Operator's Manual

ZM-100 Mains Impedance Meter

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Operators Manual
ZM-100 Mains Impedance Meter

SECTION 1 - ZM-100 OVERVIEW AND THEORY OF OPERATION

The **ZM-100 Mains Impedance Meter** is an innovative piece of test equipment designed to measure the capacity and the condition of AC electrical supplies. It can be used to determine the effective capacity and voltage drop of an unknown electrical system. Periodic use of the ZM-100 can provide a data set that can identify loose or corroded connections, and help diagnose system degradation that can lead to damaging electrical failures.

The **ZM-100 Mains Impedance Meter** is designed and constructed to withstand a wide range of voltages and operating conditions. All components are selected for safety, long life, and ease of use.

1.1 Meter Description

The **ZM-100 Mains Impedance Meter** has the following features:

- Powered from 120/240 VAC, 50/60 Hz via a standard IEC-320 receptacle. The ZM-100 is supplied with a standard NEMA 5-15 Cordset. International Cordsets are available optionally.
- Kelvin-style connections, designed for rapid connection of the meter to the mains supply, and minimal impact of lead length on the measurement.
- A rugged flight case suitable for air shipment.
- Storage space is provided for cables, manual, and optional components.
- The **ZM-100 Mains Impedance Meter** is designed to comply with UL-3111-1.

1.2 ZM-100 Functional Diagram

The **ZM-100 Mains Impedance Meter** consists of the following components:

- ZM-100 meter
- NEMA 5-15 Power Cord (2 meter)
- Test Lead (Red - 2 meter - 2 conductor)
- Test Lead (Black - 2 meter - 2 conductor)
- Safety Lead (Green - 2 meter - 1 conductor)
- Safety Test Lead Clips (Qty 3 - Black, Red, Green)
- ZM-100 Operators Manual
- Rugged Flight Case

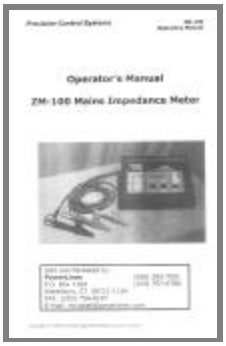
Options

- Spade Lug Terminations
- Extender Probe Clips

ZM-100 Meter
And
Cable Set

Shipping
Case

Operators
Manual



Application
Software

ZM-100 Service Kit

1.3 Theory of Operation

Mains Impedance is a measure of the total resistance to current flow in an electrical system. In practice, impedance consists of resistive and inductive elements.

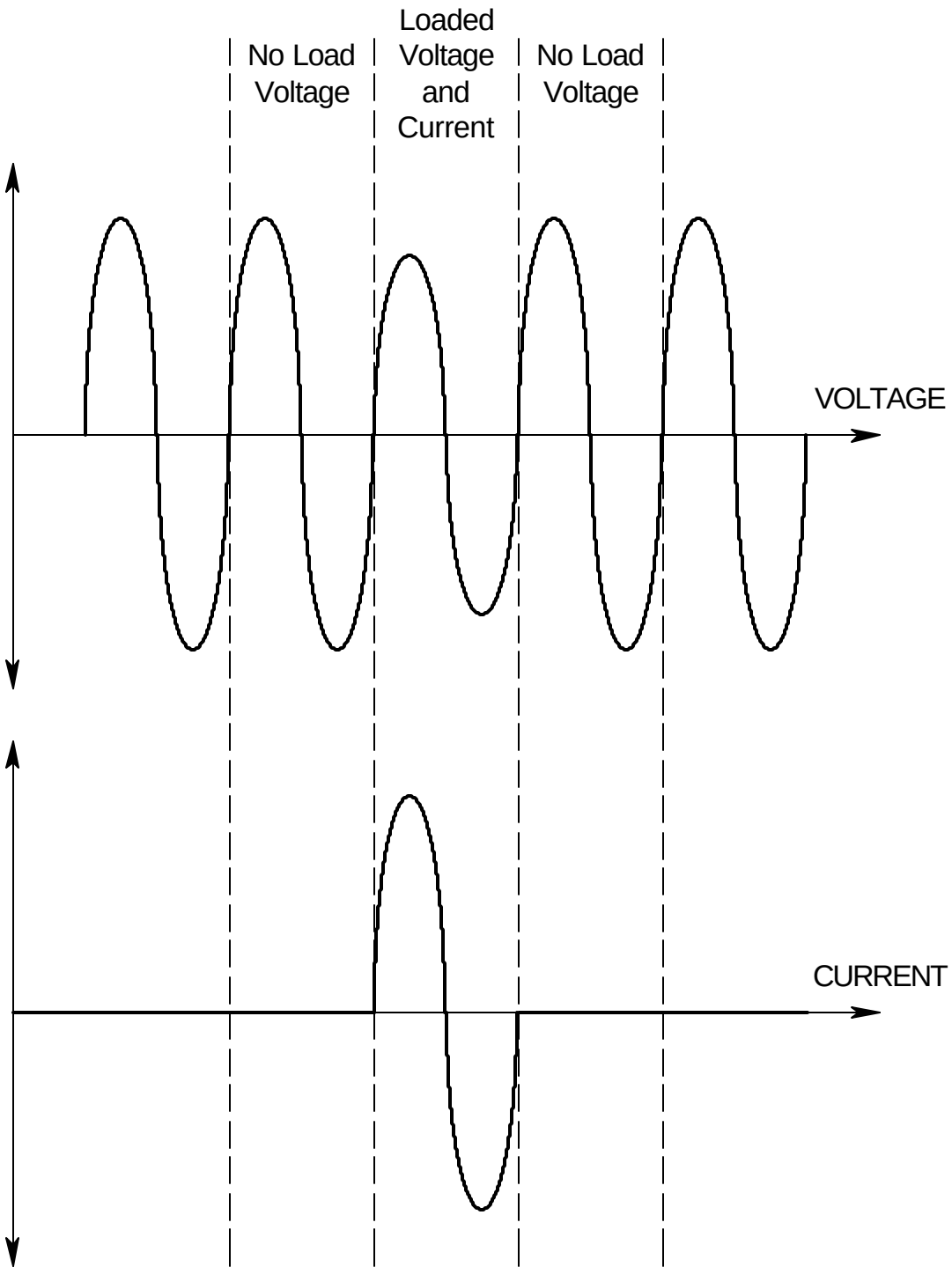
Mains impedance measurements are made by measuring the normal voltage (no load), then applying a fairly substantial load current. Impedance can be calculated as follows:

$$\text{Impedance} = \frac{\text{No Load Voltage - Load Voltage}}{\text{Load Current}}$$

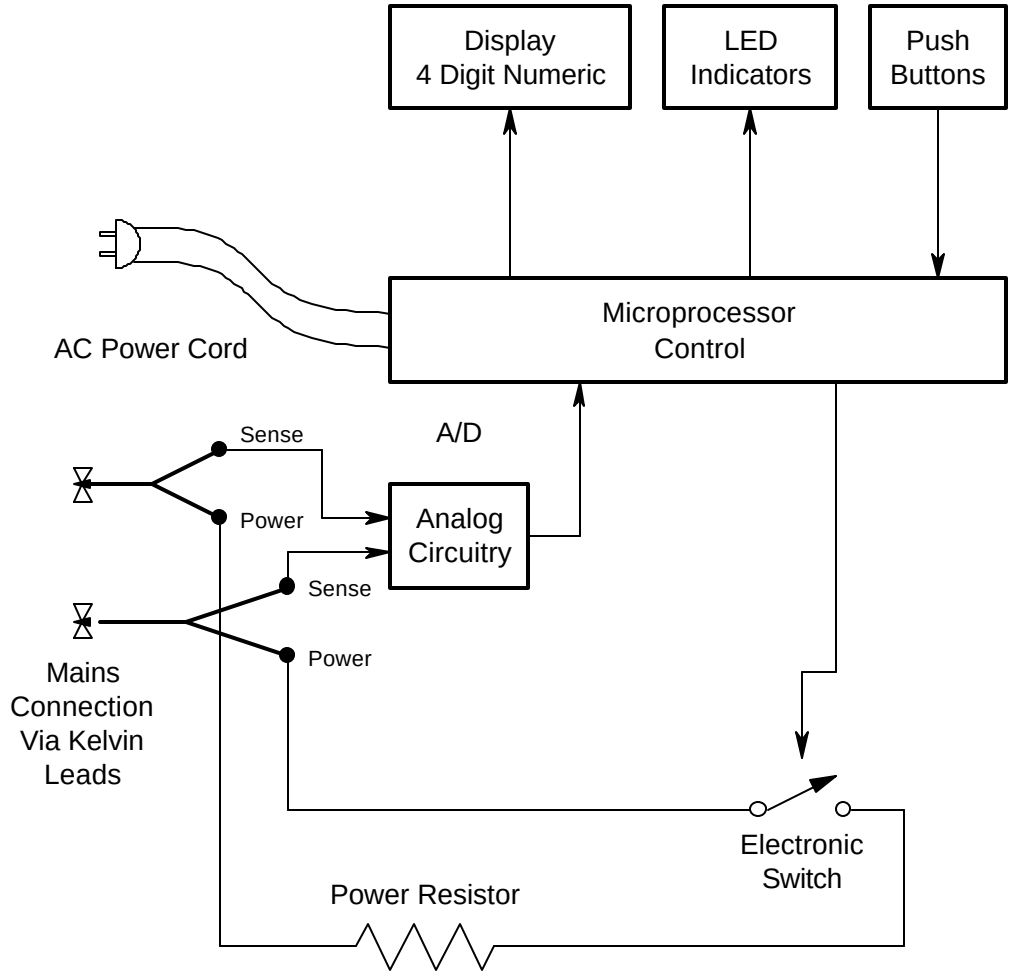
Since the impedance depends upon the ΔVoltage from no load to full load, it is important to use as large a load current as is practical for making impedance measurements. The ZM-100 uses a 10 ohm mains resistor.

Short circuit current is calculated from the measured mains impedance and the measured voltage:

$$\text{Short Circuit Current} = \frac{\text{No Load Voltage}}{\text{Mains Impedance}}$$



ZM-100 Current Draw



ZM-100 Functional Diagram

1.3.1 Voltage Flicker

Since the mains impedance calculation is heavily dependent upon a relatively small ΔVoltage, rapid changes in voltage (voltage flicker) will cause measurement errors. The ZM-100 employs a thorough check of mains voltage for stability before making a measurement. Then the meter measures the no load voltage two times, before and after the load voltage is measured. If the no load voltage has fluctuated, the meter reports a voltage flicker error.

Voltage flicker limits are specified in Section 2.4.

1.3.2 Non-linear Impedance

Normally, voltage under load is less than the no load voltage, and impedance can be calculated. Some types of loads with active voltage regulation may actually correct voltage while the ZM-100 is making a reading. These devices have a *non-linear impedance*.

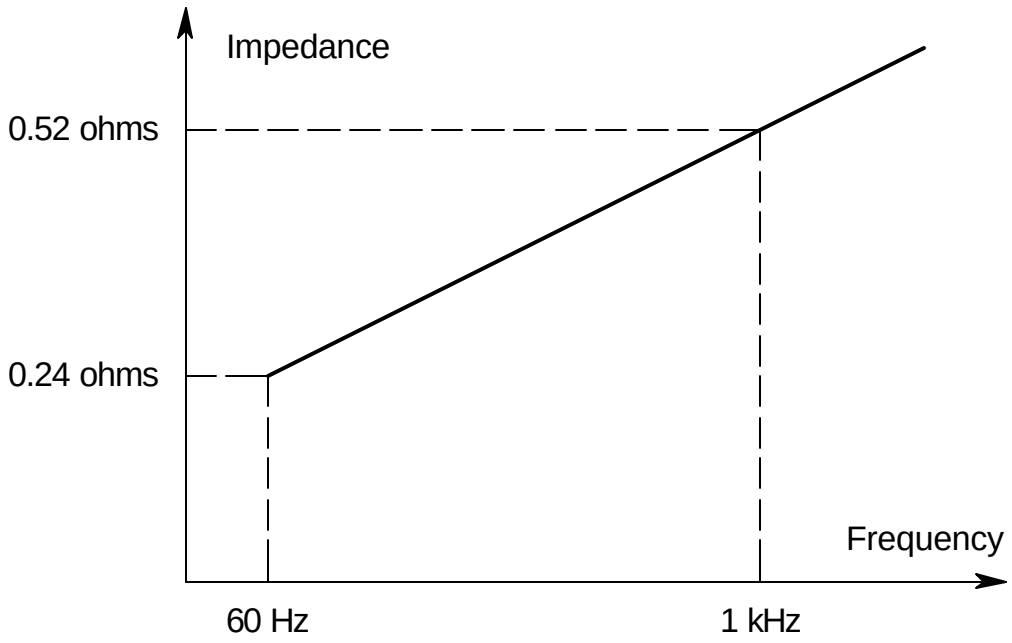
If the load voltage equals or exceeds the no load voltage, a non-linear impedance is suspected. The ZM-100 reports this as an error. It is not possible to make accurate or representative impedance measurements on this type of electrical source.

Non-linear impedance sources may include:

- Uninterruptible Power Supplies (UPS)
- Magnetic Synthesizers
- Fast responding (sub-cycle) Power Conditioners
- Fast responding (sub-cycle) Voltage Regulators

1.3.3 Complex Impedance

Impedance consists of both resistive and inductive elements. As such, impedance is often much higher at frequencies other than the fundamental power frequency (50 or 60 Hz)



The ZM-100 measures the vector amplitude of the impedance at the primary frequency only (50 / 60 Hz)

SECTION 2 - SPECIFICATIONS

2.1 Voltage Ratings

2.1.1 Power and Sense Inputs

Minimum Nominal Voltage:	120 VAC
Minimum Measurement Voltage:	80 VAC
Maximum Nominal Voltage:	480 VAC
Maximum Measurement Voltage:	520 VAC
Absolute Maximum Voltage:	580 VAC

2.1.2 Meter Power

Minimum Voltage:	80 VAC
Maximum Voltage:	260 VAC
Operating Frequency:	47 - 63 Hz
Mains Connector:	IEC-320

2.2 Current Requirements

2.2.1 Power and Sense Inputs

Current is drawn for one cycle per measurement for single measurements, and up to eight cycles within 5 seconds for multiple measurements.

Test Current (120 VAC):	12 Amps
Test Current (240 VAC):	24 Amps
Test Current (400 VAC):	40 Amps
Test Current (480 VAC):	48 Amps

2.2.2 Meter Power

Meter Current (120 VAC):	0.25 Amps
Meter Current (240 VAC):	0.13 Amps

2.3 Voltmeter Accuracy

Voltmeter uses a sampled, average voltage algorithm that is scaled for RMS voltage. Meter accuracy is based on a sine-wave voltage with less than 1% Total Harmonic Distortion.

Voltmeter Accuracy (120 VAC):	0.5%
Voltmeter Accuracy (240 VAC):	0.5%
Voltmeter Accuracy (400 VAC):	0.25%
Voltmeter Accuracy (480 VAC):	0.25%

2.3 Impedance Accuracy

Impedance is calculated using sampled, average voltage readings. Impedance readings may be affected by voltage flicker or high frequency noise.

Impedance Accuracy (120 VAC):	± 0.010 ohms
Impedance Accuracy (240 VAC):	± 0.007 ohms
Impedance Accuracy (400 VAC):	± 0.005 ohms
Impedance Accuracy (480 VAC):	± 0.005 ohms

2.4 Measurement Parameters

2.4.1 Measurement Duration

Single measurements are obtained as follows:

120 VAC range:	1 Cycle(s)
240 VAC range:	1 Cycle(s)
400 VAC range:	1 Cycle(s)
480 VAC range:	1 Cycle(s)

Multiple measurements are obtained as follows:

120 VAC range:	8 Cycle(s)
240 VAC range:	5 Cycle(s)
400 VAC range:	3 Cycle(s)
480 VAC range:	3 Cycle(s)

2.4.2 Time Delays

Fixed time delays between measurements are programmed into the ZM-100 in order to maintain internal temperatures:

120 VAC range:	1 Second
240 VAC range:	4 Seconds
400 VAC range:	10 Seconds
480 VAC range:	10 Seconds

Multiple mode time delays are as follows:

120 VAC range:	2 Seconds
240 VAC range:	8 Seconds
400 VAC range:	20 Seconds
480 VAC range:	20 Seconds

2.4.3 Voltage Flicker Limits

Voltage flicker can cause measurement errors and inaccuracy. The ZM-100 measures no load mains voltage twice - once before and once after drawing load current. Excessive change in no load voltage results in a voltage flicker error:

120 VAC range:	0.2 VAC
240 VAC range:	0.4 VAC
400 VAC range:	0.5 VAC
480 VAC range:	0.5 VAC

2.5 Environmental Specifications

Temperature (operating): 10º C - 40º C

Temperature (storage): 0º C - 50º C

Humidity (operating): 10% - 80% non-condensing

2.6 Physical Dimensions

2.6.1 ZM-100 Meter

Height: 4" (10.2 cm)

Width: 10" (25.4 cm)

Depth: 8" (20.3 cm)

Weight: 4 lbs. (1.81 kg)

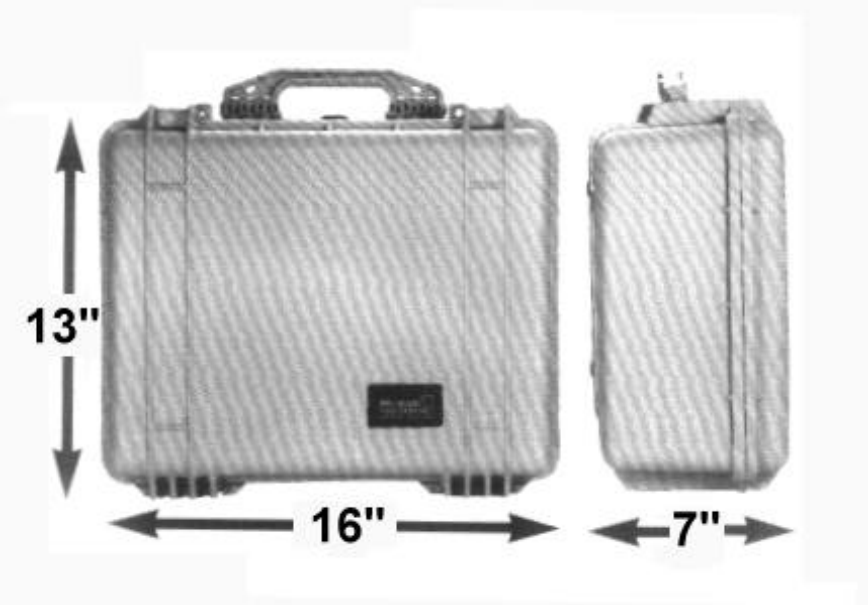
2.6.2 Shipping Case

Height: 7" (17.8 cm)

Width: 16" (40.6 cm)

Depth: 13" (33.0 cm)

Weight: 12 lbs. (5.44 kg)
Case, meter, and accessories



2.6.3 Test Leads and Cables

Power Cord: 6.5' (2.0 m)
IEC-320 plug to NEMA 5-15P

Test Leads: 6.5' (2.0 m)
Kelvin Connected, two conductor, 13 mm²
(Red and black measurement conductors)
Single conductor, 13 mm²
(Green ground conductor)
All cables rated for 1000 VAC

ZM-100 Test Leads

SECTION 3 - CONTROLS AND CONNECTIONS

3.1 Power On/Off and Power Cord

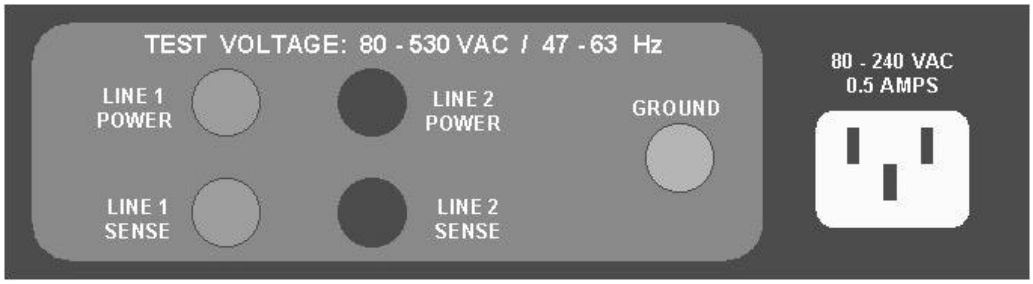
The ZM-100 does not have an On / OFF switch. When power is applied to the line cord, the meter is functioning and is ready to make measurements.

The Power interface consists of the following:

- IEC-320 standard connector. A 6' (1M) power cord with a NEMA 5-15 Plug is supplied with the ZM-100.
- An internal fuse (F5) rated for 0.25 Amps is mounted on the internal printed circuit board.

The ZM-100 accepts line voltages from 80 - 240 VAC, 50 or 60 Hz

In the event that the ZM-100 needs to be serviced, power should be removed by disconnecting the IEC-320 cable.



3.2 Test Connections

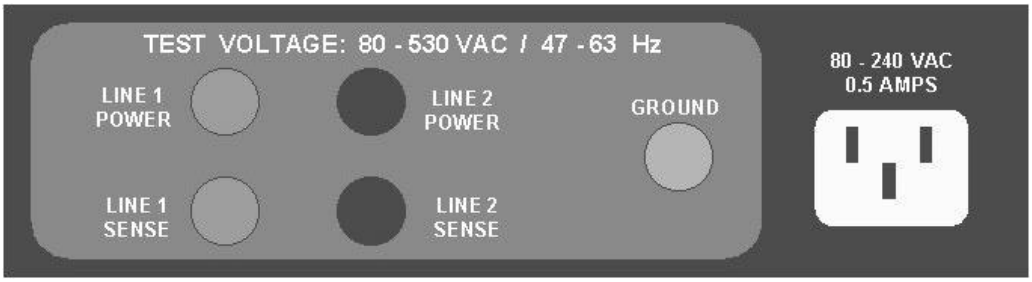
3.2.1 Voltage Ratings

The ZM-100 is designed to measure mains impedance on circuits from 120 VAC to 480 VAC. The measurement inputs can withstand voltages up to 580 VAC.

3.2.2 Kelvin Connection

The ZM-100 utilizes Kelvin connections. This type of connection is used to reduce the effect of lead resistance on measurement accuracy. Each test probe has two conductors attached. One of these is connected to the SENSE input and one to the power INPUT.

The test leads and inputs are color coded for simple connection.



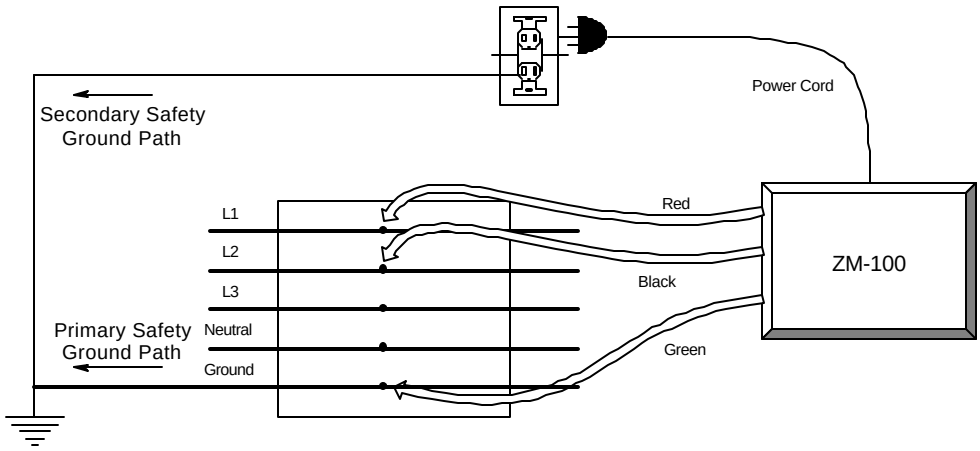
Red	Black	Green	IEC-320
Measurement Inputs		Safety Ground	Power

3.2.3 Electrical Safety

The ZM-100 is grounded via the IEC-320 cord and plugset. In addition, provision is made to connect the ZM-100 to a local ground, at the point of measurement. This redundant ground is colored GREEN for easy identification.

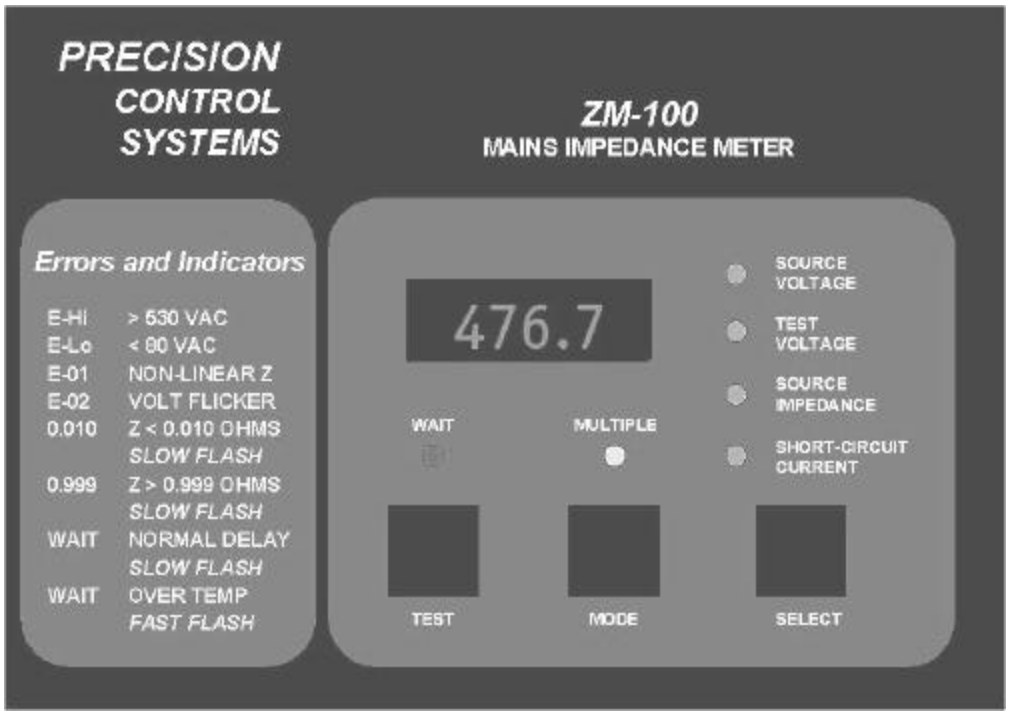
Both ground conductors must be connected to ensure operator safety and fault clearance in the event of an electrical fault.

When measuring impedance on 240-480 VAC, high current sources, the testing ground is the primary grounding path.



3.3 Front Panel Controls

The front panel controls of the ZM-100 consist of a four-segment LED display, (3) Pushbuttons, and (6) Indication Lamps.



3.3.1 LED Display

The four-segment display indicates the meter readings, as well as error and faults. The display value is indicated by the lighted Mode Select lamp.

Mode	Display	Format	Maximum	Units
Source Voltage	Voltage	000.0	600.0	VAC
Test Voltage	Voltage	000.0	600.0	VAC
Source Impedance	Ohms	0.000	1.000	Ohms
Short Circuit Current	Kilo-Amps	00.00	99.00	kAmps

After a measurement, the Test Voltage, Source Impedance, and Short Circuit Current readings are recorded. The Source Voltage continues to read actual line voltage.

The four segment display is also used to indicate Errors and Fault Codes.

Display	Condition	Additional Information
- - - -	Null Reading	No measurement made
E - H I	Voltage > 530 VAC	Measurement disabled
E - L O	Voltage < 80 VAC	Measurement disabled
E - 0 1	Non-linear Impedance	Measurement discarded
E - 0 2	Voltage Flicker	Measurement discarded
0.9 9 9	Impedance > 0.999 Ω	Slow flashing
0.0 1 0	Impedance > 0.010 Ω	Slow flashing

3.3.2 TEST Pushbutton

Press the TEST Pushbutton a single time to initiate a measurement. The SOURCE IMPEDANCE lamp illuminates, and the four-segment display will indicate Source Impedance in Ohms.

3.3.3 MULTIPLE Pushbutton

Press the MULTIPLE Pushbutton to toggle between two modes of operation.

Single Measurement Mode: One single measurement is made. MULTIPLE lamp is not illuminated.

Multiple Measurement Mode: Between 3 and 8 individual impedance measurements are made, depending on voltage range. The ZM-100 averages these and displays the average readings of voltage, impedance, and current. MULTIPLE lamp is illuminated. Multiple Mode is preferred for measurement repeatability and accuracy.

3.3.4 SELECT Pushbutton

The SELECT Pushbutton is used to cycle the four segment display through the ZM-100 measurements. Pressing the SELECT Pushbutton will change the display and the MODE SELECT Lamps.

Step	Mode	Comment
1	Source Voltage	Default on Power Application Continuous Update
2	Test Voltage	Latched (last measurement)
3	Source Impedance	Latched (last measurement)
4	Short Circuit Current	Latched (last measurement)

3.3.5 MODE Lamps

The MODE Lamps light to indicate the measurement that is presently displayed on the four segment display. Pressing the SELECT Pushbutton toggles the MODE Lamps in order, top to bottom.

3.3.6 MULTIPLE Lamp

The MULTIPLE Lamp indicates the Multiple mode of operation.

Dark: Single Measurement Mode, one single measurement is made.

Lighted: Multiple Measurement Mode, between 3 and 8 individual impedance measurements are made. The MULTIPLE Pushbutton is used to toggle between two modes of operation.

3.3.7 WAIT Lamp

The WAIT Lamp indicates that the ZM-100 is disabled, and cannot make measurements. A short delay is programmed into the ZM-100 in order to limit heat build-up in the enclosure. The delay varies depending upon mains voltage and measurement mode, but will not exceed 30 seconds (see Section 2.4.2).

In addition, a thermal sensor within the ZM-100 disables the meter in case of internal overtemperature.

WAIT Lamp	**Condition**
OFF	Normal Operating Condition
SLOW FLASH	Automatic delay after measurement 1 - 30 Seconds depending upon voltage and measurement mode
FAST FLASH	The internal overtemperature sensor has opened due to excessive meter use or cooling problem.

In the event the internal temperature sensor operates, it simply means that the internal heatsink has reached maximum recommended temperature. Allow the meter to cool off for 10-15 minutes and normal operation can be resumed.

SECTION 4 - MAKING MEASUREMENTS

4.1 Introduction

The ***ZM-100*** has been designed for use in industrial, commercial, and field service environments. It is intended for internal use. Do not expose the meter to rain, high humidity or other fluids, or excessive dust or dirt.

The ZM-100 is intended to be used only by qualified personnel familiar with working with AC electrical systems up to 480 VAC. The meter is designed to be safe for such use. However, working with AC electrical systems can be hazardous.

Do not connect or disconnect the ZM-100 leads while the circuit is energized!

1. De-energize the circuit!
2. Connect or move the meter leads
3. Re-energize the circuit in order to make a measurement.

4.2 Preparation

4.2.1 Unpacking the Meter

Unpack the ZM-100 meter, power cables, and test leads. Examine the meter for damage. Examine the cables for loose connections, nicks, and other damage.

Do not use the ZM-100 meter if the meter or cables appear to have been damaged.

4.2.2 Apply Power to the ZM-100

Connect the power cable to the IEC-320 connector on the back of the ZM-100 meter.

Connect the plug on the ZM-100 to a suitable wall outlet. The standard power cord has a NEMA 5-15P plug, however, other plugs may be used with a suitable cable. Consult Section 2.1.2 for mains voltage requirements.

The ZM-100 will energize. The SOURCE VOLTAGE lamp should be illuminated, and the four segment display should light and indicate 0.000 VAC.

4.3 Connect the Test Leads

4.3.1 De-energize the Circuit to be Tested

Ensure that the circuit to be tested is de-energized or OFF. If in doubt, test the individual conductors with a voltmeter or circuit tester.

4.3.2 Connect the Ground Test Lead

Connect the green ground cable plug to the ◎Ground terminal. Attach the green alligator clamp to the ground conductor or enclosure of the circuit to be tested.

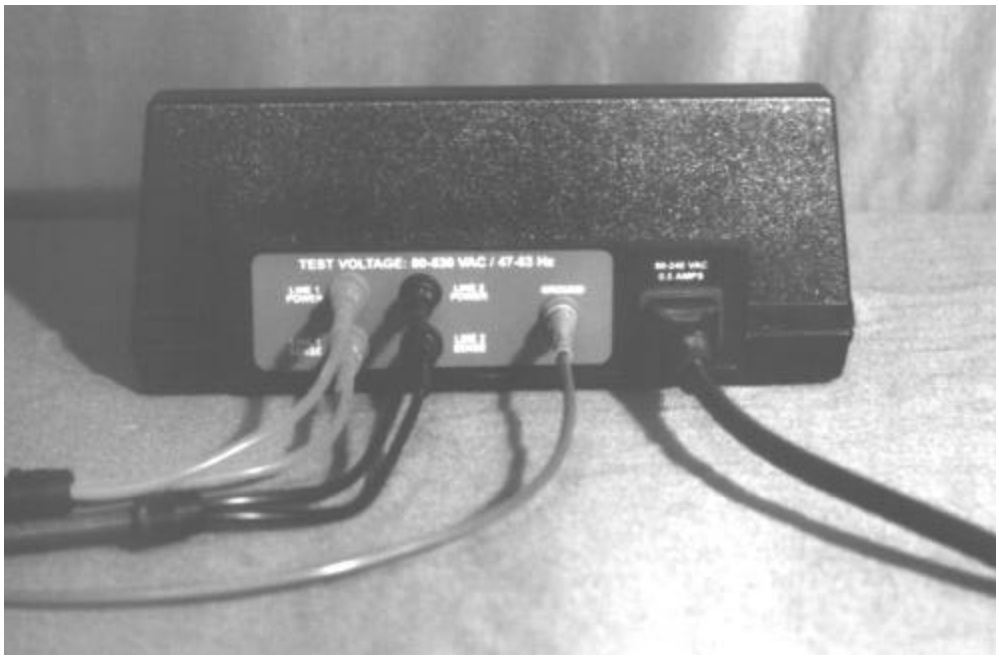
4.3.2 Connect the Red and Black Test Leads

Connect the Red test cable plugs to the ZM-100 ◎Line 1 Power and ◎Line 1 Sense terminals. Attach the Red alligator clamp to one of the phases or neutral conductors of the circuit to be tested.

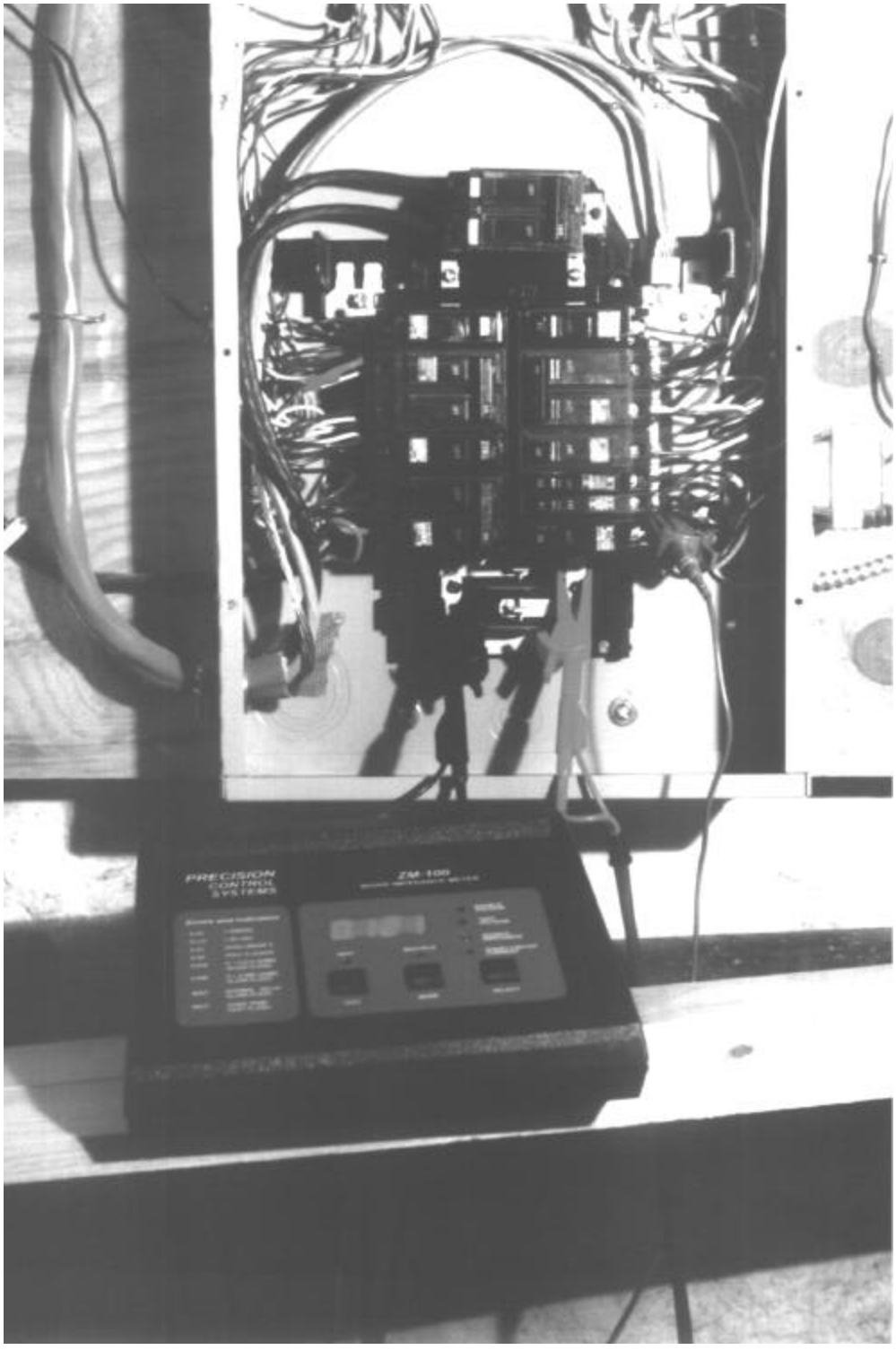
Connect the Black test cable plugs to the ZM-100 ◎Line 2 Power and ◎Line 2 Sense terminals. Attach the Black alligator clamp to a second phase or neutral conductor of the circuit to be tested.

The Kelvin-connected test leads of the ZM-100 assure that measurements are not affected by the test leads. However, it is important to ensure that the test clips are securely connected to the measurement point.

The red and black leads may be connected to either a power conductor or neutral - the ZM-100 input circuitry is not polarized and will function properly in either case.



ZM-100 Rear Connections



ZM-100 Typical Connection

4.3.3 Energize the Circuit

Ensure that all cable connections are tight and that there are no inadvertent connections between hot conductors and earth.

Energize the circuit under test. The ZM-100 display should indicate the line voltage. If the line voltage is not as expected, check your connections. If there is still a problem, your source may not be fully energized.

4.4 Making Measurements

4.4.1 Select the measurement mode. Press the MODE button to select SINGLE measurement mode or MULTIPLE measurement mode.

4.4.2 Press the TEST button. The ZM-100 should indicate MAINS IMPEDANCE immediately. However, in the event of MULTIPLE MODE or high levels of facility voltage flicker a short delay (up to 5 seconds) may be encountered.

Record the Mains Impedance (ohms).

4.4.4 Press the SELECT Button. Record the Short Circuit Current (if desired).

4.4.5 Press the SELECT Button 2x. Record the Test Voltage (if desired)

4.4.6 If additional measurements from the same source are required:

Wait for WAIT lamp to turn off, return to Step 4.4.1

4.5 Disconnecting the ZM-100

4.5.1 De-energize the circuit under test

4.5.2 Disconnect the test leads

4.5.3 Return to step 4.3 if additional measurements are required on different phases or voltage levels on the same circuit.

SECTION 5 - TROUBLE-SHOOTING

	Symptoms	**Corrective Actions**
	Mains Power Related	
5.1.1	Plug does not fit available outlet	(a) Contact PowerLines for optional mains plugs (b) Obtain alternative plugs locally
5.1.2	Plug connected, no display or Lamps lighted	(a) Confirm that mains outlet has power (b) Check plug connections at both ends of line cord (c) Check internal connector TB4 on PCS-20 (d) Check internal fuse F5 on PCS-20
	Initial Power On	
5.2.1	Voltmeter does not read 000.0 Volts on initial power-up	(a) Make sure that test leads are not plugged in to SENSE inputs (b) Reset meter by disconnecting mains power and reapplying power (c) Voltmeter may read up to 1 volt normally with no input (d) Meter problem - contact PowerLines
5.2.2	Voltmeter does not read actual line voltage	(a) Ensure that SOURCE VOLTAGE lamp is lighted. (b) Ensure that both SENSE leads are properly connected to the AC source (c) Check for high level of distortion or non-sinusoidal voltage (d) Check internal fuses F1 and F2 on PCS-20
5.2.3	Display reads "- - - -"	(a) This is normal for the TEST VOLTAGE, SOURCE IMPEDANCE, and SHORT CIRCUIT CURRENT before the first meter reading is made
5.2.4	Display reads nonsense characters	(a) Reset meter by disconnecting mains power and reapplying power (b) Meter problem - contact PowerLines

	Symptoms	**Corrective Actions**
	Measurement Problems	
5.3.1	Impedance is 0.999 flashing	(a) Impedance is greater than 1 ohm (b) False neutral on source (c) POWER test leads are not properly connected (d) Check internal fuses F3 and F4 on PCS-20
5.3.2	Impedance is 0.010 flashing	(a) Impedance is less than 0.010 ohms (b) Repeat measurement to confirm reading (c) Check internal fuses F3 and F4 on PCS-20
5.3.3	Error E-01	(a) Non-linear impedance (b) Check for power conditioner, UPS, or voltage regulator (c) Bypass power conditioner or disable voltage regulation to make a measurement
5.3.4	Error E-02	(a) Excessive voltage flicker to make an accurate measurement (b) Make a second measurement (c) Try Multiple Mode
5.3.5	Error E-HI	(a) Test voltage is too high to make a normal measurement
5.3.6	Error E-LO	(a) Test voltage is too low to make a normal measurement
	Accuracy problems	
5.4.1	Impedance readings fluctuate	(a) Voltage flicker may affect readings (b) Make multiple readings to improve averaging (c) Take several readings and discard anomalous readings
5.4.2	Impedance is abnormally low	(a) Source may have a non-linear source that does not cause negative impedance (b) Check for UPS, power conditioner, voltage regulator, etc.

SECTION 6 - MAINTENANCE AND CALIBRATION

6.1 Maintenance

The ZM-100 is composed of solid state components and high reliability mechanical components. Normally, no periodic maintenance is required.

The ZM-100 does not contain a real time clock, and therefore is not affected by Year 2000 (Y2K) issues.

6.2 Cables and Cords

The ZM-100 cables must be examined periodically for wear, fraying, and nicks. Do not use damaged cables. Contact PowerLines for replacement cables and connectors.

The probe clips supplied with the ZM-100 have been selected for contact resistance, voltage capability, safety, and jaw width. If alternate / replacement clips are required, ensure that the replacement parts have sufficient voltage and current ratings for the application.

High contact resistance will affect impedance readings.

The cable set delivered with the ZM-100 is Kelvin connected. Alternate cable sets may affect impedance readings.

6.3 Cleaning the ZM-100

The case and front panel of the ZM-100 should be wiped down periodically to remove dirt, dust, and grease. Use a clean cloth and a mild detergent to clean the ZM-100. Do not use solvents for internal or exterior cleaning of the ZM-100. Be careful not to get cleaning solutions or foreign objects in the pushbutton openings.

6.4 Calibration

Contact PowerLines for calibration service on the ZM-100. Annual calibration is recommended.

The ZM-100 is simply calibrated using an AC reference voltage and current source. Contact PowerLines for calibration procedures.

SECTION 7 - SPARE PARTS LIST

Item	Qty	Description	Part Number
1	1	AC Line Cord	00-560010-10
2	2	Fuse F1 / F2 - Type KTK, ½Amp	00-505100-17
3	2	Fuse F3 / F4 - Type KTK, 15 Amp	00-505100-16
4	1	Fuse F5 - Pico Type, Fast 1/4 Amp	00-505025-00
5	1	Printed Circuit Board PCS-20.10	02-201000-01
6	1	Load Resistor Assembly	
7	1	Thermostat N/C 77-82 Deg C	00-542750-02
8			
9			
10			
11	2	1000 Volt Safety Test Clip - Red	
12	2	1000 Volt Safety Test Clip - Black	
13	1	1000 Volt Safety Test Clip - Green	
14	1	Kelvin Connected Cable Set with Test Clips	00-560201-00
15			
16			
17			
18			
19			
20	1	Pelican Shipping Case Type #1450	
21	1	ZM-100 Manual	
22	1	ZM-100 Applications Diskette	
23			
24			
25			
26			
27			
28			

SECTION 8 - SCHEMATICS AND MECHANICAL DRAWINGS

8.1	Drawing	Mechanical View(s)
8.2	Drawing:	Electrical Schematic *User-Accessible Components and Adjustments*
8.3	Drawing:	Calibration and Adjustments
8.4	Drawing	Cables and Accessories *Under Preparation*

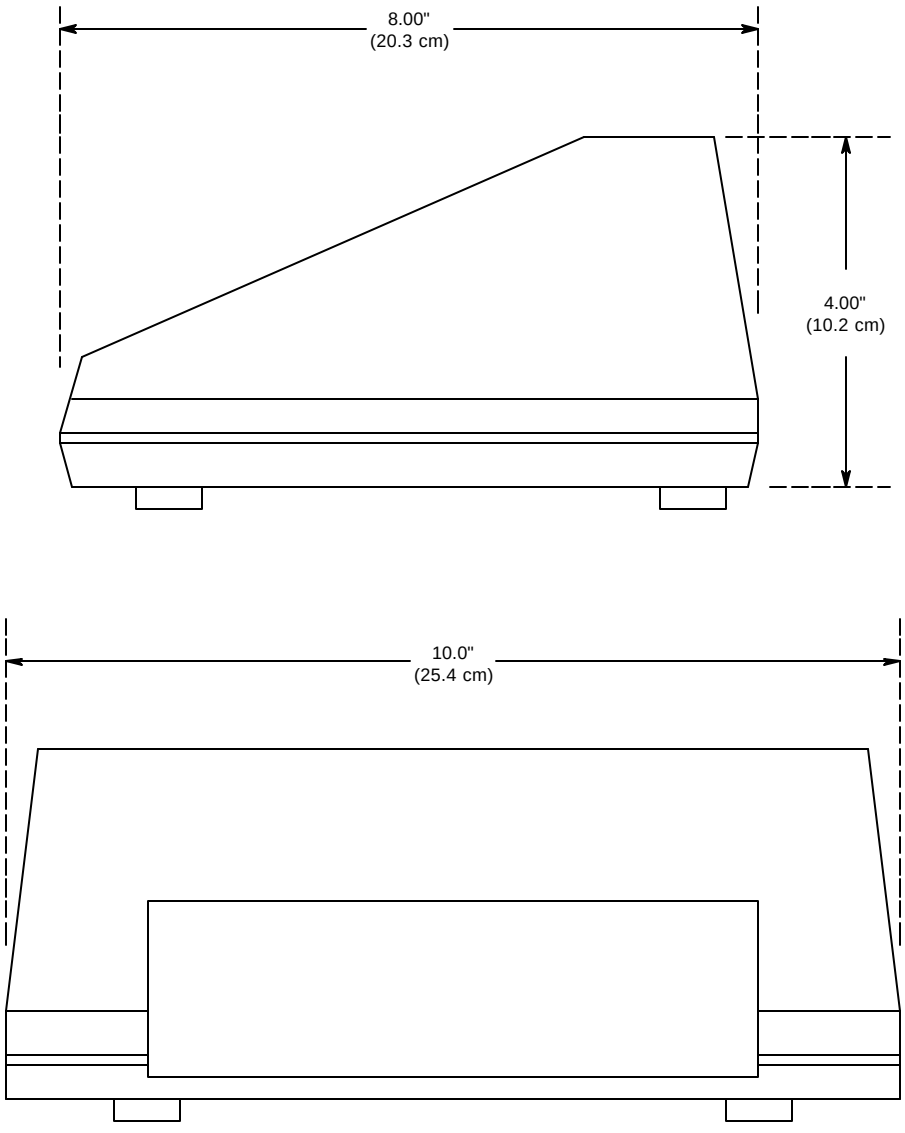


Figure 8.1:
ZM-100 Mechanical Views

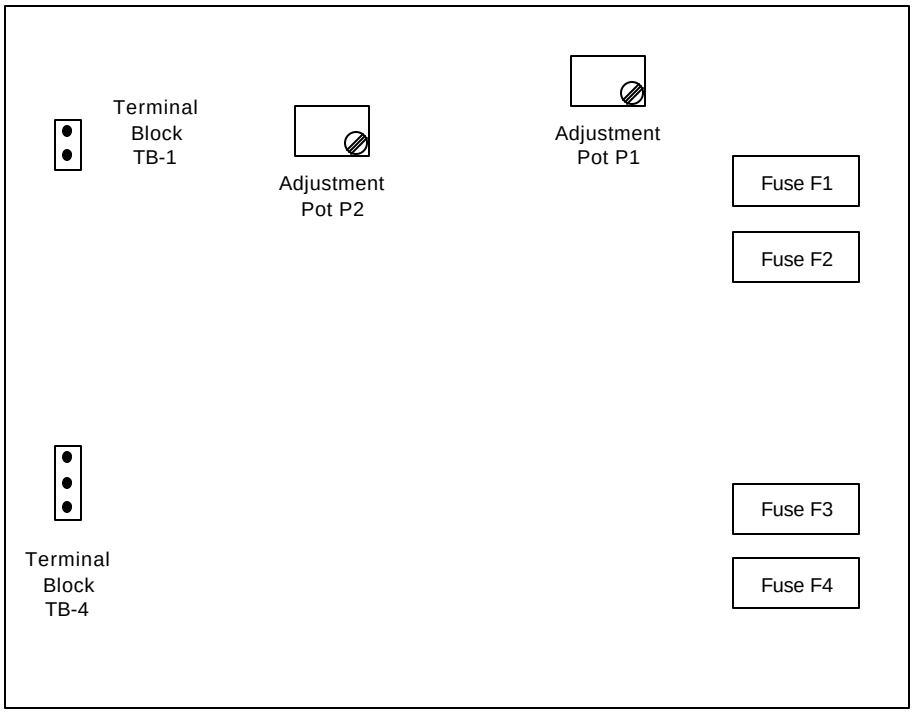


Figure 8.2:
ZM-100 Printed Circuit Board
Component Locations

8.3 Calibration and Test Procedures

Under Preparation

8.4 Optional Cables and Accessories

Under Preparation