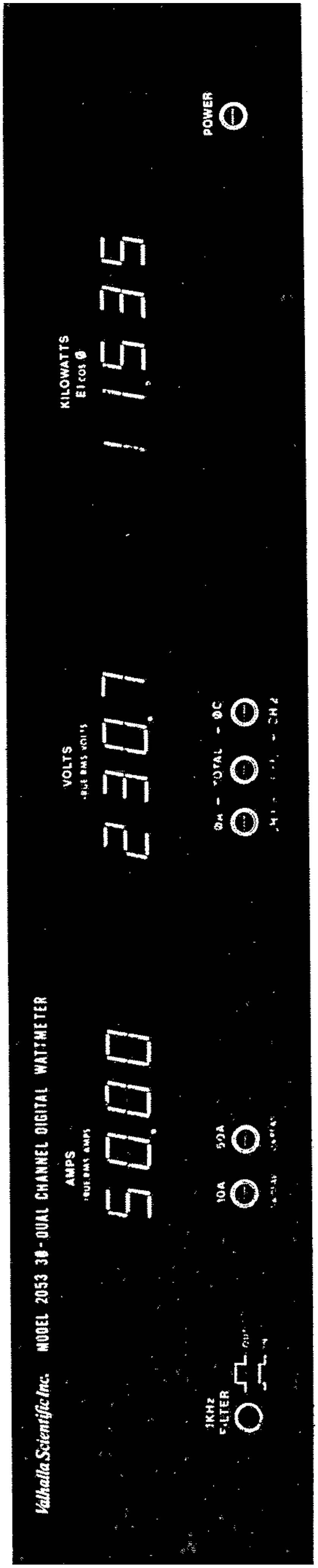
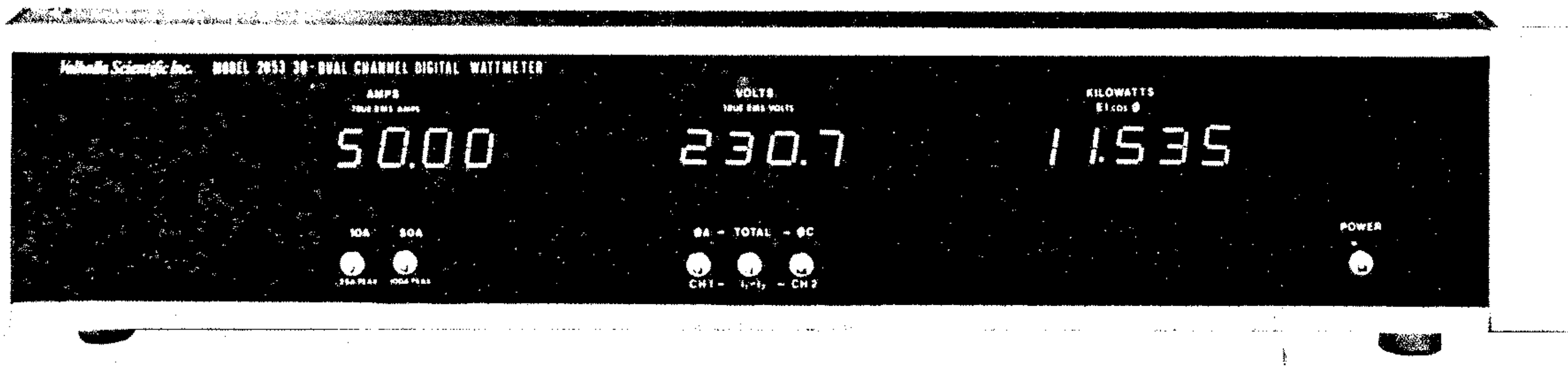


INSTRUCTION MANUAL

MODELS 2013, 2023, 2033, 2053 and 2093



MODELS 2013, 2023, 2033, 2053 AND 2093
DUAL CHANNEL POLYPHASE DIGITAL WATTMETERS

CERTIFICATION

Valhalla Scientific, Inc. certifies that this instrument was thoroughly tested and inspected and found to meet its published specifications when it was shipped from the factory. Valhalla Scientific, Inc. further certifies that its calibration measurements are traceable to the National Bureau of Standards to the extent allowed by NBS's calibration facility.

WARRANTY

Valhalla Scientific, Inc. warrants this instrument against defects in material and workmanship for one year from date of shipment. We will repair or replace the instrument during the warranty period provided it is returned to Valhalla Scientific, Inc. No other warranty is expressed or implied. We are not liable for consequential damages. Permission must be obtained directly from the factory for warranty repair returns. No liability will be accepted if returned without such permission.

2093 SERIES SPECIFICATIONS

Model Number	True RMS Current Ranges	Single Phase Watts Ranges	Three Phase Watts Ranges
2093	100A (5A min. input) 20A (1A min. input)	60.00 KW 12.00 KW	120.00 KW 24.00 KW
2053	50A (2.5A min. input) 10A (.5A min. input)	30.00 KW 6.000 KW	60.00 KW 12.000 KW
2013	10A (.5A min. input) 2A (.1A min. input)	6.000 KW 1.200 KW	12.000 KW 2.400 KW
2033	5A (.25A min. input) 1A (.05A min. input)	3000 W 600.0 W	6000 W 1200.0 W
2023	1A (50mA min. input) .2A (10mA min. input)	600.0 W 120.0 W	1200.0 W 240.0 W

True RMS Voltage Range: 30 to 600 V RMS all models.

Maximum Input: 600 V RMS, 1500 V peak; three times rated current shunt for 5 seconds with no damage.

Peak Response Capability: 2.5 times range.

Peak Detection: L.E.D. illuminates when peak response is exceeded.

Input Configuration: 4 terminal per channel.
accepts 1Ø, 2Ø or 3Ø 3-wire loads.

V-A-W Accuracy: (180 days 25°C ±5°C)

±0.25% of reading ±15 digits (40Hz to 400Hz)
±1.5% of reading ±25 digits (30Hz to 2KHz)

Power Factor Response Capability: Zero to Unity leading or lagging with no degradation in accuracy.

Displays: three 4½ digit 7 segment L.E.D.

Operating Temperature Range: 0°C to 50°C.

Temperature Coefficient: ±0.025% of range from 0°C to 20°C and 30°C to 50°C.

Conversion Rate: approximately 300mS.

Power: 115/230 VAC ±10% 50/60Hz 10 watts.

Size: 43cm W X 33cm L X 8.9cmH (17"x13"x3.5").

Weight: 7.7KG Net 11KG Shipping (17 lbs. Net, 25 lbs. Shipping)

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SECTION I—GENERAL INFORMATION

1-1 DESCRIPTION

1-2 This manual covers Valhalla Scientific Models 2013, 2023, 2033, 2053 and 2093 Dual Channel, Polyphase Digital Wattmeters. These are all similar equipments except that their individual power ranges, as listed in the Specifications table at the front of this manual, are different. Therefore, wherever the Model 2013 is referenced within this manual, the data applies to all other models as well. The calibration tests of the Maintenance Section refer to the Specifications table for determination of the load current to be used with a particular model.

1-3 Valhalla Scientific's Dual Channel, Polyphase, Digital Wattmeters are accurate, moderate-cost instruments for power analysis in engineering, production test and quality assurance departments. They provide indication of product power consumption in the 10 Hz to 50 KHz range for devices operating from AC power lines. Voltage, current and power are shown simultaneously on separate digital displays. Two separate voltage and current input channels may be displayed separately or in combined form, permitting single phase, two phase and three phase measurements of all three parameters. Voltage and current readings are true RMS; power is true watts (EI cos θ).

1-4 These Wattmeters provide a fast and convenient means of determining product efficiency, power factor and true RMS current. Load phase angle relationships may be accurately calculated using the displayed digital data.

1-5 The power computation section of the Wattmeter uses unique four-quadrant complex waveform analog multipliers. Their outputs are DC signals proportional to the product of the instantaneous values of voltage and current in each of two channels. Two resultant wattage values are integrated, summed and presented on a 4 1/2 digit display. Ranges of 100% and 20% of the instrument's maximum current are switch-selectable. Additional switching permits separate display of either input channel.

1-6 The Wattmeters are designed to operate from a 115 or 230 volt, 50-60Hz AC supply. Power is supplied through a plug-in cord equipped with a 115 volt, 15 amp connector. Other connector types are available upon request.

1-7 OPTION RX3

1-8 Option RX3 permits mounting of the Wattmeters in a standard 19-inch equipment rack.

1-9 OPTION IDO

1-10 This option provides analog and digital outputs for voltage, current and power, permitting automatic logging of these parameters during life testing or line voltage cycling tests. There are two outputs for each function; a real time waveform of 0 to 5 volts rms; and a DC output of 0 to +2 volts DC. Both outputs are DC for the watts function. The AC waveform outputs will drive a 10K ohm load. The DC output will drive a 10M ohm load.

1-11 The digital outputs are BCD positive "1" state CMOS. These outputs will drive one standard TTL load.

1-12 The output connector is an Amphenol No. 57-40500, or equivalent, and mates with an Amphenol No. 57-30500, or equivalent, cable connector.

SECTION II—INSTALLATION

2-1 INTRODUCTION

2-2 This section of the manual contains information for receiving inspection and installation of the Models 2013, 2023, 2033, 2053 and 2093 Dual Channel Polyphase Digital Wattmeters.

2-3 INITIAL INSPECTION

2-4 If the shipping container shows evidence of in-transit damage, such damage should be immediately brought to the attention of the carrier and the nature of the visible damage noted on the bill of lading.

2-5 Unpack the instrument and retain the shipping container until the instrument has been inspected for possible damage in shipment. If in-shipment damage is observed, notify the carrier and obtain his authorization for repairs before returning the instrument to the factory. If the shipping container shows evidence of damage in transit, but the instrument appears undamaged, it may be advisable to perform the calibration procedure of Section V to determine that the instrument has not sustained internal damage.

2-6 POWER REQUIREMENTS

2-7 The instrument requires 115 or 230 volts AC, 50-60 Hz, at 10 watts and, unless ordered otherwise, is connected for 115 volts AC when shipped. A detachable line cord with appropriate connector is provided.

2-8 INSTALLATION

2-9 If the Model 2013 is to be used in the bench top configuration, installation requires only that the line cord be connected to the wall receptacle and that the power source and load be connected to the terminals on the rear panel. In most applications it will be convenient to fabricate cables with connectors to match the power source and the load.

2-10 If the instrument is to be installed in a rack, assemble the unit into the rack mount adaptor, install it in the rack and connect the line cord and the power and load terminals. The instrument should not be operated at temperatures exceeding 50 degrees Celsius (122 degrees Fahrenheit). If higher temperatures are anticipated, forced air cooling should be provided to maintain the ambient temperature at or below 50 degrees Celsius.

2-11 IDO OPTION CONNECTIONS

2-12 If the IDO option is installed, the connector that will mate with the rear panel connector must be wired in accordance with Table 2-1.

Table 2-1. IDO Option Connections.

PIN NO.	FUNCTION	PIN NO.	FUNCTION
1	1	12	200
2	2	13	400
3	4	14	800
4	8	15	Analog Output 0 to +2VDC
5	Not Used	16	1000
6	10	17	2000
7	20	18	4000
8	40	19	8000
9	80	20	Analog Ground
10	Analog Waveform (AC)	21	10000
11	100	45	Hold
		50	Digital Ground

SECTION III—OPERATION

3-1 INTRODUCTION

3-2 This section of the manual contains complete operating instructions for the Models 2013, 2023, 2033, 2053 and 2093 Dual Channel Polyphase Digital Wattmeters.

3-3 FRONT PANEL CONTROLS

3-4 There are seven pushbutton switches on the front panel of the instrument, each marked with its function. The single push-on, push-off button on the right applies power to the instrument. The group of three at the center are interlocked. The left pushbutton selects for display the values of current, voltage and power for Channel1, or Phase A. The right pushbutton selects for display those values for Channel 2, or Phase C. The center pushbutton selects the vectorially summed voltages, currents and powers of both channels. A single push-on, push-off button on the left side of the panel, labeled 1 KHz FILTER, connects a separate 6db per octave, 1 KHz low-pass filter to each of the instrument's four inputs. This function removes unwanted high frequency line noise which might distort readings. A pair of push buttons located between the filter and the display selector, switches select the high and low current ranges of the instrument. The right button, selects the range where the instrument's maximum steady state current may be applied and measured. The button on the left selects the low range where the maximum readable current is 20% of the HIGH range.

3-5 FRONT PANEL INDICATORS

3-6 There are three sets of seven-segment LED digital readouts on the front panel. A four and one-half digit load CURRENT display is on the left. A four digit load VOLTAGE display is in the center and a four and one-half KILOWATTS display is on the right. Although the voltage display is capable of reading to 999.9 volts, the full scale voltage input of all the 2013 series instruments is 600 volts. The numerical maximum of the four and one-half digit displays is 19999. In order to maintain maximum display resolution, decimal points are placed between different digits as the HIGH and LOW ranges are selected. Also, the location of decimal points in both ranges is different with different models of the 2013. Full scale current and power readings for the HIGH and LOW ranges of each instrument are shown in Table 3-1.

Table 3-1. Wattmeter Current and Power Ranges.

MODEL	CURRENT AMPS HIGH	CURRENT AMPS LOW	POWER KW HIGH	POWER KW LOW
2093	100.1	19.999	120.00	24.00
2053	50.00	10.000	60.00	12.000
2013	10.000	1.9999	12.000	2.400
2033	5.000	1.0000	6.000	1.2000
2023	1.0000	0.1999	1.2000	0.2400

3-7 REAR PANEL CONNECTIONS

CAUTION

The voltages applied to the rear panel terminals of the Model 2013 Series Wattmeters are dangerous to life. Contact with the terminals while voltages are applied may result in serious injury or death. Personnel should use extreme caution to insure that source voltages are removed before connecting or disconnecting the voltage and current leads of the source and load to the rear panel terminals.

3-8 Connections are made to the voltage and current inputs of the instrument through eight 1/4-20 binding posts on the rear panel. Posts 2 and 3 are the voltage terminals, and 1 and 4 the current terminals for Channel 2. Pins 6 and 7 are the voltage terminals, and 5 and 8 the current terminals for Channel 1. To obtain accurate power measurements, it is necessary that the relative phases of the voltage and current inputs be correct. Schematic representations of the correct connections for single phase and three phase measurements are printed on the rear panel for the operator's convenience and are also shown in Figures 3-1, 3-2 and 3-3. Figure 3-4 shows the connections for four-wire sensing where the load may be located some distance from the wattmeter. With these connections, the wattmeter will measure the power dissipated in the load, compensating for the power loss in the interconnecting wires.

NOTE

Three phase power measurements may be performed only on three-wire systems. The measuring technique used will not work on four-wire three phase systems. In four-wire systems, the power in each phase must be measured separately and the results added to obtain the total power.

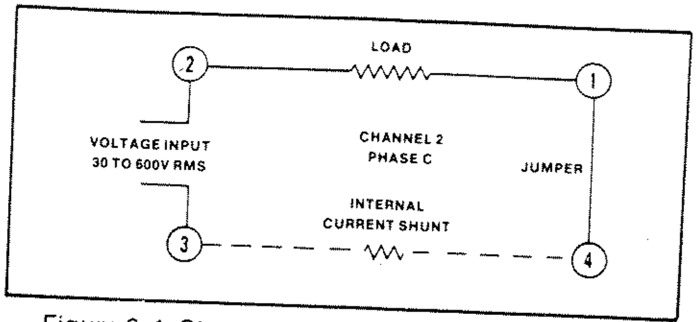


Figure 3-1. Single Phase Wattmeter Connections.

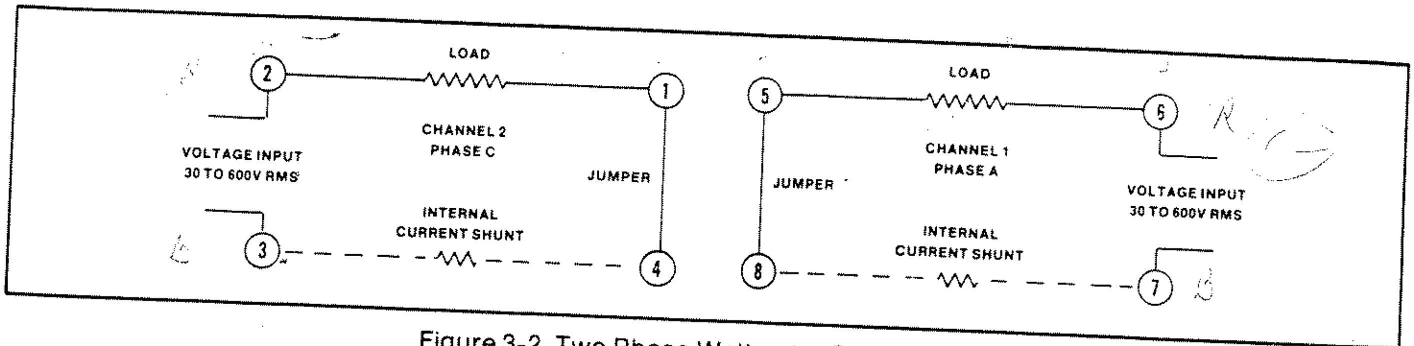


Figure 3-2. Two Phase Wattmeter Connections.

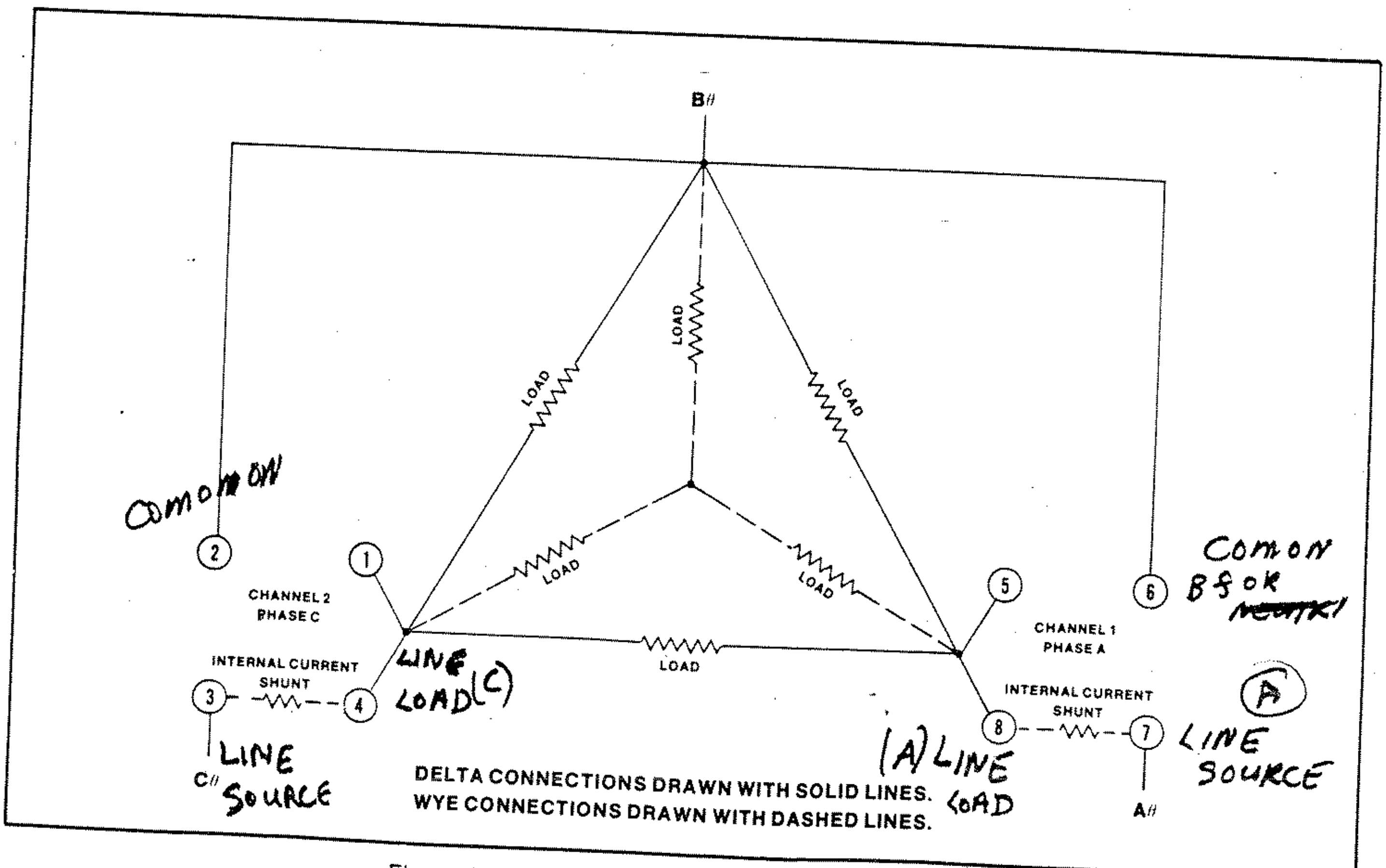


Figure 3-3. Three Phase Wattmeter Connections.

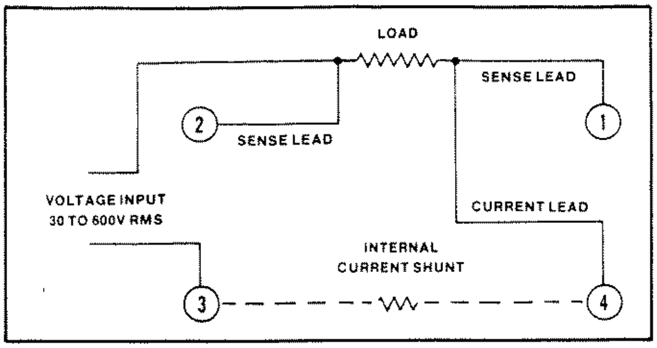


Figure 3-4. Four-Wire Power Sensing Connections.

3-9 VOLTMETER

3-10 When connected for single phase measurements, the voltage input of the channel in use is connected across the load. Selecting that channel with the front panel pushbutton will cause the true RMS voltage to be displayed. When connected for three phase measurements, each of the voltage inputs of the instrument is connected across two of the three phases. Either of the two voltages may be displayed by selecting the desired channel with the front panel pushbuttons. If the pushbutton marked BOTH is depressed, the RMS value of the vector sums of the two voltages will be displayed. In a 120° three phase system, the vector sum of 208 volts rms $\angle\phi$ + 208 volts rms $\angle\theta$ equals 208 volts rms. An indication of 360 volts rms in the three phase mode means one of the input channels is 180° out of phase. In a 90° two phase system, the vector sum of 100 volts rms $\angle\phi$ + 100 volts rms $\angle\theta$ equals 141 volts rms. In a 180° split phase system, the vector sum of 115 volts rms $\angle\phi$ and 115 volts rms $\angle\theta$ is 230 volts.

3-11 AMMETER

3-12 When connected for single phase measurements, the current sensing terminals of the channel in use are connected in series with the load. Selecting that channel with the front panel pushbutton will cause the true RMS current to be displayed. When connected for three phase measurements, the current inputs of the instrument are connected in series with the loads on two of the three phases. Either of the two currents may be displayed by selecting the desired channel with the front panel pushbuttons. If the pushbutton marked BOTH is depressed, the RMS value of the vectorially summed currents will be displayed. Careful examination of the three phase connection diagram on the rear panel will show that this value is also the total current in the third phase, since in a three-wire circuit, all current into the third phase must flow out of the other two phases.

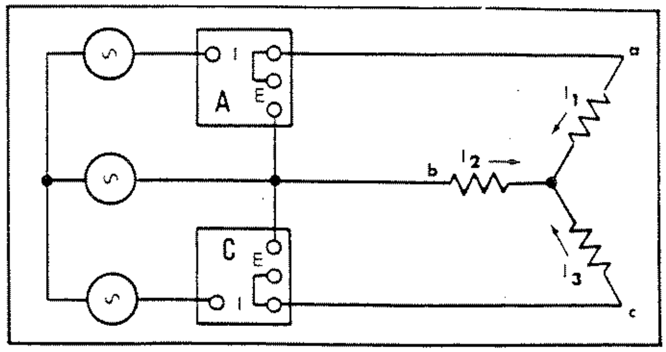


Figure 3-5. Two-Wattmeter, Three Phase Power Measurement.

3-13 WATTMETER

3-14 When connected for single phase measurements, the instantaneous values of the voltage and current applied to the inputs of the instrument are multiplied together. The integrated value of the product appears on the power display. When connected for three phase measurements, each of the instrument's input channels is measuring the instantaneous product of the current into **one** phase and the voltage across **two** phases. Therefore, the reading obtained by selecting a single channel is **not** the power in any one phase, and negative readings are possible at power factors below 0.5. If the front panel pushbutton marked BOTH is depressed, the total power in the three phase load is displayed. A discussion of this method of power measurement will be found in the next paragraph.

3-15 TWO-WATTMETER METHOD OF THREE PHASE POWER MEASUREMENT

3-16 This instrument uses two wattmeters to measure total three phase power. The two-wattmeter method yields accurate measurements whether or not the currents in the phases are balanced, and regardless of the power factor of the load in any phase. The method operates as follows. Refer to Figure 3-5.

Wattmeter A indicates the average product of the instantaneous values of I_1 and E_{ab}:

$$W_A = \int_0^T E_{ab} \cdot I_1$$

Wattmeter C indicates the average product of the instantaneous values of I_3 and E_{cb}:

$$W_C = \int_0^T E_{cb} \cdot I_3$$

The total power would be:

$$W_T = \left(\int_0^T E_{ab} \cdot I_1\right) + \left(\int_0^T E_{cb} \cdot I_3\right)$$

3-17 POWER FACTOR CALCULATION

3-18 The indicated power on the instrument power display is the average of the instantaneous product of current and voltage, which is $EI \cos \theta$ where θ is the angle by which the current leads or lags the voltage, and $\cos \theta$ is the power factor. To calculate the numerical value of the power factor, simply divide the indicated power by the product of the indicated voltage and current. Power factor is not defined for non-sinusoidal waveforms or for unbalanced loads. For balanced passive loads, power factor is calculated as shown above.

SECTION IV — THEORY OF OPERATION

4-1 GENERAL

4-2 This section of the manual provides functional and detailed descriptions of the circuits of the Model 2013 Dual Channel Digital Wattmeter. The functional descriptions are referenced to the block diagram of Figure 4-1 and are intended to assist the user in gaining a general understanding of the instrument prior to study of the detailed circuit descriptions. The information contained in this section, together with that of Section V will provide the background necessary for maintenance of the instrument.

4-3 FUNCTIONAL DESCRIPTION

4-4 The circuit descriptions of this section, while providing an overview of system operation, are arranged by circuit function to simplify the presentation.

4-5 VOLTMETER

4-6 The voltmeter converts the applied AC voltage to a DC voltage which is proportional to the RMS value of the AC input. This DC voltage is then accurately measured to provide the input to the voltmeter display. The voltage inputs of Channels 1 and 2 pass through attenuators into wideband input transformers and input amplifiers. The outputs of the input amplifiers are selected with the front panel channel select pushbutton switches to provide the input to a summing amplifier. The summing amplifier drives an RMS-to-DC converter whose DC output is proportional to the true RMS voltage applied to its input. The RMS-to-DC converter drives a dual-slope analog-to-digital converter comprising the analog processor and the digital processor. The digital processor drives a four digit, seven segment digital display with a resolution of 0.1 volt.

4-7 The maximum input that all models of the 2013 series will display accurately is 600 volts AC. If this level is exceeded, the RMS-to-DC converter will be driven outside its linear range, yielding unreliable readings. An LED indicator is provided on the front panel to alert the operator when the rated full scale voltage is exceeded.

4-8 AMMETER

4-9 The ammeter converts the AC voltage developed across its input shunt to a DC voltage which is proportional to the RMS value of the AC current input. This DC voltage is then accurately measured to provide the input to the ammeter display. The current inputs of Channels 1 and 2 are similar to the voltage inputs, with the addition of shunts across the input terminals. The voltages developed across the shunts pass through wideband input transformers and input amplifiers. The outputs of the input amplifiers are selected with the front panel channel select pushbutton switches to provide the input to a summing amplifier. The summing amplifier drives an RMS-to-DC converter, whose DC output is proportional to the true RMS voltage applied to its input. The RMS-to-DC converter drives a dual-slope analog-to-digital converter comprising the analog processor and the digital processor. The digital processor drives a four and one-half digit display. The resolution of the current display varies according to the model number of the instrument and the current range selected. Display resolutions are summarized in the Specifications.

4-10 The various models of the 2013 series display different full scale currents. The full scale current values for the various models are summarized in the Specifications. If the full scale current rating of the instrument is exceeded, the RMS-to-DC converter will be driven outside its linear range, yielding unreliable readings. An LED indicator is provided on the front panel to alert the operator when the rated full scale current is exceeded.

4-11 WATTMETER

4-12 The wattmeter processes the outputs of the voltage and current input amplifiers to provide the power display. In each channel, the outputs of the voltage and current input amplifiers are fed to a multiplier, whose output is the instantaneous product of the inputs. Each multiplier drives a multiplier output amplifier. Their outputs are selected with the front panel channel select pushbutton switches to drive a summing amplifier. The summing amplifier drives an amplifier/filter whose output is proportional to the average value of its input over time. This average of the instantaneous values of the product of voltage and current is true power, EI cos θ. The output of the amplifier/filter drives a dual-slope analog-to-digital converter comprised of an analog processor and a digital processor. The digital processor drives a four and one-half digit display.

4-13 The various models of the 2013 series display different full scale power levels. The full scale power values for each model are summarized in the Specifications.

4-14 DETAILED CIRCUIT DESCRIPTION

4-15 This section provides a detailed description of each circuit of the 2013 Series of Digital Wattmeters. Since the preceding functional descriptions provided an overview of system operation, the following descriptions individually cover only a small portion of each section of the instrument. Unless otherwise specified, the reference designators appearing in this section are those of the schematic diagram of Figure 5-5.

4-16 VOLTAGE INPUT CIRCUITS

4-17 The input circuits provide prescaling of the applied voltages and isolate the applied signals from the integrated circuit inputs. The two voltage input circuits are identical, therefore, only the circuit of the Channel 1 input is discussed. With its adjustment at midrange, the input attenuator, R56, R58, R88 reduces a 600 volt input by a factor of 6000, to 0.1 volt. The turns ratio of the input transformer is 1:1. The input amplifier, IC3, is an LF 357 JFET input, wide band operational amplifier. Its gain is set by the values of R42 and R43 to approximately 60, so that its output is approximately 6 volts for an instrument input of 600 volts. The outputs of the voltage input amplifiers drive the multipliers and are also applied to the voltage sections of the channel select pushbutton switches.

4-18 CURRENT INPUT CIRCUITS

4-19 The current input circuits provide prescaling of the voltage across the shunt and isolate the input signals from the integrated circuit inputs. The two input circuits are identical, therefore, only the current input circuit for Channel 1 is described. The voltage applied to the current input transformer is that which is developed across shunt R62. The value of the shunt is chosen so that the high range full scale voltage developed across it is 0.1 volt, and the low range full scale voltage is 0.02 volt. The turns ratio of the input transformer is 1:1. The input amplifier, IC7, is an LF 357 JFET input, wide band operational amplifier. Its gain is set by R64 and R45 to approximately 50 in the instrument's high current range. Its output is therefore approximately 5 volts at full scale in the high current range. In the instrument's low current ranges, R45 is shunted by R66 and R84 in series, increasing the gain of the input amplifer to approximately 200. Its output in the low current range is approximately 4 volts full scale. The outputs of the current input amplifiers drive the multipliers and are connected to the current sections of the channel select pushbutton switches.

4-20 MULTIPLIER AND MULTIPLIER OUTPUT AMPLIFIER

4-21 There are two identical multiplier circuits, therefore, only the circuit of Channel 1 is described. The multiplier, IC1, is an RC 4200 monolithic IC multiplier, connected in a highly accurate four-quadrant configuration. The magnitude of its output current is proportional to the product of the instantaneous values of its inputs. The inputs to the multiplier are the outputs of the voltage and current input amplifiers. The multiplier output drives the multiplier output amplifier, IC5, an LF 356 operational amplifier. The gain control for the multiplier output amplifier, R75, serves as a full scale calibration control for power and is used for balancing the two channels. The outputs of the multiplier output amplifiers are connected to the power sections of the channel select pushbutton switches.

4-22 POWER DISPLAY SUMMING AMPLIFIER

4-23 The summing amplifier, IC8, is an LF 356 JFET input, wide band operational amplifier. The values of summing resistors R78 and R79, and of feedback resistor R80, set the gain of the amplifier at 0.5. Its inputs come from either or both multipliers, IC1 and IC2, via the channel select pushbuttons. The output of the amplifier drives the amplifier/filter described in the following paragraph.

4-24 AMPLIFIER/FILTER

4-25 The amplifier/filter, IC12, is an LF 356 operational amplifier. Its gain is set by R82 and R83 at approximately 0.49. When the instrument's low current range is selected, the series combination of R77 and R81 is placed in parallel with R82, increasing the gain. In this configuration, the gain at midrange of the adjustment is about 1.2. C12 is connected between the output of the amplifier and its input, limiting the amplifier's high frequency response. As a result, the output voltage of the amplifier/filter is proportional to the average value of its input, with the ripple of the measured AC filtered out. The output of the amplifier/filter drives the analog processor portion of an A to D converter, through an attenuator comprising R90, R148 and R149.

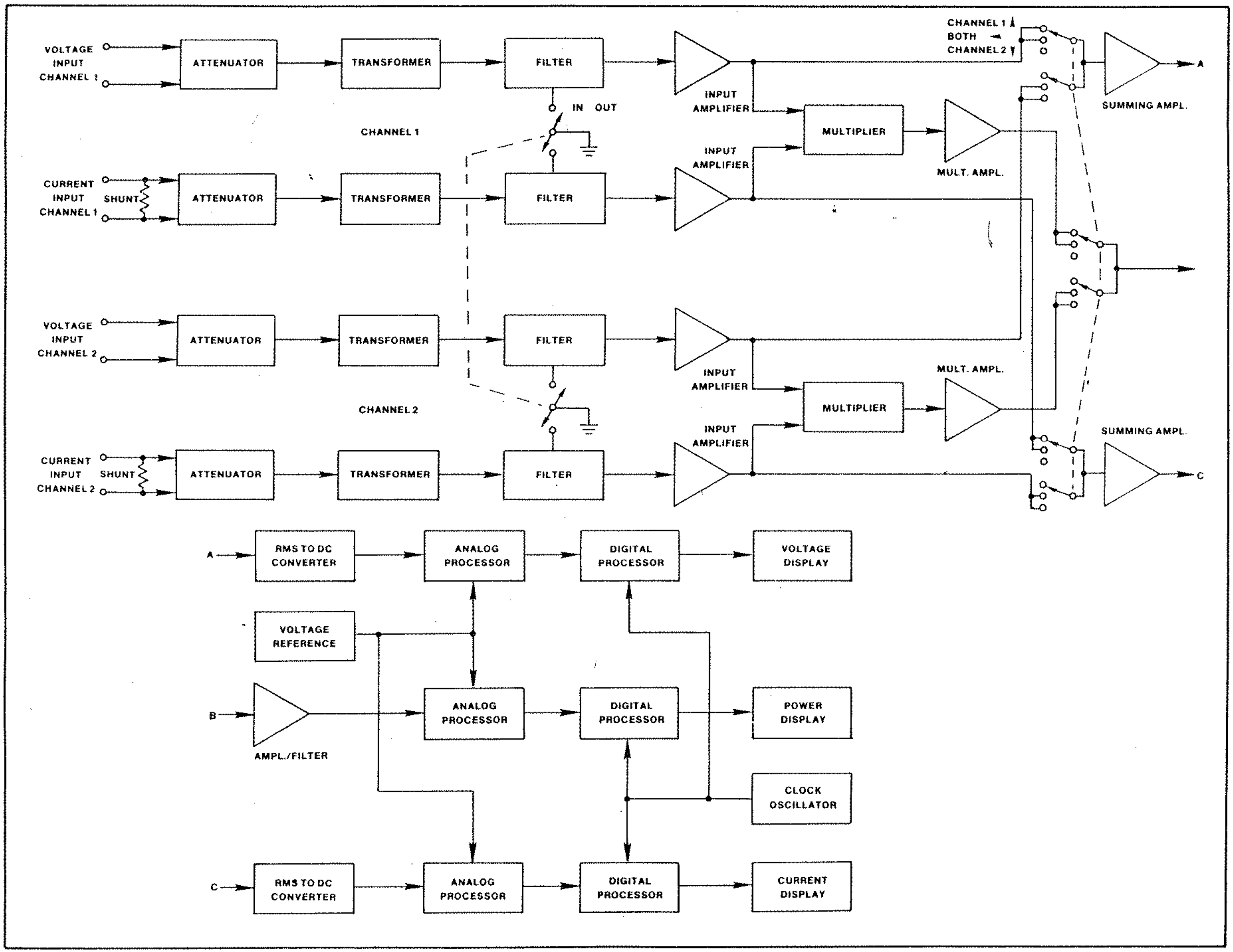


Figure 4-1. Block Diagram, Polyphase Digital Wattmeter.

4-26 POWER ANALOG AND DIGITAL PROCESSORS

4-27 The analog processor, IC17, is a TL500C dual slope integrator with built-in comparator and analog switching elements. It is designed for use with the digital processor, IC20, a TL502C control, counter and display driver. Together they act as a precision analog-to-digital converter. Inputs to the converter are clock pulses from the clock generator, a reference voltage from the voltage reference, and the voltage to be converted from the output of the amplifier/filter. The conversion process functions as follows.

4-28 The voltage to be converted is fed through an analog switch to the input of an operational integrator whose integrating capacitor is C17. The capacitor is permitted to charge for a fixed period of time, determined in the digital processor by counting clock pulses. At the end of that period, the input of the integrator is switched to the reference voltage, whose polarity is selected to discharge C17. While C17 is discharging, a counter in the digital processor is counting clock pulses. The output of the integrator is fed to a comparator. When C17 is fully discharged, the comparator trips, and the state of the counter is latched onto the digital processor's display driver outputs. The integrator charges and discharges C17 linearly. The slope of the integrator output is therefore proportional only to the capacitance of C17 and the applied voltage. Since the capacitance and the slope of the discharge are constants, the time to discharge C17 back to zero is directly proportional to the input voltage. With suitable scaling of the input, the counter output of the digital processor may be made equal to the value of the input voltage to the analog processor.

4-29 POWER DISPLAY

4-30 The power display has four and one-half digits consisting of four 7750 seven segment LED devices, DS11 through DS14, and one 7756 leading "1" display, DS10. The display is multiplexed; that is, each of the digits is driven in turn. The digit drivers, Q10 through Q14, are 2N4402 transistors. Provision is made through the range switch and R125 for changing the location of the decimal point depending on whether the high or low current range is selected.

4-31 CURRENT DISPLAY SUMMING AMPLIFIER

4-32 The summing amplifier, IC10, is an LF 356 JFET input, wide band operational amplifier operating at unity gain. The output of the amplifier drives the RMS-to-DC converter, IC13.

4-33 CURRENT RMS-TO-DC CONVERTER

4-34 The RMS-to-DC Converter, IC13, is a type AD 536. It accurately computes true RMS over a wide range of frequencies, and outputs a DC voltage proportional to the RMS value of the input. The output of IC13 is fed through a dual attenuator comprising R86, R91, R137, R138 and R143 to the current analog-to-digital converter, consisting of analog processor IC15 and digital processor IC18.

4-35 CURRENT ANALOG AND DIGITAL PROCESSORS

4-36 The current analog processor, IC15, is a TL500C, and the current digital processor, IC18, is a TL502C. For details of their functions, see paragraph 4-26 above. The output of the digital processor drives the current display.

4-37 CURRENT DISPLAY

4-38 The current display has four and one-half digits consisting of four 7750 seven segment devices, DS2 through DS5, and one 7756 leading "1" display, DS1. The display is multiplexed; that is, each of the digits is driven in turn. The digit drivers, Q1 through Q5, are 2N4402 transistors. Provision is made through the range switch and R116 for changing the location of the decimal point depending on whether the high or low current range is selected.

4-39 VOLTAGE DISPLAY SUMMING AMPLIFIER

4-40 The voltage display summing amplifier, IC11, is an LF356J FET input, wide band operational amplifier. The circuit has unity gain. Its inputs come from the voltage input amplifiers via the voltage section of the channel select pushbuttons. Its output drives the voltage RMS-to-DC converter.

4-41 VOLTAGE RMS-TO-DC CONVERTER

4-42 The RMS-to-DC converter, IC14, is an AD536 converter IC. It accurately computes true RMS over a wide range of frequencies, and outputs a DC voltage proportional to the RMS value of the input. The output of IC14 is fed through an attenuator, comprised of R87, R136 and R147, to the voltage analog-to-digital converter, consisting of Analog Processor IC16 and Digital Processor IC19.

4-43 VOLTAGE ANALOG AND DIGITAL PROCESSORS

4-44 The Analog Processor, IC16, is a TL500C, and the Digital Processor, IC19, is a TL502C. For details of their functions, see paragraph 4-26 above. The output of the Digital Processor drives the voltage display.

4-45 VOLTAGE DISPLAY

4-46 The voltage display is comprised of four type 7750 seven segment devices, DS6 through DS9. The display is multiplexed; that is, each of the digits is driven in turn. The digit drivers, Q6 through Q9, are type 2N4402 transistors. The decimal point is fixed, providiing one digit to its right.

4-47 CLOCK GENERATOR

4-48 The Clock Generator, IC23, is a type 555 timer, oscillating at 200 KHz. Its output is fed to the clock inputs of the digital processors.

4-49 VOLTAGE REFERENCE

4-50 The Voltage Reference, IC22, is an MC1403, 2.5 volt reference. Its output is reduced by the series combination of R34, R47 and R163. During calibration, R34 is adjusted to produce 1.000 volt at its wiper connecton. This reference voltage is fed to the analog processors.

4-51 OVERSCALE INDICATOR

4-52 The Overscale Indicator, IC24, is a quad operational amplifier, type TL084. Two of its inputs are connected to the voltage and current outputs of the voltage and current summing amplifiers. When the applied voltage exceeds a predetermined value, DS15 is illuminated. When the applied current exceeds a predetermined level, DS16 is illuminated. Either indicates a "peak exceeded" condition and alerts the operator that the readings displayed may not be accurate.

4-53 POWER SUPPLY

4-54 The power supply provides +12 volts, −12 volts, both at 100 milliamperes, and +5 volts at one ampere. A single fullwave brige rectifier, CR3 through CR6, produces +18 volts and −18 volts from a center tapped winding on the transformer. These two voltages are regulated by IC21 and IC22 to +12 volts and −12 volts, respectively. The +5 volts source is obtained through a separate transformer winding and a full wave rectifier, CR1 and CR2, which is filtered by C23.

SECTION V—MAINTENANCE

5-1 INTRODUCTION

5-2 This section contains maintenance information for the Model 2013 Series Dual Channel Digital Wattmeters. Included are a recommended test equipment list and calibration procedures.

5-3 RECOMMENDED TEST EQUIPMENT

5-4 A very accurate (0.1% or better) AC-DC voltammeter is the minimum requirement. A frequency counter with an accuracy of ±1.0% is required, as is a purely resistive 5 KW load, a Variac and an audio-quality oscilloscope. It is helpful but not essential to have a precision current source, such as the Valhalla 2555A Current Calibrator, which in turn requires a precision voltage standard for its operation.

5-5 CALIBRATION PROCEDURE

5-6 The following procedure should be performed at routine intervals to insure that the accuracy of the instrument remains within specified limits. In addition, calibration should be performed whenever repairs have been completed which involve accuracy determining components.

CAUTION

The voltages applied to the rear panel connectors of the Model 2013 Series Wattmeters are dangerous to life. Contact with the connectors while voltages are applied may result in serious injury or death. Personnel should use extreme caution to insure that source voltages are removed before connecting or disconnecting the voltage and current leads of the source and load to the rear panel connectors.

NOTE

The locations of calibration adjustments are identified in the Assembly Diagram, Figure 5-4.

5-7 INITIAL ADJUSTMENTS

5-8 Adjust R23 for a clock output frequency of 200KHz, measured at IC23-3.

5-9 Adjust R34 for 1.000 volt DC at its wiper.

NOTE

Do not attempt this adjustment without a measuring instrument of at least 0.1% accuracy.

5-10 VOLTAGE SECTION CALIBRATION

5-11 A combination block and simplified schematic diagram of the voltage section, Figure 5-1, shows where the adjustments are located in the circuit. The Channel 2 adjustments are shown in parentheses.

5-12 Apply 600 volts AC RMS to both CHANNEL 1 and CHANNEL 2 voltage inputs (terminals 1, 2 and 5, 6.)

5-13 Press the Phase A selector button on the front panel and observe the voltage indication; press the Phase C selector button and compare the indication with that obtained with Phase A.

5-14 Adjust R88 and R89 to produce identical indications on Phase and Phase C. These indications need not be accurate but they must be identical.

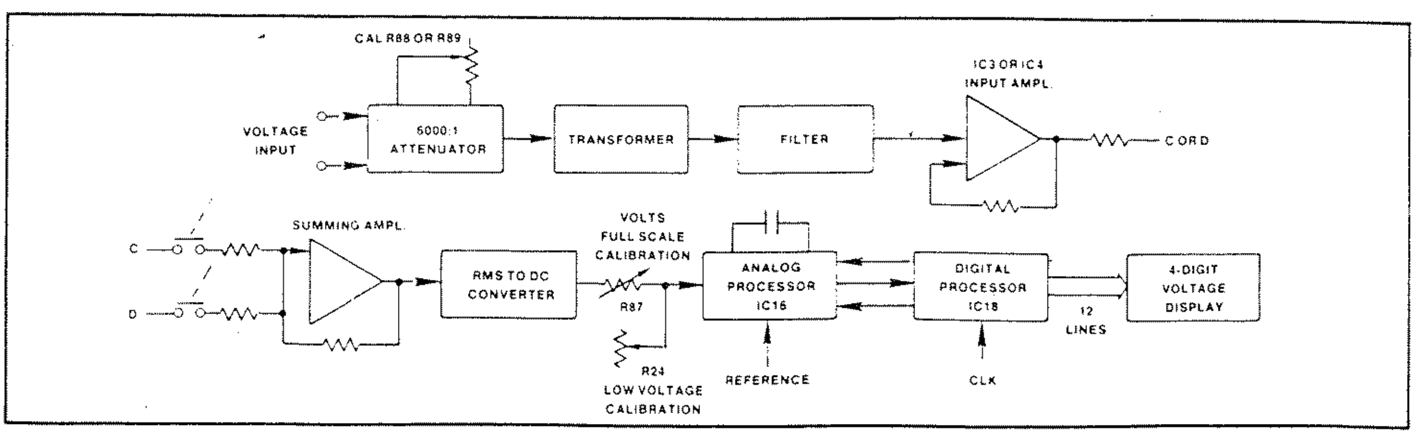


Figure 5-1. Voltage Section Adjustments.

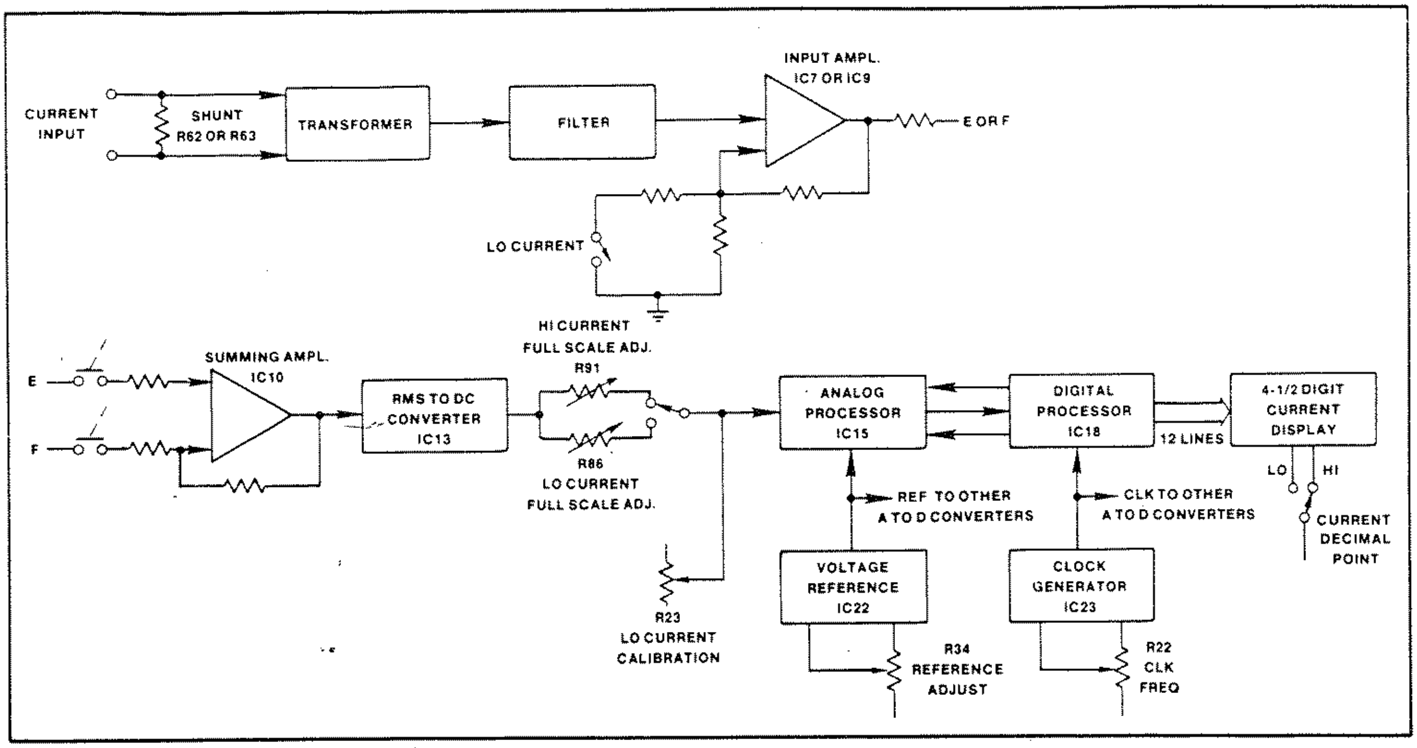


Figure 5-2. Current Section Adjustments.

5-15 Adjust R87 to produce a indication of 600.0 volts on the voltage display.

5-16 Reduce the input voltage to 30 volts AC RMS; adjust R24 for a indication of 30.0 volts.

5-17 Repeat steps 5-14 and 5-15 if necessary to obtain the required indication accuracy.

5-18 CURRENT SECTION CALIBRATION

5-19 A combination block and simplified schematic diagram of the current section, Figure 5-2, shows where the adjustments are located in the circuit.

5-20 The full scale currents of the five models of the 2013 Series Wattmeters are different. In the following steps, reference to full scale current is that listed for the model under test in the Specifications table in the front of this manual.

5-21 Select the instrument's high current range; apply the rated full scale current to the CHANNEL 1 and CHANNEL 2 current inputs, connected in series (terminals 3, 4 and 7, 8.)

5-22 Adjust R91 for a full scale current indication on the current display.

5-23 Reduce the current to 10% of full scale and adjust R23 to obtain an accurate indication.

5-24 Adjust the input current to the full scale value of the instrument's lower current range; select the lower current range using the front panel pushbutton.

5-25 Adjust R86 for an accurate full scale current indication.

5-26 Press the CHANNEL 1 selector button and observe the current indication; press the CHANNEL 2 selector button and compare the indication with that on Channel 1. Labled R35 on PCB

5-27 Adjust R84 and R85 to obtain identical indications on Channel 1 and Channel 2. These indications need not be accurate but they must be identical.

5-28 Repeat step 5-23.

5-29 POWER SECTION CALIBRATION

5-30 A combination block and simplified schematic diagram of the power section, Figure 5-3, shows where the adjustments are located in the circuit.

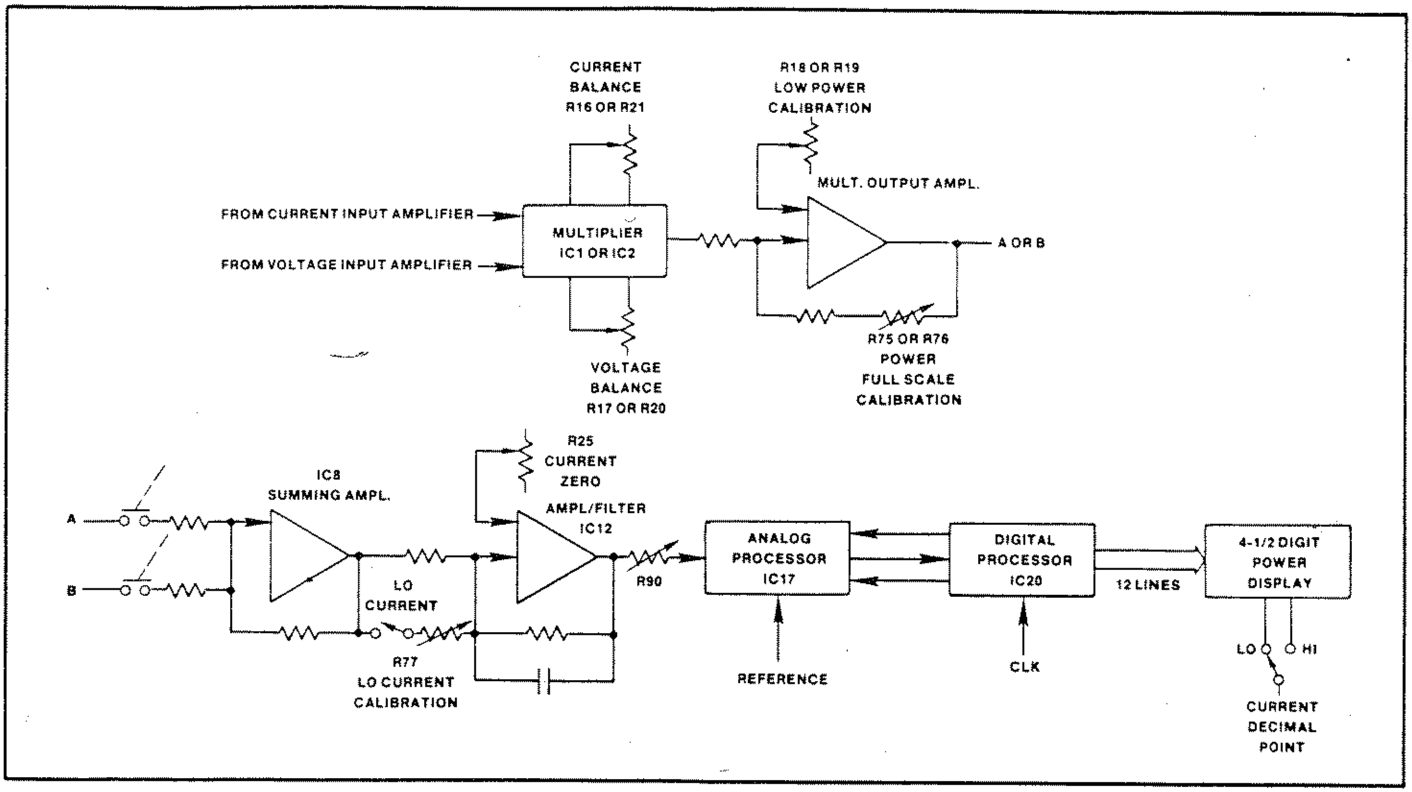


Figure 5-3. Power Section Adjustments.

5-31 The full scale power ranges of the five models of the 2013 Series Wattmeters are different. In the following steps, reference to full scale power is that listed for the model under test in the Specifications table in the front of this manual.

5-32 Connect a 600 volt AC RMS source to both CHANNEL 1 and CHANNEL 2 voltage inputs; apply a full scale current into a resistive load through the current terminals of CHANNEL 1 and CHANNEL 2. The voltage terminals may be connected in parallel, the current terminals in series. Separate supply sources may be used for voltage and current provided they are in phase.

5-33 Place the CHANNEL 1 voltage OPERATE-TEST switch in the TEST position. The switch is located on the PC board near the voltage input transformer.

5-34 Adjust R16 for minimum output at IC5-6, viewed on an oscilloscope.

5-35 Place the CHANNEL 1 voltage OPERATE-TEST switch in the OPERATE position. Place the CHANNEL 1 current OPERATE-TEST switch in the TEST position.

5-36 Adjust R17 for minimum output at IC5-6.

5-37 Place the CHANNEL 1 current OPERATE-TEST switch in the OPERATE position. Place the CHANNEL 2 voltage OPERATE-TEST switch in the TEST position.

5-38 Adjust R21 for minimum output at IC6-6.

5-39 Place the CHANNEL 2 voltage OPERATE-TEST switch in the OPERATE position. Place the CHANNEL 2 current OPERATE-TEST switch in the TEST position.

5-40 Adjust R20 for minimum output at IC6-6.

5-41 Place the CHANNEL 2 current OPERATE-TEST switch in the OPERATE position.

5-42 Press the CHANNEL 1 selector button on the front panel and observe the power indications. Press the CHANNEL 2 selector button and compare the indication with that on Channel 1.

5-43 Adjust R75 and R76 to produce identical indications on Channel 1 and Channel 2. These indications need not be accurate but they must be identical.

5-44 Adjust R80 to produce an accurate full scale reading on the power display.

5-45 Reduce the current to the full scale value of the instrument's low current range. Select the low current range using the front panel pushbutton.

5-46 Adjust R77 for an accurate power reading.

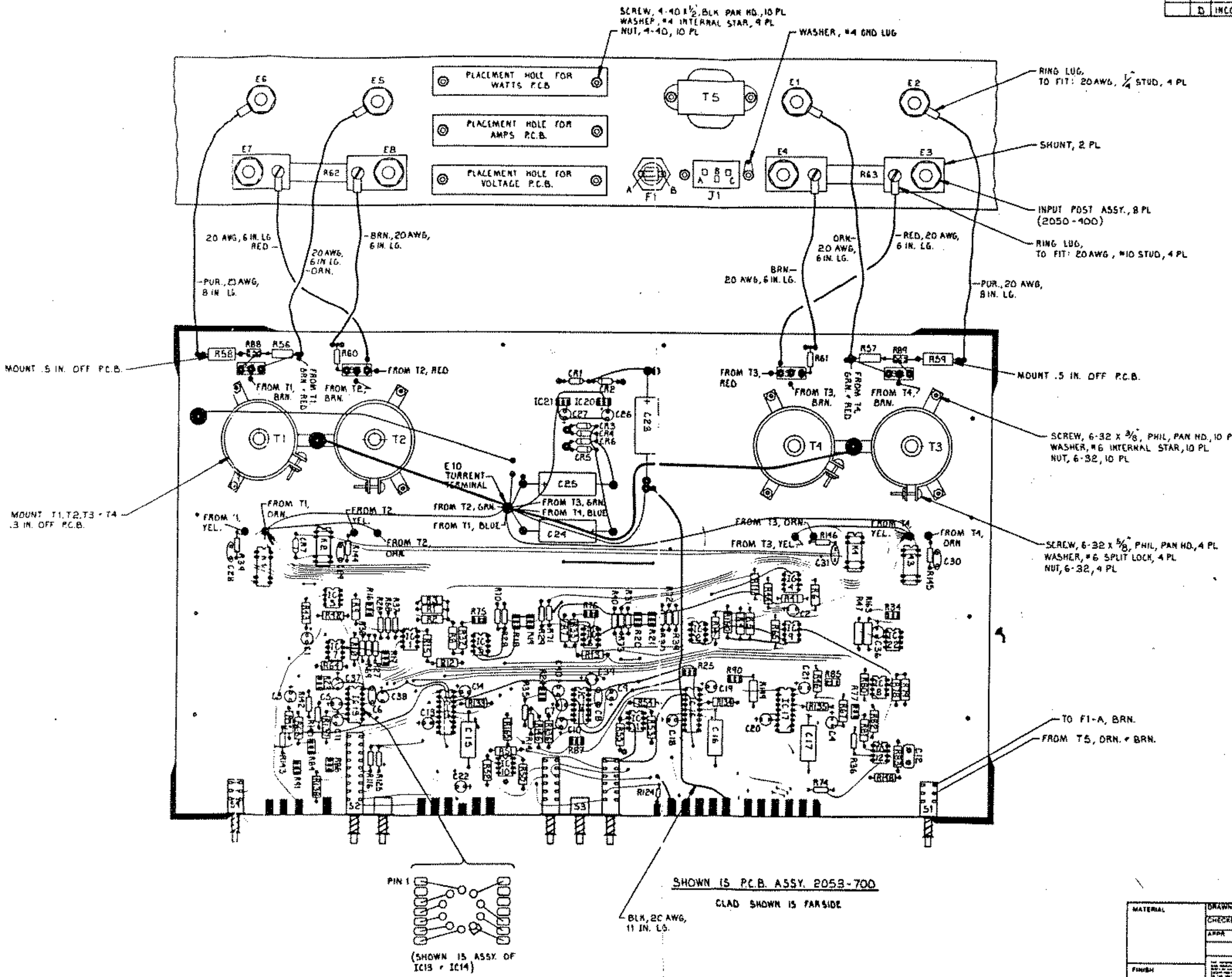
5-47 Reduce the voltage and current to zero on both Channel 1 and Channel 2.

5-48 Press the CHANNEL 1 selector button and observe the power reading. Press the CHANNEL 2 selector button and compare the power reading with that on Channel 1.

5-49 Adjust R18 and R19 to produce identical readings on Channel 1 and Channel 2. These readings need not be accurate but they must be identical.

5-50 Adjust R25 for a reading of zero on the power display.

REVISIONS				
ZONE	LTR	DESCRIPTION	DATE	APPROVED
	D	INCORP ECO C.R.E. 12-17-81		



MATERIAL	DRAWN C.R.E. 12/17	**Valhalla Scientific Inc.** SAN DIEGO, CALIFORNIA
FINISH	CHECKED R.M. 1/82	ASSY. P.C.B. 2053-600
	SCALE NONE	CODE IDENT NO. 83804 · SIZE D · DRAWING NO. 2053-600 · REV. D
	SHEET 1 OF 1	

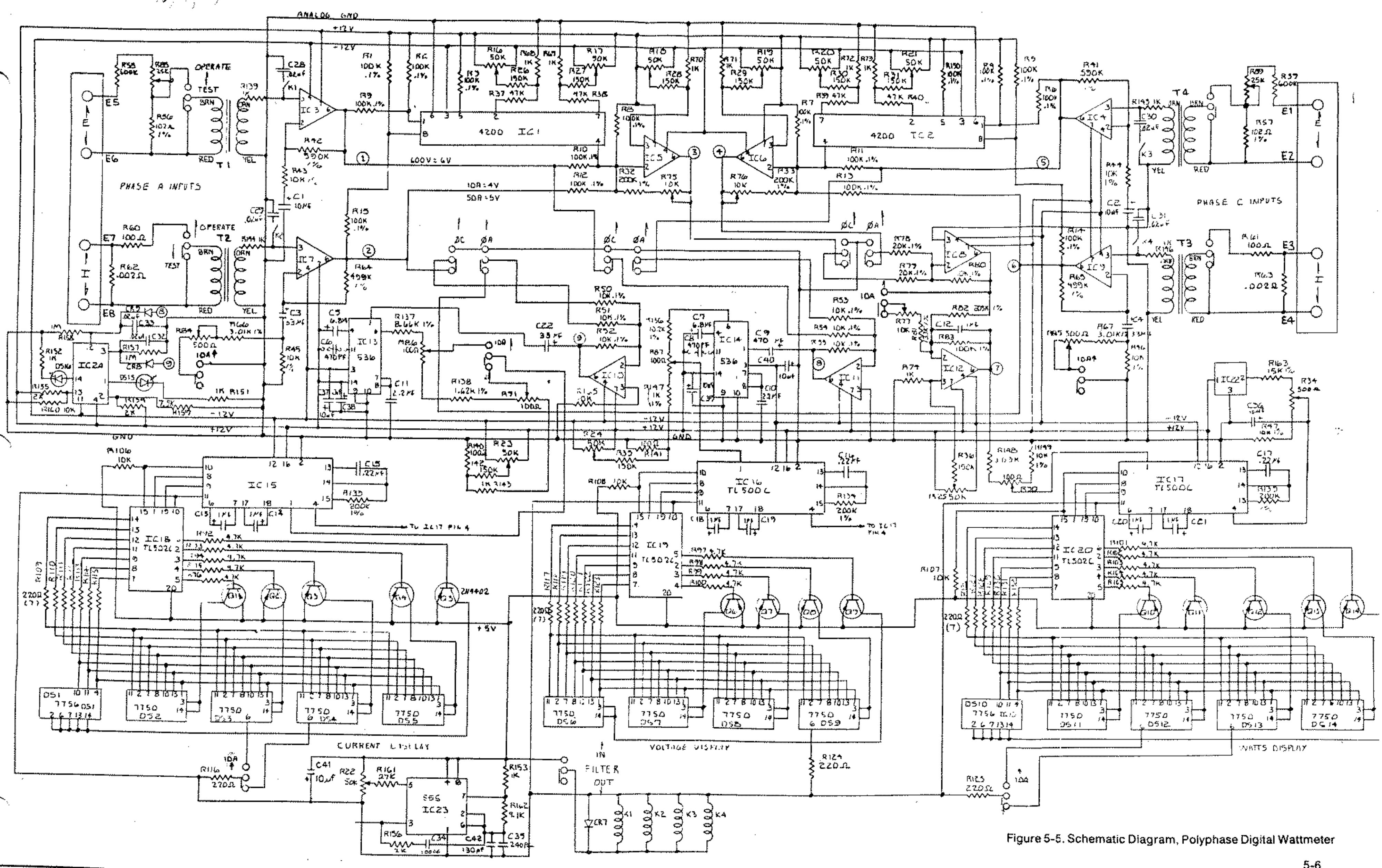


Figure 5-5. Schematic Diagram, Polyphase Digital Wattmeter

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PARTS LIST

3 PHASE WATTMETER

MODEL	DWG NO	REV
2053		A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
1	C 1,2,26,27,36, 37,38,39,40,41	2-30001	CAP TAN 10µf	05397	T360B106M025AS	10					
2	C 3,4,22	2-30002	CAP TAN 33µf	05397	T360B336M010AS	3					
3	C 5,7	2-30008	CAP TAN 6.8µf	05397	T360B685M010AS	2					
4	C 10,11	2-30007	CAP TAN 2.2µf	05397	T360B225M010AS	2					
5	C 12	2-80002	CAP MYLAR 1µf	81349	Z5A105	1					
6	C13,14,18,19,20,21	2-30004	CAP TAN 1µf	05397	T360B105M010AS	6					
7	C 15,16,17	2-50000	CAP POLY .22µf	27556	PA2A224	3					
8	C 23	2-40000	CAP ELECT 4000µf	56289	39D4086015JL4	1					
9	C 24,25	2-40004	CAP ELECT 2200µf	14655	16T2200	2					
10	C 32,33,28-31	2-10012	CAP CERAMIC .02µf	56289	5GAS20	6					
11	C 34	2-20013	CAP MICA 100pf	81349	CM05FD101J03	1					
12	C 35	2-20008	CAP MICA 240pf	81349	CM05FD241J03	1					
13	C 9	2-20009	CAP MICA 470pf	81349	CM05FD471J03	1					
14	C 42	2-20000	CAP MICA 130pf	81349	CM05FD131J03	1					
15											
16	CR 1-6	3-20002	DIODE RECT	07263	IN4001	6					
17	CR 7,8,9	3-20000	DIODE	07263	IN4148	3					
18											
19	DS 1,10	5-01018	LED±DISPLAY	28480	5082-7756	2					
20	DS 2-9,11-14	5-01007	LED 0-9 DISPLAY	28480	5082-7750	12					
21	DS 15,16	5-01005	LED, RED	28480	MV5074	2					

NOTES:

Valhalla Scientific Inc.

PARTS LIST

3 PHASE WATTMETER | MODEL 2053 | DWG NO | REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
22	IC 1,2	3-30091	IC MULTIPLIER	49956	RC4200ANB	2					
23	IC 3-12	3-30090	IC OP-AMP	27014	LF356N	9					
24	IC 13,14	3-30045	IC RMS TO DC CONV	A.D.	AD536JD	2					
25	IC 15-17	3-30087	IC ANALOG CHIP	01295	TL500C	3					
26	IC 18-20	3-30088	IC DIGITAL CHIP	01295	TL502C	3					
27	IC 25	3-30015	IC REG POS	27014	LM340T-12	1					
28	IC 21	3-30092	IC REG NEG	27014	LM320T-12	1					
29	IC 22	3-30064	IC REFERENCE	04713	MC1403	1					
30	IC 23	3-30009	IC TIMER		NE555V	1					
31	IC 24	3-30070	IC QUAD FET OP-AMP	01295	TL084/CN	1					
32											
33	K 1-4	5-03012	RELAY	CLAIR	PRME1A005	4					
34											
35	Q 1-14	3-10010	TRANSISTOR PNP	04713	2N4402	14					
36											
37	R 1-15,150	1-10049	RES FXD 100K .1%	81349	RN60C1003B	16					
38	R 16-25	1-50028	RES VAR 50K	73138	68WR-50K	10					
39	R26-31,35,36,142	1-01083	RES FXD 150K 1/4W 5%	81349	RC07GF154J	8					
40	R 37-40	1-01073	RES FXD 47K 1/4W 5%	81349	RC07GF473J	4					
41	R 41,42	1-10095	RES FXD 590K 1%	81349	RN60C5903F	2					
42	R43,44,45,46, 47,165	1-10008	RES FXD 10K 1%	81349	RN60C1002F	6					
43	R 50-55,80	1-10037	RES FXD 10K .1%	81349	RN60C1002B	7					

NOTES:

Valhalla Scientific Inc.

PARTS LIST

3 PHASE WATTMETER | MODEL 2053 | DWG NO | REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
44	R 56,57	1-10094	RES FXD 100Ω 1%	81349	RN60C1000F	2					
45	R 58,59	1-10089	RES FXD 600K	CADDOCK	MG714-600K .1%	2					
46	R 60,61	1-01021	RES FXD 100Ω 1/4W 5%	81349	RC07GF101J	2					
47	R 62,63	1-20055	RES FXD .002Ω	EMPRO	HA-50-100	2					
48	R 64,65	1-10020	RES FXD 499K 1%	81349	RN60C4993F	2					
49	R 66,67	1-10067	RES FXD 3.01K 1%	81349	RN60C3011F	2					
50	R 68-74,139,143 144,145,146,151-153	1-01041	RES FXD 1K 1/4W 5%	81349	RC07GF102J	14					
51	R 75-77	1-50012	RES VAR 10K	73138	68WR-10K	3					
52	R 78,79	1-10096	RES FXD 20K .1%	81349	RN60C2002B	2					
53	R 81	1-10097	RES FXD 133K 1%	81349	RN60C1333F	1					
54	R 82	1-10098	RES FXD 205K 1%	81349	RN60C2053F	1					
55	R 83	1-10006	RES FXD 100K 1%	81349	RN60C1003F	1					
56	R 84,85,34	1-50029	RES VAR 500Ω	73138	68WR-500Ω	3					
57	R 86,87,90,91	1-50014	RES VAR 100Ω	73138	68WR-100Ω	4					
58	R 92-105	1-01053	RES FXD 4.7K 1/4W 5%	81349	RC07GF472J	14					
59	R 106-108,160,149	1-01061	RES FXD 10K 1/4W 5%	81349	RC07GF103J	5					
60	R 159	1-01058	RES FXD 7.5K 1/4W 5%	81349	RC07GF752J	1					
61	R 133-135,32,33	1-10087	RES FXD 200K 1%	81349	RN60C2003F	5					
62	R 136	1-10099	RES FXD 10.2K 1%	81349	RN60C1022F	1					
63	R 138	1-10029	RES FXD 1.62K 1%	81349	RN60C1621F	1					
64	R140,141,109-132	1-01021	RES FXD 100Ω 1/4W 5%	81349	RC07GF101J	26					
65	R 147	1-10001	RES FXD 1K 1%	81349	RN60C1001F	1					

NOTES:

Valhalla Scientific Inc. | **PARTS LIST** | 3 PHASE WATTMETER | MODEL 2053 | DWG NO | REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
66	R 88,89	1-50030	RES VAR 25K	73138	68WR-25K	2					
67	R 154-156	1-01045	RES FXD 2K 1/4W 5%	81349	RC07GF202J	3					
68	R 157,158	1-01100	RES FXD 1M 1/4W 5%	81349	RC07GF105J	2					
69	R 161	1-01068	RES FXD 27K 1/4W 5%	81349	RC07GF273J	1					
70	R 162	1-01060	RES FXD 9.1K 1.4W 5%	81349	RC07GF912J	1					
71	R 163	1-10004	RES FXD 15K 1%	81349	RC07GF1502F	1					
72	R 137,148		FACTORY SELECT								
73											
74	S 1,9	5-03003	POWER SWITCH	71590	5-03003	2					
75	S 2	5-03027	10A/50A RANGE SWITCH	71590	5-03027	1					
76	S 3	5-03028	PHASE SELECTOR SWITCH	71590	5-03028	1					
77	S 5-8	5-03021	SLIDE SWITCH	09353	1101M1	4					
78											
79	T 1-4	4-20023	WIDEBAND SIGNAL XFMR	53504	2050-010A	4					
80	T 5	4-20024	POWER XFMR	53504	2053-010	1					
81											
82		4-30048	P.C.B. MAIN	53504	2053-700	1					
83		4-30049	P.C.B. DISPLAY	53504	2053-701	1					
84											
85		4-10173	CHASSIS	53504	2053-200	1					
86		4-10181	FRONT PANEL	53504	2053-206	1					
87		4-10182	REAR OVERLAY	53504	2053-207	1					
88		4-10180	COVERS TOP/BOTTOM	53504	2053-205	2					

NOTES:

Valhalla Scientific Inc.

PARTS LIST

3 PHASE WATTMETER | MODEL 2053 | DWG NO | REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
89		4-10178	P.C. SUPPORT BRACKET	53504	2053-203	8					
90		4-10170	BEZEL	53504	2701-200	2					
91		4-10171	RACK BRACKET	53504	2701-201	2					
92		4-10063	BCD COVER PLATE	53504	4250-207	3					
93		5-10194	XFMR MTG BKT	76055	VR-6	4					
94											
95											
96		5-10018	FUSE HOLDER	75915	342004-A	1					
97		5-04010	FUSE 1/4A	75915	.25A SLO BLO	1					115V ONLY
98	J1	5-10063	POWER CONN	70903	17252	1					
99		5-10067	POWER CORD	70903	17250	1					
100											
			HARDWARE:								
101		5-10237	INPUT POST ASSEMBLY	53504	2050-402	4					
102			BOLT, BRASS 3/8 HEX HD		1/4-20x1"	4					
103			SCREW, PHIL PAN BLK		6-32x3/8	10					
104			SCREW, PHIL PAN CAD		6-32x1/2	4					
105			SCREW, PHIL PAN BLK		6-32x1/4	22					
106			SCREW, PHIL FLAT BLK		6-32x3/8	10					
107			SCREW, PHIL PAN BLK		4-40x1/2	6					
108											

NOTES:

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PARTS LIST

3 PHASE WATTMETER

MODEL 2053

DWG NO

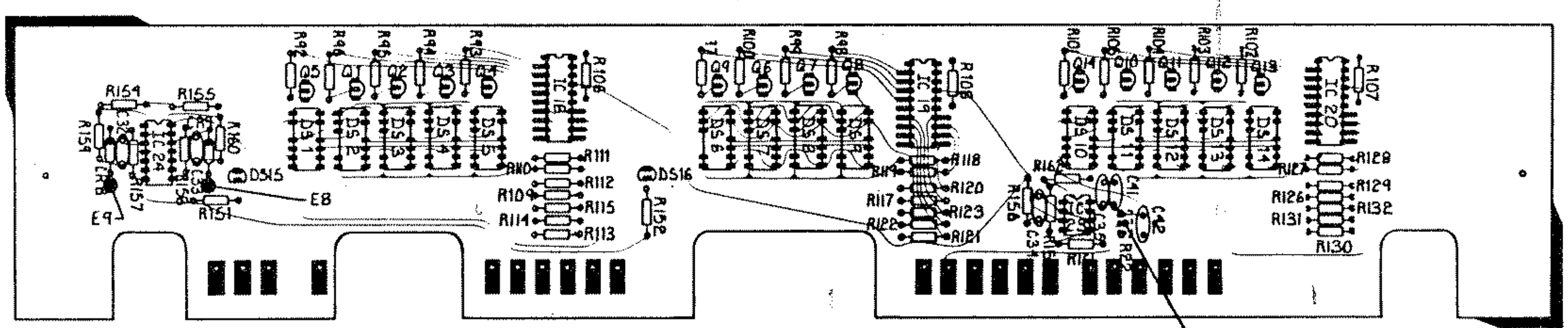
REV A

#	REF DES	VALHALLA PART NO	DESCRIPTION	CODE IDENT	MFG PART NO	QTY I	QTY N	I	N		REMARKS
109		5-10155	WASHER, FIBER	83330	2166	8					
110		5-10154	WASHER,NYLON SHOULDER	83330	2685	8					
111			WASHER, INT. STAR		6-32	22					
112		5-10086	WASHER, GND LUG	83330	1412-6	2					
113			WASHER, SPLIT LOCK		4-40	6					
114											
115		5-10156	NUT, TINNERMAN	78553	C8094-632-24 BLK	16					
116			NUT, HEX BRASS		1/4-20	4					
117			NUT, STD HEX		6-32	16					
118			NUT, RADIO HEX		4-40	6					
119		5-10174	NUT, PEM FASTENERS	46384	S-632-2	4					
120											
121		5-10214	RING LUGS, RED	83330	4876	8					
122		5-10007	TERMINAL, TURRET	00002	1300B	1					
123			TUBING, HEAT SHRINK		1/8"	AR					
124											
			WIRE:								
			PURPLE, 12"		20 AWG	1					
			ORANGE, 24"		20 AWG	1					
			BROWN, 24"		20 AWG	1					
			RED, 12"		20 AWG	1					
			BLUE, 8"		20 AWG	1					

NOTES:

NOTES:
1. FOR PARTS LIST SEE 2053-700.
2. FOR SCHEMATIC SEE 2053-070.

REVISIONS			
ZONE	LTR	DESCRIPTION	APPROVED
	C	INCORP ECO 12	



SHOWN IS P.C.B. ASSY. 2053-701
CLAD SHOWN IS FARSIDE

MATERIAL	DRAWN C.R.E.	12-14	Valhalla Scientific Inc. SAN DIEGO, CALIFORNIA			
	CHECKED Rm	1/81				
	APPR.					
FINISH			ASSEMBLY, P.C.B. 2053-701			
	SCALE NONE		CODE IDENT NO 53504	SIZE C	DRAWING NO 2053-601	REV C
	SHEET 1 OF 1					

2053-601 C

FEDERAL SUPPLY CODE
for
MANUFACTURERS CATALOGING HANDBOOK H4-1

00001	Monsanto, Electronic Special Products, Cupertino, Calif.
00656	Aerovox Corporation, New Bedford, Mass
00853	Sangamo Electric Company, Pickens, S.C.
01121	Allen-Bradley Company, Milwaukee, Wisc.
01255	Litton Industries, Inc., Beverly Hills, Calif.
01281	T R W Semiconductors, Inc., Lawndale, Calif.
01295	Texas Instruments, Inc., Dallas, Texas
02335	Fairchild Controls Corp., Hicksville, LI, N.Y.
02660	Amphenol Corporation, Broadview, N.Y.
03507	General Electric Company, Syracuse, N.Y.
04713	Motorola Semiconductor Prod., Inc., Phoenix, Ariz.
04963	3-M, St. Paul, Minn.
05276	Pomona Electronics Co., Inc., Pomona, Calif.
05397	Kemet, Union Carbide Corp., Cleveland, Ohio
05820	Wakefield Engineering, Inc., Wakefield, Mass.
07088	Kelvin Electric Company, Van Nuys, Calif.
07256	Silicon Transistor Corp., Garden City, N.Y.
07263	Fairchild Camera and Instr. Corp., Mt. View, Calif.
07716	I R C, Incorporated, Burlington, Iowa
07910	Continental Devices, Hawthorne, Calif.
08065	Accurate Rubber and Plastics Co., San Diego, Calif.
09026	Babcock Electronics Corp., Costa Mesa, Calif.
12405	Hysol Corporation, El Monte, Calif.
12406	Elpac, Incorporated, Fullerton, Calif.
12697	Clarostat Mfg. Co., Incorporated, Dover, N.H.
13454	Texas Crystals, River Grove, Ill.
14655	Cornell-Dubilier Elect. Corp., Newark, N.J.
14752	Electro Cube, Incorporated, San Gabriel, Calif.
16758	Delco Radio Div., General Motors, Kokomo, Ind.
17838	Mektron, California General, Inc., Chula Vista, Calif.
18324	Signetics, Sunnyvale, Calif.
18722	R C A, Mountaintop, Pa.
21604	Buckeye Stamping Company, Columbus, Ohio
25684	Victoreen Instrument Co., Inc., Oak Lawn, Ill.
27014	National Semi-Conductor Corp., Santa Clara, Calif.
27556	IMB Electronic Products, Santa Fe Springs, Calif.
28480	Hewlett-Packard Co., Palo Alto, Calif.
30983	Electra/Midland, San Diego, Calif.
44655	Ohmite Manufacturing Company, Skokie, Ill.
71279	Cambridge Thermionic Corp., Cambridge, Mass.
71400	Bussmann Mfg. Div., McGraw-Edison Co., St. Louis, Mo.
71450	CTS Corporation, Elkhart, Ind.
71468	ITT Cannon Electric, Inc., Los Angeles, Calif.
71590	Centralab Div., Globe-Union, Inc., Milwaukee, Wisc.
71785	Cinch Manufacturing Company, Chicago, Ill.
73899	J F D Electronics Company, Brooklyn, N.Y.
75915	Littlefuse, Incorporated, Des Plaines, Ill.
76055	Mallory Controls, Frankfort, Ind.
76493	J. W. Miller Company, Los Angeles, Calif.
78488	Stackpole Carbon Company, St. Marys, Pa.
80294	Bourns, Incorporated, Riverside, Calif.
81095	Triad Transformer Corp., Venice, Calif.
81312	Winchester Electronics, Oakville, Ct.
81349	Military Spec., Standardization Division, Chicago, Ill.
82389	Switchcraft, Incorporated, Chicago, Ill.
83330	Herman H. Smith, Inc., Brooklyn, N.Y.
84171	Arco Electronics, Inc., Great Neck, N.Y.
86684	R C A, Harrison, N.J.
88245	Useco Div., Litton Industries, Van Nuys, Calif.
90201	Mallory Capacitor Company, Indianapolis, Ind.
91637	Dale Electronics, Inc., Columbus, Neb.
91929	Micro Switch Div., Honeywell, Inc., Freeport, Ill.
92194	Alpha Wire Corporation, Elizabeth, N.J.
93332	Sylvania Electric Products, Inc., Woburn, Mass
98978	IERC, Burbank, Calif.
00002	Jordan Electronics, Van Nuys, Calif.
53504	Valhalla Scientific, San Diego, Calif.

MODELS 2013, 2023, 2033, 2053 AND 2093
DUAL CHANNEL POLYPHASE DIGITAL WATTMETERS

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MODEL 2013	12 KW DUAL CHANNEL POLYPHASE WATTMETER
MODEL 2053	60 KW DUAL CHANNEL POLYPHASE WATTMETER
MODEL 2093	120 KW DUAL CHANNEL POLYPHASE WATTMETER
OPTION RX3	RACK MOUNTING KIT
OPTION IDO	ANALOG AND DIGITAL OUTPUT MODULE

FOB:San Diego, California   Terms: Net 30 Days   DELIVERY
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(714) 578-8280