for the 2300 to enter the Remote mode, the following sequence, stipulated by IEEE-488 1978, must occur:

1. The remote enable, REN, wire on the bus must be asserted (pulled low).
2. The 2300 must receive its listen address.

With an HP 85 computer, this is accomplished by the statement REMOTE 712, assuming that the 2300 address is 12. In all future examples, an HP 85 computer is assumed as is the 2300 address of 12.

When the 2300 is in remote, the REMOTE-IEEE-488 indicator on the front panel will be illuminated and all front panel keys (except POWER) are inhibited.

The computer may reset the 2300 to the local state any time by the command LOCAL 7 (or LOCAL 712 if only the 2300 is to be returned to the Local mode). Note also that a device clear command will return the unit to local control.

4.6 SIMPLE COMMANDS AND EXAMPLES

Simple commands, with examples, are shown in the following paragraphs:

Range Selection -- Voltage and Current Ranges are selected by the commands V and I followed by an number.

V0 - 50V range (5V in 2300L)
V1 - 150V range (15V in 2300L)
V2 - 300V range (30V in 2300L)
V3 - 600V range (60V in 2300L)

I0 - 0.2A
I1 - 0.5A
I2 - 1A
I3 - 2A
I4 - 5A
I5 - 10A
I6 - 20A
I7 - 50A
I8 - 100A

Example: Output 712; "V2I7" will select the 300V and 50A ranges.

Watts Display -- The displayed (and outputted) watts data is controlled by the "W" command followed by a number.

W0 - Phase A
W1 - Phase B
W2 - Phase C
W3 - 3-wire power
W4 - 4-wire power

Example: Output 712; "W0" selects Phase A power data.

Output Data -- The data read by the controller is selected by the "T" command followed by a number.

T0 - Selects that voltage data will be read
T1 - Selects that current data will be read
T2 - Selects that watts data will be read
T3 - Selects that average watts data will be read
T4 - Selects that watts/hours data will be read

T3 and T4 are only available with TL-5.

Return to Local -- As mentioned previously, the controller may return the unit to Local by the normal IEEE Local commands. To ensure full compatibility with computers which do not have this capability (e.g., PET) the command "L" will also return the unit to Local.

Example: Output 712; "L"

Programming Status -- Sending the command "E" will cause the unit to output the programming status instead of the selected data the next time the unit is made a talker.

```
Example:  Output 712; "E"
          Wait 100
          Enter 712; A$
```

A$ will contain VnInWnTnOnDn

where n is the applicable number for each data, e.g., V2I1W3T0Q0D0 indicates that the 2300 is on the 300V, 0.5A ranges indicating three-phase, three-wire power with volts data output over the bus, no SRO's and CR LF at end of transmitted data.

Average Watts and Watt/Hours Control -- The controls for average watts and watt/hours are the commands S and F.

S commands the unit to start compiling data, whilst F commands the unit to stop compiling data and to calculate the average watts or watt/hours since receipt of "S". (Which is calculated is determined by the "T" mode current at the time "F" was received).

F commands received before an S, and vice versa, are ignored.

Note that these commands are only present in the TL-5 option.

Data read is the data atributable to the previous S...F cycle.

```
Example:  Output 712; "S"
          Output 712; "T3"
          Output 712; "F"
          Enter 712; A$
```

A$ will contain the average watts data.

4.7 ADVANCED COMMANDS

Output Data Termination -- Output data may end in any one of the following terminators:

E0 - Carriage return and line feed
E1 - Carriage return and line feed with EOI
E2 - Carriage return
E3 - Carriage return with EOI

4.8 SRQ AND SERIAL POLL

SRQ Definition -- The 2300 may assert the SRQ wire if an error in input data is detected. This is defined by the user sending "On", where n is the numeric code for the required reasons.

Q0 - Disables the 2300 from asserting SRQ
Q1 - Enables the 2300 to assert SRQ

Serial Poll Response Byte -- When the controller is the system conducts a serial poll, the 2300 responds with a byte of data informing the controller of the reasons for the SRQ. If the 2300 did not generate the SRQ, a zero byte is used as the response.

SECTION V - THEORY OF OPERATION

5.1 GENERAL

This section describes operation of the circuits of the Model 2300 Programmable Single-Phase/Three-Phase Power Analyzer. A functional description is referenced to the block diagram of Figure 5-1. It is intended to assist the user in gaining a general understanding of instrument operation. The circuit descriptions are more detailed and are referenced to the schematic diagrams of Section IX. The circuit descriptions are intended to acquaint the user with the circuit operation to the degree necessary for logical troubleshooting. The information contained in this section, together with that of Section VI, will provide the background necessary for maintaining the instrument.

5.2 FUNCTIONAL DESCRIPTION

A simple block diagram of the Model 2300 is shown in Figure 5-1. The display board includes the voltage and Current Range Selector switches, the Power Display Selector switch, the watts/kilowatts, overload and remote status displays as well as the main instrument displays of voltage, current and power. Range and display selection information from the display board is connected through the main board to the signal processor boards where it actuates relays which adjust amplifier gain and route signals to provide the various ranges and displays.

5.3 DETAILED CIRCUIT DESCRIPTIONS

This section describes in detail the operation of each circuit of the Model 2300. The reference designators used in this section are those of the schematic diagrams of Section IX.

5.3.1 POWER SUPPLIES

The power supplies are shown in Figure 9-6. A switch on the rear panel connects the two transformer primary windings on each transformer in parallel for 115-volt operation and in series for 230-volt operation. There are four independent power supplies. The first, supplied from T1 and T2, supplies +5 volts for the logic, and ±15 volts and ±7.5 volts for the portion of the analog circuitry which is not isolated from ground. CR-1-CR3 and CR2-CR4 are positive and negative full-wave rectifiers whose outputs are filtered by C1 and C2, respectively. The positive voltage is regulated by IC1, a 78M15 positive 15-volt regulator, and the negative voltage is regulated by IC2, a 79M15 negative 15-volt regulator. The 7.5-volt outputs are obtained by division in R1-R3 and R2-R4. C3-C12 provide high-frequency decoupling.

The other three supplies have electrostatic shielding between primary and secondary transformer windings. They provide the regulated ±15 volts required for the floating analog circuits and are completely

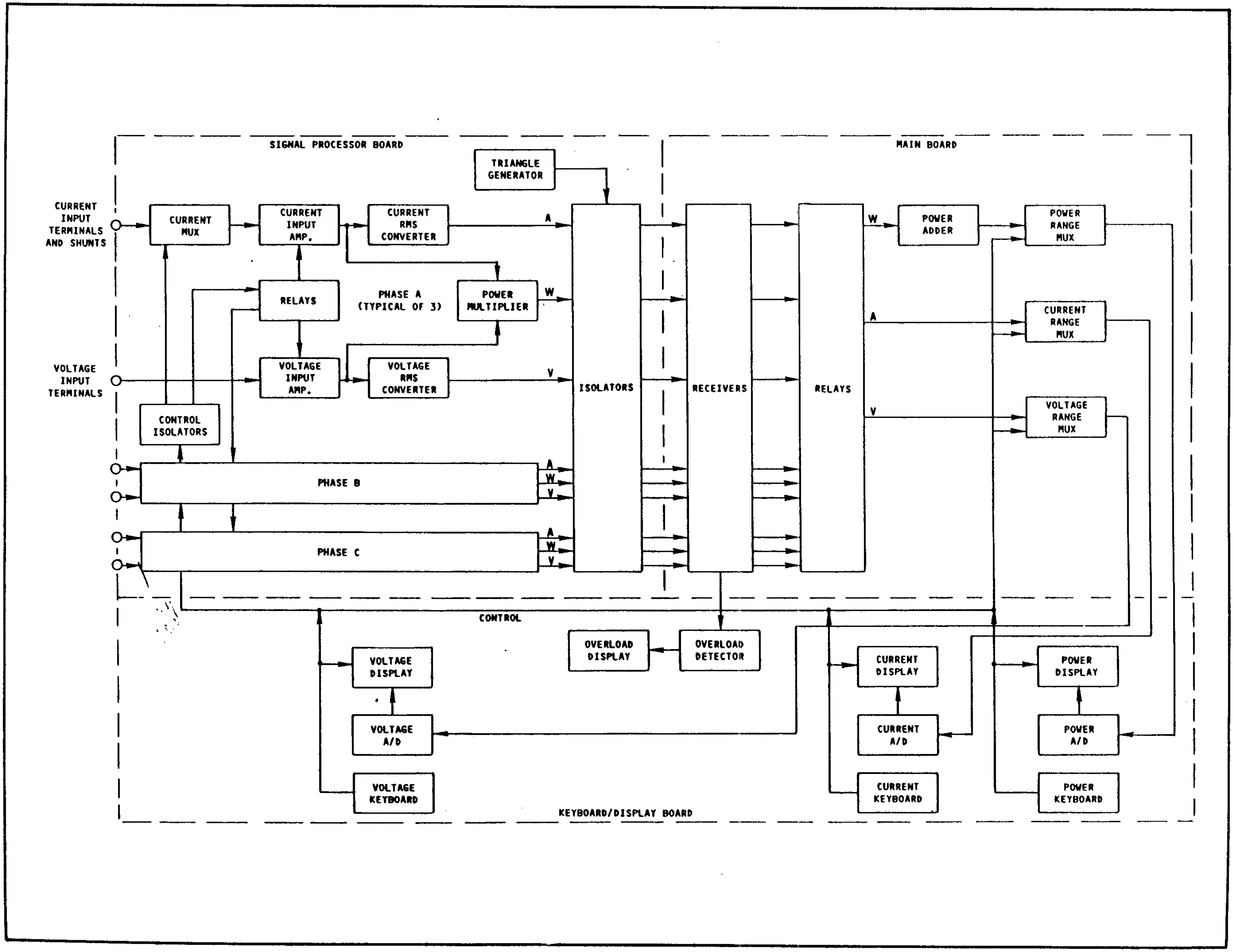

Figure 5-1. Block Diagram, Model 2300 Circuits.

isolated from ground. Because the three phases of a power system are at different potentials, three such supplies isolated from each other, are necessary. Their operation is essentially the same as the ±15-volt non-isolated supply.

The Phase A Power Supply is shown in detail in Figure 9-6. The other two floating supplies are shown as blocks. The reference designators begin with 100 for Phase A, 200 for Phase B and 300 for Phase C. Thus, to locate the negative 15-volt regulator for Phase B, locate the same device in the Phase A supply as shown in Figure 9-6. It is marked IC102. The corresponding device in the Phase B supply is IC202.

5.3.2 SIGNAL PROCESSING BOARD

There are three identical signal processing boards. One is used for each phase of the instrument. Refer to the schematic in Figure 9-4.

5.3.2.1 CURRENT MULTIPLEXER

IC1 is a CD4052 CMOS dual 4-channel analog multiplexer. Pins 9 and 10 are binary select lines which select which pair of inputs is connected to the outputs. The current shunts on the rear panel are connected across paired inputs to IC1. Pins 1 and 12 are connected across the 1 amp shunt, pins 5 and 14 across the 10 amp shunt, and pins 2 and 15 across the 100 amp shunt. Resistive networks R5-R6 and R7-R8 are input attenuators, used to adjust the voltage into the board to compensate for the resistance tolerance of the shunts.

The multiplexer inputs are selected by the front panel current range switches via the control isolators as described below. The outputs of IC1, pins 3 and 13, drive IC2, the current input amplifier.

5.3.2.2 CURRENT INPUT AMPLIFIER

The input current amplifier consists of IC2, and LF357 JFET input operational amplifier, and IC3, and LF356 JFET input operational amplifier. The gain of IC2 is determined by R11 and the series combination of R16 and R17. When various current ranges are selected, K1 or K2 is energized (or both), and series combinations R12-R13 and R14-R15 adjust the gain so that the output of IC2 is always 5.0 volts AC at full scale of the range selected. To set an exact relationship between the various selectable gains, R13, R14 and R17 are trimmed by R12, R15 and R16, respectively. The output of IC2 drives IC3.

The current input amplifier gain is selected by the front panel current range switches via the control isolators as described below.

IC3 is connected as a non-inverting unity-gain follower serving as a buffer for IC2. Its output drives pin 6 of IC9, the power multiplier, pin 1 of IC10, the current RMS converter, and pins 5 and 6 of IC5, the current peak comparator.

5.3.2.3 CURRENT RMS CONVERTER

IC10 is an AD536 true RMS-to-DC converter. Its output, at pin 6, is a DC voltage which is equal in value to the RMS AC voltage input amplifier sets the current analog voltage at the input of IC10 to 5.0 volts RMS full scale, the output of IC10 is also 5.0 volts full scale. Its output drives IC13-6, part of the isolator circuit described below.

5.3.2.4 VOLTAGE INPUT AMPLIFIER

The voltage input amplifier is IC4, an LF356 JFET input operational amplifier. Its non-inverting input, pin 3, is connected to the current common (volts high) terminal for one phase on the rear panel. The input level to the amplifier is set by the series combination of R23 and potentiometer R22. The amplifier's gain is set by R24 and a series combination selected by energizing K3, K4 or K5 or any combination of them. To set an exact relationship between the various selectable gains, resistors R26, R28 and R30 are trimmed by R25, R27 and R29, respectively.

The gain of the voltage input amplifier is selected by the front panel voltage range switches via the control isolators as described below. The gain is set so that the output of the amplifier is always 5.0 volts for full scale of the range selected.

The voltage input amplifier's output, pin 6, drives pin 1 of IC8, the voltage RMS converter, and pin 1 of IC9, the power multiplier, and pins 5 and 6 of IC7, the voltage peak comparator.

5.3.2.5 VOLTAGE RMS CONVERTER

IC8 is an AD536 true RMS-to-DC converter. Its output, at pin 6, is a DC voltage which is equal in value to the RMS AC voltage input at pin 1. Since the voltage input amplifier sets the input to IC8 to 5.0 volts RMS full scale, the DC output of IC8 is 5.0 volts at full scale. Its output drives IC13-8, part of the isolator circuit described below.

5.3.2.6 POWER MULTIPLIER

IC9 is an AD534 four-quadrant multiplier. Its output, at pins 7 and 8, is a DC voltage equal to one-tenth the product of the two AC voltage inputs at pins 1 and 6. The inputs from the voltage and current input amplifiers are set at 5.0 volts full scale; the output of IC9 is 2.5 volts full scale.

5.3.2.7 ISOLATORS

All of the circuitry described to this point is referenced to a floating ground, well isolated from the instrument ground. The purpose of the isolators is to pass the DC analogs of the voltage, current and power measurements from the floating part of the instrument to the grounded part for further processing and display.

The isolators consist of comparators IC13(a), IC13(b) and IC13(c) driving type 6N36 optical isolators IC14, IC15 and IC16. IC13 is an LM339 quad comparator. The voltage, current and power information is in the form of DC voltages at the inputs of the three sections of IC13, pins 5, 6 and 8. The transmission method used to pass this information without loss of accuracy is a form of pulse width, or duty cycle, modulation.

A very linear triangle from the triangle generator is connected to pins 4, 7 and 9 of IC13. The DC voltage from IC10, the current RMS converter, is connected to IC13-6. At IC13-1 a pulse is generated whose width is equal to the period of time the instantaneous value of the triangle voltage remains above the DC. See Figure 5-2. If the voltage from IC10 increases, the pulse will become narrower; if the voltage falls, the pulse will become wider. The duty cycle of the output pulse is 50% for zero modulating voltage.

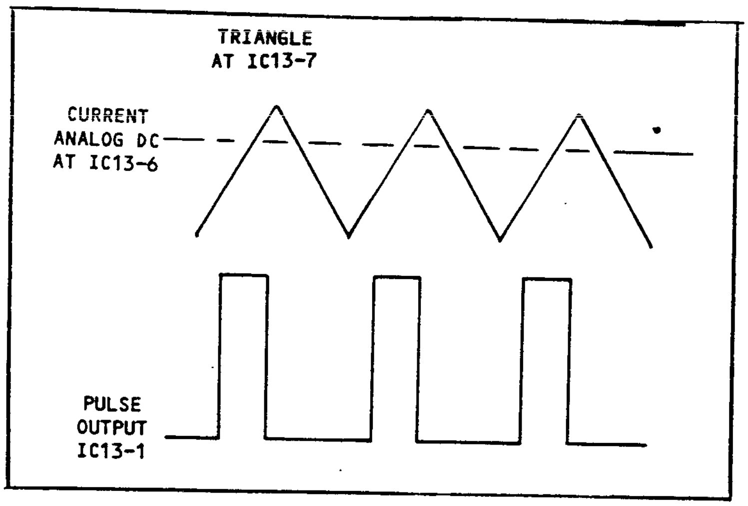

Figure 5-2. Modulator Waveforms.

The train of current measurement pulses from IC13-1 drives IC14-3, and appears at IC14-6, normalized to instrument ground. Similarly, the power information output is IC15-6, and the voltage output is IC16-6. Subsequent processing is covered in the description of the main PC board.

5.3.2.8 TRIANGLE GENERATOR

IC11 and IC12 are a pair of JFET input operational amplifiers, connected as a precision triangle generator. It runs at a frequency of approximately 5 kHz, with an output amplitude, set by D4 and D5, of approximately 6 volts. The frequency is not especially critical; the accuracy depends on the linearity of the triangle.

The linearity of the triangle is assured by the method of generation. IC12 is connected as a precision integrator, driven by IC11, whose output is clipped to a symmetrical square wave by D4 and D5. D2 and D3 prevents forward biasing of D4 and D5. When a square wave is integrated by a precision integrator, the result is a very linear triangle. IC11 is connected as a comparator, with R42 supplying positive feedback. The output of IC12 is fed to IC11-3 through R43. When the output of IC12 passes through zero, moving in a positive direction, IC11-6 abruptly swings from its most negative to its most positive extreme, aided by the positive feedback. IC12-6 begins moving linearly in a negative direction. When it reaches zero, IC11-6 instantly swings to its positive extreme, IC12-6 begins moving positive again, and the cycle repeats.

5.3.2.9 PEAK COMPARATORS/ISOLATORS

If the RMS converters and power multiplier are operated outside a prescribed range of input levels, inaccurate readings may result. To prevent this source of measurement error, the peak comparators IC5 and IC7 monitor the positive and negative peaks from the outputs of the current and voltage input amplifiers. If an overload occurs, a front panel LED warns the operator. The current comparator/isolator comprises three sections of IC5, and LM339 quad comparator, and IC6, and ILCT-6 optical isolator. The outputs of IC6, pins 6 and 7, feed the overload information off the board to the front panel.

5.3.2.10 CONTROL ISOLATORS/RELAY DRIVERS

The gains of the voltage and current input amplifiers and the choice of current shunts by the current multiplexer are controlled by the range switches on the front panel.

The selection voltages for the relays and for the current multiplexer enter the signal processing board through resistor array RN1, pass through IC17 and IC18, a pair of quad optical isolators. Two of the outputs of IC17, pins 10 and 11, drive the select inputs of the current multiplexer. The remaining outputs of IC17 and IC18 are buffered by transistors TR1-TR5, whose outputs drive the coils of relays K1-K5.

5.3.3 MAIN PC BOARD

The schematic of the main PC board is shown in Figures 9-6 and 9-7. Referring first to Figure 9-6, the pulse width modulated voltage, current and power information from the signal processing board enters the main PC board at the upper left, where they are connected to the voltage, current and power receivers.

5.3.3.1 RECEIVERS

The receivers shown consist of three sections of IC103, an LM339 quad comparator. The input pulses from the signal processing boards are connected to the inverting inputs of the comparators. The non-inverting inputs of all three comparators are set to approximately 7.5 volts by R102 and R103. The comparators buffer and square the pulses from the optical isolators on the signal processing board.

The operation of the Phase A current receiver will be described; the voltage and power receivers are identical, as are the receivers for Phases B and C. The amplitude of the output pulse train from IC103-2 is set to approximately 12.4 volts by D15 and D16, which are connected to reference diodes D17 and D18. The clamping action of D15 and D16 assure that the pulses remain symmetrical about zero volts, regardless of the duty cycle. As a result, the average DC value of the pulse train varies with duty cycle of the pulses.

The pulses then drive IC106, an LF356, JFET input operational amplifier. IC106 is connected as a two-pole active low-pass filter. It filters out the pulse train. At its output, pin 6, is the DC value of the pulse train. This value is the same as the DC that was originally applied to the isolators on the signal processing board. The recovered DC analog of the AC voltage and current is fed via K4-K9 to the voltage and current multiplexers; the power information is connected via K1-K3 to the power adder.

The voltage and current receivers have additional outputs ahead of the comparators. These outputs, from IC103-2 and IC103-14, are used to trigger the two monostable multivibrators of IC11, whose function is described later in this section. Their counterparts in the Phase B and Phase C receivers drive IC12 and IC13, respectively.

5.3.3.2 POWER ADDER

The power adder consists of IC4 and its associated components. IC4 is an OP07DP operational amplifier, connected as a unity-gain inverting adder. The gain is determined by R9 and summing resistors R5, R6 and R7. The gain can be changed by K10. When it is energized, K10 connects R8 in parallel with R9, reducing the gain of the adder to 0.1. The power information from the power receivers for Phases A, B and C connect to the adder through K1, K2 and K3. The relays are energized by the Power Display Selection pushbuttons on the front panel. When a single-phase is to be displayed, the corresponding relay is energized.

When the operator selects the three-phase three-wire mode, K1 and K3 are energized, and the instrument displays the sum of the power in the two phases according to Blondel's theorum. When the three-phase four-wire mode is chosen, all three input relays are energized. The inputs at K1, K2 and K3 are each 2.5 volts full scale. Thus, when three-phase measurements are performed, the equivalent input to IC4 can be 5 volts (three-wire) or 7.5 volts (four-wire). K10 is energized only for three-phase measurements, and only when the products of the full-scale voltage and current ranges selected exceed the allowable input to the following circuitry. The output of the adder, IC4-6, is a DC voltage proportional to the total power selected by the operator for display. It feeds the power multiplexer, IC7.

5.3.3.3 MULTIPLEXERS

IC5, IC6 and IC7 are type 4051 CMOS analog multiplexers. Each is fed by a divider chain, R10-R16, R17-R25 and R26-R42. Together, they serve as variable attenuators for three A-to-D converters (described later) which generate the display data from the DC analog voltages for voltage, current and power.

The outputs of the current and voltage receivers are approximately 5 volts full scale for all ranges. The output of the power adder may be 0.75 volts, 2.5 volts or 5 volts full scale, depending on the voltage and current ranges selected, and on whether a single-phase or three-phase display is selected. The A-to-D converters require 1 volt for 10000 display. The taps on the dividers attenuate the 5-volt (or 2.5-volt) full scale analog voltages to the value required for a full scale display reading.

For example, the full scale values of current ranges are multiples of 1, 2 and 5. For a 5-volt input to the divider at R10, the voltage at the tap on R11 is 1 volt, at R13, 0.5 volts, and at R15, 0.2 volts. The corresponding full scale display readings are 10000, 5000 and 2000. The range switches place the decimal points in the proper location for each range. Similarly, the full scale ranges for voltage are multiples of 3, 5, 6 and 15. For a 5-volt input to the divider at R17, the voltage at the tap on R18 is 1.5 volts, at R20, 0.6 volts, at R22, 0.5 volts, and at R24, 0.3 volts. The corresponding displays are 15000, 6000, 5000 and 3000. These values are not in the same descending order as the range selector switch; the 150-volt range uses 1.5 volts rather than 0.15 volts in order to provide 5-digit display resolution.

For the power display, the full scale ranges are determined indirectly by the voltage and current ranges. The possible full scale power ranges are the products of all of the possible voltage and current range switch settings, plus additional factors arising out of the two-meter and three-meter measurement techniques for three-phase power. These products are multiples of 1, 1.2, 1.5, 1.8, 2.0, 2.25, 2.4, 2.5, 3, 3.6, 4.5, 5, 6, 7.5 and 9. In practice, many of these values are grouped in a smaller number of ranges without any loss of resolution.

For single-phase measurements, with an input to the divider at R26 of 2.5 volts, the tap at R41 provides 0.15 volts, at R39, 0.2 volts, at R37, 0.4 volts, at R35, 0.5 volts, at R33, 0.75 volts and at R31, 1.0 volts. For three-phase measurements, when the taps higher in the divider are used, or when lower taps are used and the voltage at R26 exceeds 2.5 volts, K10 is energized, reducing the gain of IC4 to 0.1. With inputs to the divider at R26 of 0.75 volts or 0.5 volts, the voltages at the highest tap are 0.45 volts or 0.3 volts, respectively.

The selection codes for the multiplexers come from IC8, which is an EPROM. The type may be either 2516 or 2716 2k by 8-bit or 2532 or 2732 4k by 8-bit. The power multiplexer uses a 3-bit code applied to pins 9, 10 and 11. The voltage and current multiplexers use 2-bit codes connected to pins 10 and 11. The purpose of the EPROM is to choose the correct scale factor for all of the displays. Its most complex task is to choose the correct power scale factor for every possible combination of voltage and current ranges. The address lines of IC8 are driven by encoded range switch status, via J6, from the display board, Figure 9-11.

5.3.3.4 OVERLOAD DETECTORS

The overload detection circuits consist of IC9-IC13, Figure 9-6. The six sections of IC9, a 7407 hex open-collector buffer, serve as receivers for the voltage and current overload information transmitted via optical isolators on each of the three-signal processing boards. Their outputs drive overload warning LEDs on the display board, Figure 9-9.

IC11-13 are 4528 CMOS dual retriggerable monostable multivibrators. The operation of IC11 is typical of all three, and will be described in detail in later paragraphs. The trigger inputs of IC11, pins 4 and 12, are driven from the voltage and current receivers, IC103-2 and IC103-14, Figure 9-7. Recall that these receivers are driven by width-modulated pulse trains from isolators on the signal processing board. If either pulse width modulator is overdriven, its pulse train will be interrupted. The purpose of IC11 is to detect such an interruption.

The pulses from the two sections of IC103 continually trigger the two sections of IC11. External timing components R56-C13 and R57-C14 set the period of the one-shots slightly longer than the period of the input pulses. As long as the pulses continue, the one-shot remains in the set state. If the pulses stop, the one-shot resets. The outputs of IC11 drive the two sections of IC10, a 7407 hex open-collector buffer. The open-collector output stage permits a wired-OR connection with the output of IC9, so that IC10 drives the overload warning LEDs on the display board as well.

5.3.4 DISPLAY BOARD

The display board is shown in Figures 9-9 through 9-11. Figure 9-9, for the most part, shows the selection and display circuits for voltage. Figure 9-10 shows current and Figure 9-11 shows power. The three figures are quite similar. Figure 9-9 is first described in detail. When a reference designator for a key circuit element is given, the equivalent designator for Figures 9-10 and 9-11 are given in parentheses. Circuitry in any of these figures which has no counterpart in the others in described separately.

5.3.4.1 KEYBOARD

Pushbuttons S1-S4 (S5-S13, S14-S18) are the voltage range selection switches. A pair of relay contacts, K2 in Figure 9-11, are in parallel with S4, the 600-volt range selector. K2 is energized briefly when the power is first turned on, selecting the highest voltage range. K1 and K3 perform the same function for the power and current functions.

The range selector switches are connected to IC6 (IC14, IC22), a 74C922 CMOS 12-key keyboard encoder. Its latching binary weighted outputs, at pins 14 through 17, are connected to the inputs of IC7 (IC15, IC23), a 40257 CMOS quad AND/OR select gate. The function of IC7 is to select local or remote control. When pin 1 is high, the encoded pushbutton selection appears at the output of IC7. When it is low, selection information from the IEEE interface (if installed) selects the range.

5.3.4.1.1 KEYBOARD VOLTAGE CIRCUITS

This paragraph describes the voltage circuitry only. The outputs of IC7 (IC15, IC23) drive IC8 (IC16, IC24), a 74145 BCD-to-decimal decoder. The two low-order outputs of IC7 drive two of the address lines of IC20 in Figure 9-11 and two of the address lines of IC8 (pins 1 through 4) perform three functions. First, they drive DS101-DS104, which are status lamps on the range selector switches. Second, they drive D4 through D7, steering diodes which conduct the output of IC8 to the decimal point LEDs in DS4 and DS5. Third, they drive gain setting relays K3-K5 on the signal processing boards, Figure 9-4.

5.3.4.1.2 KEYBOARD CURRENT CIRCUITS

In the current circuitry, Figure 9-10, the outputs of IC15 perform four functions. First, they drive IC16, a 74145 BCD-to-decimal decoder. Second, they drive the address lines of IC13. Third, they drive four of the address lines of IC20, Figure 9-11. Fourth, they drive four of the address lines of IC8 on the main board, Figure 9-7. The outputs of IC16 (pins 1 through 4) drive DS105-DS113, which are status lamps on the range selector switches.

IC13 is an 18S030 32 by 8-bit TTL PROM. Its outputs perform two functions. First they drive gain setting relays K1 and K2 on the signal processing boards, Figure 9-4. Second, they drive decimal point LEDs in DS7-DS10.

5.3.4.1.3 KEYBOARD POWER CIRCUITS

In the power circuitry, Figure 9-11, the outputs of IC23 drive IC24, a 74145 BCD-to-decimal decoder. The three low-order outputs of IC23 drive three of the address lines of IC20 and two of the address lines of IC8 on the main board, Figure 9-7. The outputs of IC24 (pins 1 through 4) perform two functions. First, they drive DS114-DS118, which are status lamps on the display selector switches, Second, they drive D14 through D21, steering diodes which conduct the output of IC24, via J6, to the phase selector relays K1-K9 on the main board, Figure 9-7.

IC20 is an EPROM whose address inputs are driven by bits from the voltage and current range selection codes and the power display selection code from the keyboard. The type may be either 2516 or 2716 2k by 8-bit or 3532 or 2732 4k by 8-bit.

5.3.4.2 DISPLAY

The display circuitry consists of an A-to-D converter driving seven-segment LED displays. The A-to-D converter comprises IC2 (IC12, IC18) IC3 (IC13, IC19) and their associated components, and clock IC4, which is common to all three displays. IC2 is an 8068 dual-slope integrator/

comparator. IC3 is a 7103 reference/counter/display driver. The two are designed to work together as a precision A-to-D converter. IC4 is an AE404 100 kHz clock.

The operating cycle of the dual-slope integrating A-to-D converter is divided into three phases, whose duration is set by an external clock. During the first, or auto-zero, phase, the analog input is internally shorted to analog ground, and C3 (C13, C21) is charged to the integrator's output offset voltage, which is connected to the integrator's non-inverting input, subtracts from the analog input, cancelling the offset.

During the second, or input integrate, phase, the input voltage is connected to the integrator, and IC2 integrates the input for a precise time (10,000 counts of the clock) by charging C2, C18) linearly toward the input voltage. The waveform on C2 is a very linear ramp whose slope is proportional to the input voltage. Thus, the charge on C2 at the end of this phase is also proportional to the input voltage.

During the third, or reference integrate, phase, a fixed reference voltage of polarity opposite the input voltage is applied to the integrator. IC2 begins discharging C2 toward the reference voltage. Because the voltage is fixed, the discharge slope is always the same. Therefore, the time required to discharge C2 back to zero is proportional to the original input voltage. This time is measured by a counter in IC3 counting the oscillator pulses. The IC2-IC3 set is designed to give a count of 10,000 for one volt input. The count, which is numerically equal to the value of the input to IC3, is displayed as the measured voltage.

The reference integration counts, which are accumulated in an internal counter of IC3, are latched into a mulitplexer, also inside IC3, at the end of the count period. During the next series of auto-zero and integration periods, each digit of the counts latched into the multiplexer are sequentially placed on the BCD outputs of IC3 and on the inputs of IC1, a 7447 binary-to-seven segment decoder/driver. While the most significant digit data is applied to IC1, transistor TR1 is turned on by the digit output of IC3 to provide the anode voltage for DS1. When the next digit data is applied to IC1, TR1 is turned off and TR2 is turned on to provide the anode voltage for DS2. The sequence is continued for TR3/DS3, TR4/DS4 and TR5/DS5 and then repeated. The repetition rate is sufficiently high that all digits appear to be continuously illuminated.

5.3.5 IEEE-488 INTERFACE

The IEEE-488 interface enables a remote controller to enter commands into the Model 2300 when both are interconnected to a general purpose interface bus (GPIB) meeting the requirements of IEEE Stardard 488 (1978). Programming for control of the Model 2300 in such a system is covered in Section IV. The schematic of the IEEE-488 interface is shown in Figure 9-14.

SECTION VI - CALIBRATION AND MAINTENANCE

WARNING

> Although this unit does not produce high voltages, potentially lethal voltages and currents may be present at the inputs. Therefore,
>
> DEATH
>
> on contact may result if personnel fail to observe safety precautions. The individual phase signal processing boards are floating with respect to each other and ground. Therefore, avoid contact with the input terminals and the signal processing boards.

6.1 GENERAL

This section provides calibration procedures for all of the Model 2300 family of wattmeters. A troubleshooting section with a troubleshooting chart is also provided which lists a number of trouble symptoms and the components or circuit areas which may produce them. The Valhalla Scientific Model 2300 Three-Phase Digital Wattmeter is a solid state instrument designed to give long service without malfunctions. Maintenance is limited to periodic cleaning in accordance with commercial shop practices, and periodic calibration.

6.2 CALIBRATION

Calibration should be performed with the Model 2300 covers in place, except when making adjustments requiring their removal, and after power has been applied for a minimum of two hours to achieve temperature stabilization.

6.2.1 CALIBRATION PROCEDURES

Two calibration procedures follow. One, called Routine Calibration, should be performed at regular intervals to assure that instrument accuracy is maintained. The other, called Maintenance Calibration, need only be performed after you have replaced a component on the Phase A signal processing board, the main printed circuit board or the display board.

NOTE

> If a sudden change in calibration occurs which affects all three displays, check IC18 on the display board for correct output before making adjustments. IC18 is the reference for

all three displays. If it is necessary to replace IC18, reselect R47 for the best nominal reading on all three displays with 150 volts and 1 amp applied.

6.2.2 ROUTINE CALIBRATION

6.2.2.1 GENERAL

The routine calibration procedure should be performed at regular intervals to assure the continuing accuracy of the instrument. The procedure sets the adjustments common to all three phases during the Phase A calibration steps. The Phase B and Phase C adjustments are made to the respective boards for those phases.

NOTE

Although the Phase A, B, and C circuit boards are identical, their calibration adjustments will differ with their placement. They may not be interchanged without performing the routine calibration procedure.

6.2.2.2 EQUIPMENT REQUIRED

The following test equipment is required:

1. AC Voltage Calibrator -- Valhalla Model 2703 or equivalent
2. AC Slave Voltage Calibrator -- Valhalla Model 2705 or equivalent
3. AC Transconductance Amplifier -- Valhalla Model 2500E or equivalent

6.2.2.3 VOLTAGE CALIBRATION

NOTE ON MODEL 2300L

To calibrate the Model 2300L, reduce all of the voltage inputs to one-tenth the value given.

NOTE ON MODEL 2301

Only steps 1 through 9 need be performed when calibrating the Model 2301.

1. Connect the AC Voltage Calibrator to the 2300 with the volts high of the 2703 to the Volts Common of Phase A of the 2300, and the Volts Low of the 2703 to the Volts High of Phase A of the 2300.
2. Select the Phase A, 150.00-volt range.
3. Apply 150.00 volts AC and adjust R18 on the main circuit board for 150.00 on the display.
4. Reduce the voltage to one-tenth of the range and adjust R119 on the main circuit board for 15.00 on the display.
5. Repeat steps 3 and 4 until interaction between the two adjustments is minimized.
6. Select the 600-volt range. Apply 600.00 volts AC and adjust R20 on the main circuit board for 600.00 on the display. Remove the applied voltage.

7. Select the 50-volt range. Apply 50.00 volts AC and adjust R22 on the main circuit board for 50.00 on the display.
8. Select the 300-volt range. Apply 300.0 volts AC and adjust R24 on the main circuit board for 300.0 on the display. Remove the applied voltage.
9. Select the Phase B, 600-volt range. Move the voltage leads to the Phase B voltage terminals.
10. Apply 600.0 volts AC and adjust R22 on the Phase B board for 600.0 on the display.
11. Reduce the voltage to one-tenth of the range and adjust R219 on the main circuit board for 60.0 on the display.
12. Repeat steps 10 and 11 until interaction between the two adjustments is minimized.
13. Select the 300-volt range. Apply 300.0 volts AC and adjust R25 on the Phase B circuit board for 300.0 on the display. Remove the applied voltage.
14. Select the 150-volt range. Apply 150.00 volts AC and adjust R27 on the Phase B circuit board for 150.00 on the display.
15. Select the 50-volt range. Apply 50.00 volts AC and adjust R29 on the Phase B circuit board for 50.00 on the display.
16. Select the Phase C, 600-volt range. Move the voltage leads to the Phase C voltage terminals.
17. Perform steps 10 through 15, adjusting potentiometers on the Phase C circuit board. In step 11, substitute R319 on the main circuit board for R219.

6.2.2.4 CURRENT CALIBRATION

NOTE ON MODEL 2301

Only steps 1 through 10 need be performed when calibrating the Model 2301.

1. Connect the current calibrator leads to the Phase A, 1-amp current terminals. Select the Phase A, 1-amp current range.
2. Apply 1 amp and adjust R11 on the main circuit board for 1.000 on the display.
3. Apply 0.1 amp, and adjust R128 on the main circuit board for 0.1000 on the display.
4. Repeat steps 2 and 3 until the interaction between the two adjustments is minimized.
5. Select the 15-amp range. Apply 0.5000 amps, and adjust R13 on the main circuit board for 0.5000 on the display.
6. Apply 0.2000 amps, select the 0.2-amp range and adjust R15 on the main circuit board for 0.2000 on the display. Remove the applied current.
7. Select the 10-amp current range and move the current lead to the 10-amp terminal.
8. Apply 10.000 amps and adjust R5 on the Phase A circuit board for 10.000 on the display. Remove the applied current.
9. Select the 100-amp current range, and move the current lead to the 100-amp terminal.
10. Apply 100.00 amp and adjust R7 on the Phase A circuit board for 100.00 on the display. Remove the applied current.

11. Connect the current calibrator leads to the Phase B, 1-amp current terminals. Select the Phase B, 1-amp current range.
12. Apply 1.0000 amps and adjust R16 on the Phase B circuit board for 1.0000 on the display.
13. Apply 0.1000 amp and adjust R228 on the main circuit board for 0.1000 on the display.
14. Repeat steps 12 and 13 until the interaction between the two adjustments is minimized. Remove the applied current.
15. Select the 0.5-amp range. Apply 0.5000 amps and adjust R15 on the Phase B curcuit board for 0.5000 on the display. Remove the applied current.
16. Select the 0.2-amp range. Apply 0.2000 amps and adjust R12 on the Phase B circuit board for 0.2000 on the display. Remove the applied current.
17. Select the 10-amp current range, and move the current lead to the 10-amp terminal.
18. Apply 10.000 amps. Adjust R5 on the Phase B circuit board for 10.000 on the display. Remove the applied current.
19. Select the 100-amp current range, and move the current lead to the 100-amp terminal.
20. Apply 100.00 amps. Adjust R7 on the Phase B circuit board for 100.00 on the display.
21. Connect the current calibrator leads to the Phase ~~B~~ C, 1-amp current terminals. Select the Phase B, 1-amp current range.
22. Perform steps 12 through 20, adjusting potentiometers on the Phase C circuit board. In step 13, substitute R328 on the main circuit board for R228.

6.2.2.5 WATTS CALIBRATION

NOTE ON MODEL 2300L

To calibrate the Model 2300L, reduce all of the voltage inputs to one-tenth the value given. All of the wattage readings will be one-tenth of those specified.

NOTE ON MODEL 2301

Only steps 1 through 6 need be performed when calibrating the Model 2301.

1. Connect the AC Voltage Calibrator to the 2300 with the volts high of the 2703 to the Volts Common of Phase A of the 2300. Connect the Volts Low of the 2703 to the Volts High of Phase A of the 2300. Connect the current calibrators to the Phase A, 1-amp current terminals. Before proceeding, verify that the voltage and current sources are in phase and that their interconnection has not introduced ground loops.
2. Select the Phase A, 1-amp range and the 150-volt range.
3. Apply 150.00 volts and 1.0000 amps and adjust R27 on the main circuit board for 150.00 on the display.
4. Reduce the voltage to 15.00 volts and adjust R110 on the main circuit board for 15.00 on the display.

5. Repeat steps 3 and 4 until the interaction between the adjustments is minimized.
6. Continue calibration of Phase A using Table 6-1.
7. Connect the voltage calibrator to the Phase B terminals and the current calibrators to the Phase B, 1-amp current terminals. Before proceeding, determine that the voltage and current sources are in phase and that their interconnection has not introduced ground loops.

Table 6-1. Power Adjustments.

PHASE A 1A SHUNT INPUT CURRENT	PHASE A INPUT VOLTAGE	ADJUST	WATTS DISPLAY READING
1A	50V	R37	50.00
1A	150V	R27	150.00
1A	300V	R39	300.0
1A	600V	R35	600.0
0.5A	50V	R41	25.00
0.5A	150V	R33	75.00
0.5A	300V	*	150.00
0.5A	600V	*	300.00
0.2A	50V	R31	10.000
0.2A	150V	*	30.00
0.2A	150V	*	60.00
0.2A	600V	R29	120.00

8. Select the Phase B, 1-amp range, 150-volt range.
9. Apply 150.00 volts and 1.0000 amps and adjust R40 on the Phase B circuit board for 150.00 on the display.
10. Reduce the voltage to 15.00 volts and adjust R210 on the main circuit board for 15.00 on the display.
11. Repeat steps 9 and 10 until the interaction between the adjustments is minimized.
12. Connect the voltage calibrator to the Phase C terminals and the current calibrators to the Phase C, 1-amp current terminals. Before proceeding, determine that the voltage and current sources are in phase and that their interconnection has not introduced ground loops.
13. Select the Phase C, 1-amp range, 150-volt range.
14. Apply 150.00 volts and 1.0000 amps and adjust R40 on the Phase C circuit board for 150.00 on the display.
15. Reduce the voltage to 15.00 volts and adjust R310 on the main circuit board for 15.00 on the display.
16. Repeat steps 14 and 15 until the interaction between the adjustments is minimized.

6.2.3 MAINTENANCE CALIBRATION

6.2.3.1 GENERAL

The maintenance calibration procedure should be performed whenever repairs have been made on the instrument. The procedure sets the adjustments common to all three phases during the Phase A calibration steps. The Phase B and Phase C adjustments are made to the respective boards for those phases. It may be possible to omit those parts of this procedure which apply only to boards which have not been repaired. When in doubt, perform the entire procedure.

NOTE

> Although the Phase A, B, and C circuit boards are identical, their calibration adjustments will differ with their placement within the instrument. They may not be interchanged without performing the routine calibration procedure.

6.2.3.2 EQUIPMENT REQUIRED

The following test equipment is required:

AC Voltage Calibrator:
  Valhalla 2703 or equivalent
AC Slave Voltage Calibrator:
  Valhalla 2705 or equivalent
AC Transconductance Amplifier:
  Valhalla 2500E or equivalent
Digital Voltmeter with DC and AC
  accuracy of at least 0.3%

6.2.3.3 VOLTAGE CALIBRATION

NOTE ON MODEL 2300L

> To calibrate the 2300L, reduce all of the voltage inputs and range settings to one-tenth the value given.

1. Remove the shield from the component side of the Phase A circuit board. Connect the DVM lead to the remaining Phase A shield and the high lead to the front end of R33. Adjust R3 on the Phase A board for zero ±100 mv DC on the DVM.
2. Leave the DVM connected as before, but switch to its DC function. Connect the AC Voltage Calibrator to the 2300 with the Volts High terminal of the 2703 to the Volts Common terminal of the 2300, and the Volts Low terminal of the 2703 to the Volts High terminal of the 2300. Select Phase A and the 600 volt range on the 2300.
3. Apply 600.00 volts AC and adjust R25 on the Phase A circuit board for 5.000 volts DC on the DVM.
4. Reduce the input voltage to 300.00 volts. Select the 300 volt range on the 2300 and adjust R25 on the Phase A circuit board for 5.000 volts DC on the DVM.

5. Reduce the input voltage to 150.00 volts. Select the 150 volt range on the 2300 and adjust R27 on the Phase A circuit board for 5.000 volts DC on the DVM.
6. Reduce the input voltage to 50.000 volts. Select the 50 volt range on the 2300 and adjust R29 on the Phase A circuit board for 5.000 volts DC on the DVM.
7. Reduce the input voltage to zero.

6.2.3.4 CURRENT CALIBRATION

1. Remove the DVM high lead from R33 and connect it to the front lead of R38 on the Phase A circuit board. Select the DC function on the DVM. Adjust R9 on the Phase A circuit board for zero ±100 mv DC on the DVM.
2. Leave the DVM connected as before, but switch to its DC function. Leave the AC Voltage Calibrator connected as before. Connect the AC Current Calibrator to the 2300 with its Current High terminal to the 1-amp current shunt terminal, and its Current Low terminal to the 2300 Current Low terminal.
3. Select the 150 volt range and the 1-amp range. Apply 150.00 volts and 1.000 ampere. Adjust R16 on the Phase A circuit board for 5.000 volts DC on the DVM.
4. Reduce the current input to 0.5000 ampere. Select the 0.5-amp range and adjust R15 on the Phase A circuit board for 5.000 volts DC on the DVM.
5. Reduce the current input to 0.2000 amperes. Select the 0.2-amp range and adjust R12 on the Phase A board for 5.000 volts DC on the DVM. Remove the voltage and current inputs.
6. Connect the AC Current Calibrator Current High terminal to the 2300 10-amp shunt terminal. Apply 150 volts and 10 amperes. Adjust R5 on the Phase A circuit board for 5.000 volts DC on the DVM. Remove the voltage and current inputs.
7. Connect the AC Current Calibrator Current High terminal to the 2300 100-amp shunt terminal. Apply 150 volts and 100 amperes. Adjust R7 on the Phase A circuit board for 5.000 volts DC on the DVM. Remove the voltage and current inputs.

6.2.3.5 WATTS CALIBRATION

NOTE ON MODEL 2300L

To calibrate the 2300L, reduce all of the voltage inputs and voltage range settings to one-tenth the value given. All of the wattage readings will be one-tenth of those specified.

1. Connect the AC Voltage Calibrator to the 2300 with the Volts High terminal of the 2703 to the Volts Common terminal of the 2300, and the Volts Low terminal of the 2703 to the Volts High terminal of the 2300. Connect the AC Current Calibrator to the 2300 with its Current High terminal to the 1-amp current shunt terminal, and its Current Low terminal to the 2300 Current Low terminal. Connect the DVM LOW lead to the rearmost lead of R109 on the main circuit board, and the HIGH lead to the frontmost lead of R9 on the main circuit board. Select the DVM's DC function.

2. Select the 150-volt range and the 1-amp range. Apply 150.00 volts and 1.000 ampere. Adjust R40 on the Phase A circuit board for 2.500 volts on the DVM. If this voltage cannot be reached, reselect R41.
3. Reduce the current to 0.1000 ampere. Adjust R110 on the main circuit board for 0.250 volts DC and the DVM.
4. Repeat steps 2 and 3 until the interaction between the readings is minimized.

6.2.3.6 ADDITIONAL STEPS

This completes the maintenance calibration of the 2300. This must be followed by performance of the routine calibration procedure.

6.3 TROUBLESHOOTING

WARNING

> Although this unit does not produce high voltages, potentially lethal voltages and currents may be present at the inputs. Therefore,
>
> DEATH
>
> on contact may result if personnel fail to observe safety precautions. The individual phase signal processing boards are floating with respect to each other and ground. Therefore, avoid contact with the input terminals and the signal processing boards.

It is not possible to anticipate all failure modes of the integrated circuit devices and other components of the Model 2300. Therefore, the servicing technician should be familiar with the contents of Section V -- Theory of Operation. Experience has shown that apparent malfunctions of the Model 2300 are often the result of poor input signals or misinterpretation of the specifications. Check to be sure that the inputs are neither noisy or erratic, that phase and polarity are correct, and that the characteristics of the Model 2300, as defined in the specifications, are fully understood. Knowledge of circuit operation is a requisite for efficient servicing of the 2300.

As a servicing aid, the troubleshooting chart, Table 6-2, lists a number of fault symptoms and possible sources. If the exhibited symptom is not listed or a check of the sources listed does not locate the defective component, it will be necessary to employ normal troubleshooting procedures.

The following steps will help to localize the area of the malfunction.

1. Measure the following voltages on each phase board:

J2-7	Common
J2-6	+15 volts
J2-8	-15 volts

2. Measure the following voltages on the main board:

Earth ground	Common
E8	+5 volts
Positive side of C6	+15 volts
Either side of R1	+7.5 volts
One side of R2	-15 volts
Other side of R2	-7.5 volts

3. Measure the display board voltages as follows:

J5-9	Analog Common
J5-8	+15 volts
J5-10	-15 volts
J6-2	Digital Common
J6-1	+5 volts

4. The reference voltages are found on pin 7 of IC3, IC12 and IC19. Each display reference can read 1 VDC ±5% since each is adjusted against the display after initial adjustment in the maintenance calibration procedure. The reference master is IC18 with the factory selected resistor, R47.

Table 6-2. Troubleshooting Chart.

SYMPTOM	POSSIBLE TROUBLE SOURCE
No display	Main PCB power supplies, clock on display PCB IC4.
Display over range	Reference IC18, A-to-D IC's on display PCB.
Phase overload no input	Overload detection IC11, IC12 and IC13. Individual signal processor board (if one phase only), if all phases CR17, CR18, IC9 and IC10.
Single-phase volts, amps or watts not functioning or out of tolerance	Signal processing board in that phase or section before main PCB relays K1 through K9 (e.g., IC103, IC104, IC105 and IC106).
All phases volts, amps or watts not functioning or out of tolerance	Circuit after main PCB relays K1 through K9, IC5 for amps, IC6 for volts, IC7 for watts and associated scaling resistors.
Single-phase fullscale any range	On suspected ØPCB IC 17 for current IC 18 for volts

SECTION VII - AVAILABLE OPTIONS

7.1 GENERAL

This section describes several options available from Valhalla Scientific to increase the utility of the Model 2300/2301.

7.2 OPTION TL-4

The TL-4 is a full talk/listen interface giving full control over the 2300/2301 and having the capability of outputting any of the displayed data. (See Section IV for full details).

7.3 OPTION TL-5

The TL-5 has all of the capabilities of the TL-4 with the addition of the ability to compute average power or Watt-Hours over a controlled time period.

7.4 OPTION I-150

The I-150 is a single 150-Amp current transformer of the clamp-on type. The transformer ratio is 1000:1(i.e., 150 milliampere output at 150 amperes input) and can accomodate up to 1/2-inch diameter conductors. The accuracy is ±2% from 50 to 400 Hz.

7.5 OPTION I-1000

The I-1000 is a single 1000-Amp current transformer of the clamp-on type. The transformer ratio is 1000:1(i.e., 1 ampere output at 1000 amperes input) and can accomodate up to 2-inch diameter conductors. The accuracy is ±2% from 50 to 400 Hz.

7.6 OPTION RX-7

The RX-7 is a rack-mount adapter kit for the Model 2300/2301.

7.7 OPTION IOX

This option provides a 5-volt full scale output of voltage, current and power for each phase and also 3-wire and 4-wire power.

Option IOX provides eleven analog output signals corresponding to Phase A Volts, Amps, Watts, Phase B Volts, Amps, Watts, Phase C Volts, Amps, Watts, Three Phase Three-Wire Watts and Three Phase Four-Wire Watts. The outputs are referenced to chassis ground of the Model 2300. The outputs provide a 5 Volt full scale output for full scale readings of the three displays on the 2300 front panel. Output connections are made via a 24 pin "D" connector which is supplied with Option IOX according to table 7-1.

Table 7-1.

PIN	FUNCTION
1	ØA VOLTS
2	ØA AMPS
3	ØA WATTS
4	ØB VOLTS
5	ØB AMPS
6	ØB WATTS
7	ØC VOLTS
8	ØC AMPS
9	ØC WATTS
10	3Ø 3-WIRE WATTS
11	3Ø 4-WIRE WATTS
12	COMMON
↓	↓
24	COMMON

7.7.1 CALIBRATION

Option IOX should be calibrated only after the Model 2300 has been calibrated. Allow at least 2 hours for the Model 2300 to warm up before calibrating Option IOX.

1. Connect a voltage standard and current source to the Phase A input terminals. Select the Phase A, 1-amp and 150 volt ranges on the 2300.

   a) Apply 150.00 volts and adjust RV12 for an output of 5.000 volts at pin 1 of the IOX connector.
   b) Apply 15.00 volts and adjust RV1 for an output of .500 volts at pin 1 of the IOX connector.
   c) Repeat steps a and b for minimum interaction.
   d) Apply 1.0000 amps and adjust RV13 for an output of 5.000 volts at pin 2 of the IOX connector.
   e) Apply .1000 amps and adjust RV2 for an output of .500 volts at pin 2 of the IOX connector.
   f) Repeat steps d and e for minimum interaction.
   g) Apply 150.00 volts and 1.0000 amps; adjust RV14 for 5.000 volts at pin 3 of the IOX connector.
   h) Apply 15.00 volts and 1.0000 amps and adjust RV7 for .500 volts at pin 3 of the IOX connector.
   i) Repeat steps g and h for minimum interaction.

j) Apply 150.00 volts and 1.0000 amps; adjust RV15 for 2.500 volts at pin 10 of the IOX connector.
k) Apply 15.00 volts and 1.0000 amps and adjust RV10 for .250 volts at pin 10 of the IOX connector.
l) Repeat steps j and k for minimum interaction.
m) Apply 150.00 volts and 1.0000 amps and adjust RV16 for 1.666 volts at pin 11 of the IOX connector.
n) Apply 15.00 volts and 1.0000 amps and adjust RV11 for .166 volts at pin 11 of the IOX connector.
o) Repeat steps m and n for minimum interaction.

2. Connect the voltage standard and current source to the Phase B input terminals. Select Phase B, 1-amp and 150 volt ranges on the 2300.

   a) Apply 150.00 volts and adjust RV17 for 5.000 volts at pin 4 of the IOX connector.
   b) Apply 15.00 volts and adjust RV3 for .500 volts at pin 4 of the IOX connector.
   c) Repeat steps a and b for minimal interaction.
   d) Apply 1.0000 amps and adjust RV18 for 5.000 volts at pin 5 of the IOX connector.
   e) Apply .1000 amps and adjust RV4 for .500 volts at pin 5 of the IOX connector.
   f) Repeat steps d and e for minimal interaction.
   g) Apply 150.00 volts and 1.0000 amps and adjust RV10 for 5.000 volts at pin 6 of the IOX connector.
   h) Apply 15.00 volts and .1000 amps and adjust RV8 for .500 volts at pin 6 of the IOX connector.
   i) Repeat steps g and h for minimal interaction.
   j) Apply 150.00 volts and 1.0000 amps and adjust RV20 for 1.666 volts at pin 11 of the IOX connector.

3. Connect the voltage standard and current source to the Phase C input terminals. Select Phase C, 1-amp and 150 volt ranges on the 2300.

   a) Apply 150.00 volts and adjust RV21 for 5.000 volts at pin 7 of the IOX connector.
   b) Apply 15.00 volts and adjust RV5 for .500 volts at pin 7 of the IOX connector.
   c) Repeat steps a and b for minimal interaction.
   d) Apply 1.0000 amps and adjust RV22 for 5.000 volts at pin 8 of the IOX connector.
   e) Apply .1000 amps and adjust RV6 for .500 volts at pin 8 of the IOX connector.
   f) Repeat steps d and e for minimal interaction.
   g) Apply 150.00 volts and 1.0000 amps; adjust RV23 for 5.000 volts at pin 9 of the IOX connector.
   h) Apply 15.00 volts and 1.0000 amps and adjust RV9 for .500 volts at pin 9 of the IOX connector.

i) Repeat steps g and h for minimal interaction.
j) Apply 150.00 volts and 1.0000 amps and adjust RV24 for 2.500 volts at pin 10 of the IOX connector.
k) Apply 150.00 volts and 1.0000 amps and adjust RV25 for 1.666 volts at pin 11 of the IOX connector.