OPERATOR'S MANUAL

MODEL 464 DIGITAL MULTIMETER

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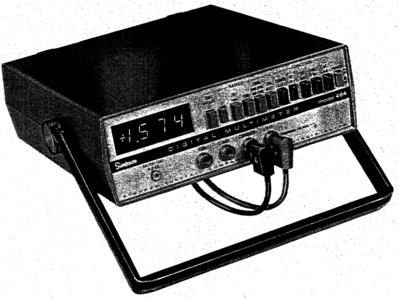

Figure 1-1. Model 464 Digital Multimeter

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WARNING

This Instrument is designed to prevent accidental shock to the operator when properly used. However, no engineering design can render safe an instrument which is used carelessly. Therefore, this manual must be read carefully and completely before making any measurements. Failure to follow directions can result in a serious or fatal accident.

SHOCK HAZARD: As defined in American National Standard, C39.5, Safety Requirements for Electrical & Electronic Measuring & Controlling Instrumentation, a shock hazard shall be considered to exist at any part involving a potential in excess of 30 volts rms (sine wave) or 42.4 volts DC or peak and where a leakage current from that part to ground exceeds 0.5 milliampere, when measured with an appropriate measuring instrument defined in Section 11.6.1 of ANSI C39.5.

NOTE: The proper measuring instrument for the measurement of leakage current consists essentially of a network of a 1500 ohm non-inductive resistor shunted by a 0.15 microfarad capacitor connected between the terminals of the measuring instrument. The leakage current is that portion of the current that flows through the resistor. The Simpson Model 229-Series 2 AC Leakage Current Tester meets the ANSI C39.5 requirements for the measurement of AC leakage current and can be used for this purpose. To measure DC Leakage current, connect a 1500 ohm non-inductive resistor in series with a Simpson 0-500 DC microammeter and use this as the measuring instrument.

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SECTION I

INTRODUCTION

1.1 GENERAL

1.1.1 The Simpson Model 464 Digital Multimeter is a compact, 3-1/2 digit instrument, suitable for use in general electronic maintenance, production, and laboratory. It features 0.1% DCV accuracy, integrated circuit electronics, solid-state LED display, and pushbutton switch selection for ranges and functions. Additional features are automatic polarity, automatic zeroing, high input impedance for voltage measurements, and excellent temperature and over-ranging characteristics.

1.1.2 The Model 464 is available in two versions. Model 464A is the standard instrument designed to operate from a 120 or 240 volts AC (50-400 Hz) power source (check rear panel designation). Model 464D is an optional version designed for either AC line operation, or battery operation using rechargeable nickel-cadmium cells. The battery can operate the Instrument for eight hours continuously. Recharging is automatic when the Instrument is in the OFF position and with the line cord connected. In an emergency, commercially available "D" size (flashlight type) batteries can be used. Refer to paragraph 6.5.1 for precautions and instructions. Hereafter, all information and data applies to both instruments (referred to as Model 464), unless otherwise indicated.

1.1.3 The Model 464 (see Figure 1-1) measures DC and AC voltage, DC and AC current and resistance as specified in Table 1-1. The charge-balance integration technique is used for the analog-to-digital (A/D) conversion circuitry and is contained in two Large-Scale-Integration (LSI) modules, which provide high reliability and compact design.

1.1.4 The numerical display is a 7-segment light-emitting-diode (LED) display for easy viewing and solid-state reliability. The numerals are 0.43 inch high and in a single plane for distant and wide-angle viewing. Ambient lighting effects are minimized by a filter which reduces reflections and background illumination.

1.2 ACCESSORIES AND SUPPLIES

All supplies and accessories required for the operation of the 464 (using line power) are furnished with the Instrument and listed in Table 7-1. Batteries for the 464D are not supplied.

1.3 TECHNICAL DATA

Table 1-1 lists the technical specifications for the Simpson 464 Digital Multimeter.

Table 1-1. Technical Data

1. DC VOLTAGE:

Range	Maximum Indication	Input Resistance	Overload Protected To
200 mV	±199.9 mV	10 MΩ	±1100 V
2 V	±1.999 V	10 MΩ	±1100 V
20 V	±19.99 V	10 MΩ	±1100 V
200 V	±199.9 V	10 MΩ	±1100 V
1000 V	±1000 V (Max. Input)	10 MΩ	±1100 V

Accuracy: (from +15°C to +35°C) ±(0.1% of reading + 1 digit)

Input Bias Current: 40 pA at reference conditions

Sensitivity: 100μV on 200 mV range

Full Range Step Response: (to rated accuracy)	1 second, maximum
Normal Mode Rejection:	55 dB minimum at 60 Hz
Common Mode Rejection:	90 dB minimum at 60 Hz
Overrange Capability:	Linear to 1000 counts beyond maximum indication (except on 1000 V range, where any indication greater than 1100 is an overload).
Temperature Coefficient: (from 0°C to +55°C)	±(0.01% of reading + 0.05 digit)/°C

2. AC VOLTAGE:

(Average-Sensing, RMS Calibrated Sine Wave 40 Hz to 10 kHz)

Range	Maximum Indication	Input Impedance	Overload Protected To
200 mV	199.9 mV	10 MΩ and 75 pF	650 V RMS
2 V	1.999 V	10 MΩ and 75 pF	650 V RMS
20 V	19.99 V	10 MΩ and 75 pF	650 V RMS
200 V	199.9 V	10 MΩ and 75 pF	650 V RMS
600 V*	600 V (Max. Input)	10 MΩ and 75 pF	650 V RMS

Accuracy: (from +15°C to +35°C)	±(0.5% of reading + 2 digits), 40 Hz to 1000 Hz. ±(1.0% of reading + 2 digits), 1000 Hz to 10 kHz.
Sensitivity:	100μV on 200 mV range
Full Range Step Response: (to rated accuracy)	5 seconds, maximum

*Frequency Range: 40 Hz to 1000 Hz.

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Temperature Coefficient: (from 0°C to +55°C) — ±(0.05% of reading + 0.05 digit)/°C

3. RESISTANCE:

Range	Maximum Indication	Full Scale Voltage	Test Current	Overload Protected To
200 Ω	199.9 Ω	200 mV	1 mA	135 V RMS
2 kΩ	1.999 kΩ	2 V	1 mA	135 V RMS
20 kΩ	19.99 kΩ	2 V	100 μA	250 V RMS
200 kΩ	199.9 kΩ	200 mV	1 μA	250 V RMS
2000 kΩ	1999 kΩ	2 V	1 μA	250 V RMS
20 MΩ	19.99 MΩ	2 V	100 nA	250 V RMS

Accuracy: (from +15°C to +35°C) — ±(0.5% of reading + 1 digit) except on the 20 MΩ range, which is ±(1.0% of reading + 1 digit)

Sensitivity: — 0.1Ω on 200Ω range

Full Range Step Response: (to rated accuracy) — 2 seconds, except on 20 MΩ range, which is 7 seconds

Temperature Coefficient: (from 0°C to +55°C) — ±(0.05% of reading + 0.05 digit)/°C

Overrange Capability: — Linear to 1000 counts beyond maximum indication

4. DC CURRENT:

Range	Maximum Indication	Full Range Voltage Drop	Overload Protected To
200 μA	±199.9 μA	200 mV	±2.5 A*
2 mA	±1.999 mA	200 mV	±2.5 A*
20 mA	±19.99 mA	200 mV	±2.5 A*
200 mA	±199.9 mA	200 mV	±2.5 A*
2000 mA	±1999 mA	200 mV	±2.5 A*
10 A	±10.00 A (Max. Input)	100 mV	±10 A

*Fuse Protected

Accuracy: (from +15°C to +35°C)	±(0.5% of reading + 1 digit), except on 2000mA and 10A ranges, which are ±(1.0% of reading + 1 digit)
Sensitivity:	100 nA on 200 μA range
Full Range Step Response: (to rated accuracy)	1 second
Temperature Coefficient: (from 0°C to +55°C)	±(0.05% of reading + 0.05 digit)/°C
Overrange Capability:	Linear to 500 counts beyond maximum indication (except on 10 A range, where any indication greater than 1000 is an overload).

5. AC CURRENT (40 Hz to 10 kHz):

Range	Maximum Indication	Full Range Voltage Drop	Overload Protected To
200 μA	199.9 μA	200 mV	2.5 A*
2 mA	1.999 mA	200 mV	2.5 A*
20 mA	19.99 mA	200 mV	2.5 A*
200 mA	199.9 mA	200 mV	2.5 A*
2000 mA	1999 mA	200 mV	2.5 A*
10 A	10.00 A (Max. Input)	100 mV	10 A

Accuracy: (from +15°C to +35°C)	±(1.5% of reading + 2 digits), except on 2000 mA and 10A ranges, which are ±(2.0% of reading +2 digits)
Sensitivity:	100 nA on 200 μA range
Full Range Step Response: (to rated accuracy)	5 seconds, maximum

*Fuse Protected

Temperature Coefficient: (from 0°C to +55°C)	±(0.1% of reading + 0.1 digit)/°C
Overrange Capability:	Linear to 500 counts beyond maximum indication (except on 10 A range, where any indication greater than 1000 is an overload).

6. RATED CIRCUIT-TO- GROUND VOLTAGE:

(Maximum Common Mode Voltage)	1000 volts (DC plus peak AC) maximum from any measuring terminal to power line (earth) ground terminal.

7. RESOLUTION:

1 part in 2000

8. DISPLAY:

Numerical Display:	3-1/2 digit, 7-segment light-emitting-diode (LED) type, with flashing digits for counts over 1999.
Conversion Rate:	3 readings per second, nominal
DC Polarity Selection:	Automatic with "+" or "−" indication

9. POWER REQUIREMENT:

AC Operating (464A) or Battery Charging (464D):	120 VAC or 240 VAC ±10% (check rear panel designation), 50-400 Hz, 5 VA nominal.
Battery Operation (464D):	Four nickel-cadmium "D" size rechargeable cells, Eveready type CH4 or equivalent (each cell is rated at 1.25V, 4-ampere-hours).
Battery Operation Time: (continuous with fully charged battery)	8 hours, nominal
Battery Recharge Time:	16 hours, nominal

10. TEMPERATURE RANGE:

Operating:	0°C to +55°C
Storage:	−40°C to +60°C

11. RELATIVE HUMIDITY: 0 to 90% (non-condensing)

12. REFERENCE CONDITIONS:

Temperature:	+23°C ±1°C
Relative Humidity:	30 to 60%
Atmospheric Pressure:	575 to 800 mmHg

13. DIMENSIONS:

Height:	2.70 in. (68.6mm)
Width:	8.40 in. (213.4mm)
Depth:	9.00 in. (228.6mm)

14. WEIGHT: Approximately 3 lbs. (1.36 kg)

SECTION II

INSTALLATION

2.1 UNPACKING AND INSPECTION

2.1.1 Examine the shipping carton for signs of damage prior to unpacking. If there is none, then unpack and inspect the Instrument for possible damage in shipment. Check the electrical performance as soon as possible. If damage is noted, notify the carrier and supplier before using the Instrument. Also check that all items are included (Table 7-1).

2.1.2 Save the shipping carton and packing materials for future storing or shipping of the Instrument.

2.2 POWER SOURCE REQUIREMENTS

2.2.1 The Model 464A is designed to be operated from the AC line. The Model 464D is designed to be operated from either the AC line or self-contained nickel-cadmium cells (not furnished with the Instrument but available from any local electronic parts distributor). Refer to Table 1-1, item 9.

2.2.2 AC Line Operation

The Model 464 is wired at the factory for 120 VAC (50 to 400 Hz) operation. To convert your Instrument for 240 VAC operation, consult your nearest Simpson Authorized Service Center.

CAUTION

For AC line operation, insure that the grounding pin of the power plug is securely connected to an earth (power line) ground. Use a 3-wire grounded outlet which conforms to the latest electrical code.

2.2.3 Battery Operation (464D)

Battery operation is automatic whenever cells are installed, the line cord is disconnected, and one of the FUNCTION switches set to a position other than the POWER OFF position.

2.2.4 For battery installation and battery test refer to paragraph 6.5.

2.3 INSTALLATION

The Instrument may be set horizontally on its four rubber feet or vertically on its back and operated in either position. The Instrument can also be set at an inclined angle by positioning the 8-position carrying handle under the unit. To set the Instrument at a desirable viewing angle, use the following procedure:

a. Pull out both knobs on sides of Instrument.

b. Rotate handle to one of eight positions.

c. Push both knobs into a locking position.

SECTION III

CONTROLS, CONNECTORS AND INDICATORS

3.1 GENERAL

All operating and adjusting controls, connectors, and indicators are described in Table 3-1. Become familiar with each item prior to operating the Instrument for the first time.

3.2 FRONT AND REAR PANEL DESCRIPTION

Table 3-1 lists all front and rear panel controls, connectors and indicators (see Figure 3-1 and 3-2 for identification).

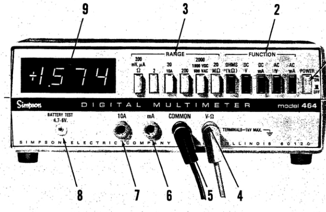

Figure 3-1. Front Panel Description

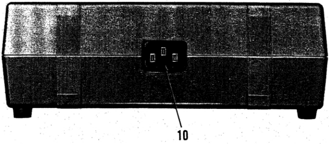

Figure 3-2. Rear Panel Description

Table 3-1. Front and Rear Panel Description

1. POWER Switch:	
ON	Applies primary power to the Instrument.
OFF	Disconnects primary power from all circuits except the battery charging circuit.
2. FUNCTION Switches:	
Position	
AC mA	Connects the COMMON and mA jacks to the AC current measuring circuits.
AC V	Connects COMMON and V-Ω jacks to the AC voltage measuring circuits.
DC mA	Connects the COMMON and mA jacks to the DC current measuring circuits.
DC V	Connects COMMON and V-Ω jacks to the DC voltage measuring circuits.
OHMS (kΩ)	Connects the COMMON and V-Ω jacks to the resistance measuring circuits.
3. RANGE Switches:	
Position	
200 mV, μA Ω	Selects the circuits required for full range measurements of 0 to ±200 mV DC, 0 to 200 mV AC, 0 to ±200 μA DC, 0 to 200 μA AC, 0 to 200 ohms, depending on the function switch selected.
2, 20 10A, 200, 2000 1000 VDC 600 VAC	Selects the circuits required for full range measurements of 0 to the corresponding numerical values of AC mA, ±DC mA, Ω, ±DC V or AC V depending on the function switch selected.

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20 MΩ — Selects the circuits required for the full range measurement of resistance from 0 to 20 MΩ when the function switch OHMS (kΩ) is selected.

4. V-Ω Jack: This terminal is used to connect the "high" side of the circuit being measured to all voltage and resistance measuring circuits through the range and function switches.

5. COMMON Jack: This jack is used to connect the "low" side of the circuit measured to the internal circuit COMMON and is isolated from the AC power line ground.

6. mA Jack: This terminal is used to connect the "high" side of the currents being measured to the current measuring circuits through the FUNCTION and RANGE switches. The "low" side is connected to the COMMON jack.

7. 10A Jack: This terminal is used to connect the "high" side of the 10 ampere full scale currents being measured to the current measuring circuits when RANGE switch 20 (10 A) and function switch DC mA or AC mA are selected. The "low" side is connected to the COMMON jack.

8. BATTERY TEST 4.7-6V (Model 464D only): This jack connects to the positive terminal of the battery installed. For battery test, connect a test lead between the V-Ω jack and the BATTERY TEST jack, with the function switch DCV and the RANGE switch 20 (10 A) selected. The numerical display must indicate a voltage between +4.7 volts and +6.0 volts for proper operation. If the display indicates greater than +6.0 volts, either the battery is not installed or the battery is not installed properly.

9. Numerical Display: The digital display uses LED's and includes a polarity (+, −) sign, a "1" digit, three 7-segment type 0 to 9 digits and a decimal point, to indicate the polarity and the value of the signal being measured. The decimal point is properly positioned by the selection of the range switch. Over-range (or out-of-range) condition is indicated by a flashing display for 2000 counts or greater.

10. AC Power Receptacle: This receptacle accepts the AC line power cord used for AC operation or battery charging.

SECTION IV

OPERATION

4.1 GENERAL

WARNING

The Model 464 is designed to prevent accidental shock when properly used. However, no engineering design can render safe an Instrument which is used carelessly. Therefore, this manual must be read completely prior to making any measurements. Failure to do so can result in a serious or fatal accident.

This section of the manual contains information required to use and operate the Model 464 in a safe and proper manner.

4.2 SAFETY PRECAUTIONS

4.2.1 The Model 464 is designed to be used only by personnel qualified to recognize shock hazards and trained in the safety precautions required to avoid possible injury. Refer to SHOCK HAZARD definition on page v.

4.2.2 Do not work alone when making measurements where a shock hazard can exist. Notify another person that you are, or intend to make such measurements.

4.2.3 Remember, voltages might appear unexpectedly in defective equipment. An open bleeder resistor can result in a capacitor's retaining a dangerous charge. Remove all power and discharge all capacitors in the circuit being measured and remove all power from the Model 464 before making connections or disconnections. The Instrument itself is well protected against electrical overload, as noted throughout paragraph 1.3. However, the above precautions are wise even in the laboratory, and especially in field usage of the Instrument where many strange or unknown safety hazards might prevail.

4.2.4 Locate all voltage sources and accessibility paths prior to making any measurements or connections.

4.2.5 For your own safety, before each use, inspect the test leads, prods, connectors and power cable for cracks, breaks or crazes in the insulation. If any defects exist, destroy and replace the defective item(s) immediately.

4.2.6 Do not make measurements in a circuit where corona is present. Corona can be identified by a pale-blue color emanating from sharp metal points in the circuit or a buzzing sound, or the odor of ozone. In rare instances, such as around germicidal lamps, ozone might be generated as a normal function. Ordinarily, the presence of ozone indicates presence of high voltage, and probably a malfunction of some kind.

4.2.7 Hands, shoes, floor and workbench must be dry. Avoid making measurements under humid, damp, or other environmental conditions that could affect the dielectric withstanding voltage of the test leads or the Instrument.

4.2.8 For maximum safety, do not touch test leads, circuit, or Instrument while power is applied to the circuit being measured.

4.2.9 Use extreme caution when making measurements in an rf circuit where dangerous composite voltages could be present, such as in a modulated rf amplifier.

4.2.10 Do not use test leads which differ from those originally furnished with the Instrument.

4.2.11 Before the Instrument is used for AC operation, make sure that the "third wire" on the AC power cord is connected to an earth or power line ground.

4.2.12 Do not float any measuring terminal more than 1000 volts (DC plus AC peak) with respect to the power line or earth ground.

4.3 PRELIMINARY NOTES AND CHECKS

NOTE: Prior to operation of the Instrument, review and perform (where applicable) the following notes and checks. These steps can be used also as a general functional check.

4.3.1 For AC line operation:

a. Insure that the power source used matches the requirements of the Instrument as marked on the rear panel.

b. Insert the plug into a 3-wire power outlet which conforms to the latest electrical code. The Model 464D will operate with or without battery power. When the Model 464D is operating on the AC line with the internal battery installed, the battery is being "trickle" charged.

4.3.2 For Model 464D battery operation follow this procedure:

CAUTION

Do not operate the Instrument with cells in the completely discharged state, which is common for all new cells as acquired from the vendor. See paragraph 6.6.

a. Disconnect the AC line cord and set the POWER switch to the OFF position. Install four "D" size nickel-cadmium cells (not supplied with Instrument). Observe polarity as shown on label inside battery holder. Assemble case and turn unit ON.

b. Depress the DCV function and 20 (10A) range switches.

c. Connect a test lead between the V-Ω jack and the BATTERY TEST jack. The reading must be between +4.7 volts and +6.0 volts for proper operation of the Instrument.

d. If the battery voltage is below +4.7 volts, or if the display does not emit light, either the battery is improperly installed or recharging is required.

NOTE: If the battery is not installed, or not installed properly, the BATTERY TEST reading will be greater than +6 volts. This voltage is the open-circuit charging voltage for the battery.

4.3.3 To recharge the battery, follow this procedure:

a. Set the POWER switch to the OFF position. Connect the line cord plug into a 3-wire power outlet which conforms to the power requirements of the Instrument as marked on the rear panel, and to the latest electrical code.

b. The battery is being charged at full rate.

NOTE: If the battery test indicates a voltage below +4.7 volts, set the POWER switch in the OFF position for at least 15 minutes before operating.

4.4 GENERAL FUNCTIONAL CHECK

a. **Review the safety precautions in paragraph 4.2.**

b. Connect the black test lead to the COMMON jack and the red test lead to the V-Ω jack. Short the test leads together.

c. Depress and set the OHMS (KΩ) function and 2 range switches.

d. Open the test leads. The numerical display will be flashing in the out-of-range condition.

e. Short the test leads together. The display reading will return to .000 ±1 digit.

f. If difficulty is encountered in the above steps, see Section VI.

4.5 DC VOLTAGE MEASUREMENTS

a. **Review the safety precautions in paragraph 4.2.**

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress DCV function switch.

d. Depress the appropriate voltage range switch as indicated in Table 4-1. If the voltage being measured is unknown, begin with the 1000 range VDC switch.

Table 4-1. DC Voltage Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Voltage	Remarks
0 to ±200mV	200mV	DCV	V-Ω, COMMON	±1100V	Auto-Polarity on all ranges
0 to ±2V	2	DCV	V-Ω, COMMON	±1100V	
0 to ±20V	20	DCV	V-Ω, COMMON	±1100V	
0 to ±200V	200	DCV	V-Ω, COMMON	±1100V	
0 to ±1000V	1000 VDC	DCV	V-Ω, COMMON	±1100V	

e. Turn off the power to the device or circuit under test and discharge all capacitors.

CAUTION

Do not attempt to measure voltages on the 1000 VDC range which might be greater than 1100 volts DC.

f. Connect test leads to the circuit being measured.

g. Apply power to the circuit being measured. The Instrument will automatically indicate the correct polarity. The value of the voltage being measured will be indicated on the numerical display.

h. **Remove all power from the circuit being measured and discharge all capacitors prior to disconnecting test leads.**

4.6 AC VOLTAGE MEASUREMENT

a. **Review safety precautions in paragraph 4.2.**

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress the ACV function switch.

d. Depress the appropriate voltage range switch as indicated in Table 4-2. If the voltage being measured is unknown, begin with the 600 range VAC switch.

CAUTION

Do not attempt to measure voltages on the 600 VAC range which might be greater than 650 volts.

Table 4-2. AC Voltage Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Max. Voltage	Frequency Range
0 to 200mV	200mV	ACV	V-Ω, COMMON	650V RMS	40 Hz - 10 kHz
0 to 2V	2	ACV	V-Ω, COMMON	650V RMS	40 Hz - 10 kHz
0 to 20V	20	ACV	V-Ω, COMMON	650V RMS	40 Hz - 10 kHz
0 to 200V	200	ACV	V-Ω, COMMON	650V RMS	40 Hz - 10 kHz
0 to 600V	600VAC	ACV	V-Ω, COMMON	650V RMS	40 Hz - 1 kHz

e. Remove all power from the circuit being measured and discharge all capacitors.

f. Connect test leads to the circuit being measured.

g. Apply power to the circuit being measured. The value of the voltage being measured will be indicated on the numerical display.

h. **Remove all power from the circuit being measured and discharge all capacitors prior to disconnecting test leads.**

4.7 RESISTANCE MEASUREMENTS

a. **Review the Preliminary Notes and Checks in paragraph 4.3.**

b. Connect input test leads to the V-Ω and COMMON terminals.

c. Depress the OHMS (KΩ) function switch.

d. Depress the appropriate resistance range switch as indicated in Table 4-3.

e. If the resistance being measured is connected into a circuit, be certain that all power is removed from the circuit and all capacitors are discharged. Check for current paths other than through the resistance being measured. These paths can result in a measured value which is lower than the actual value of the resistance being measured.

f. Connect the test leads to the resistance being measured. Be careful not to contact adjacent points, even if insulated, particularly when making high resistance measurements. Some insulators can have relatively low insulation resistance, which can sufficiently shunt the resistance being measured to result in a measured value lower than the presumed value.

NOTE: If the resistance being measured is polarity or voltage sensitive (for example, semiconductors), careful considerations must be given when making connections and selecting the resistance range (refer to Table 4-3).

g. Allow time for the display to stabilize. This procedure is especially important when measuring a high value resistance shunted by a large value of capacitance.

h. Disconnect test leads.

Table 4-3. Resistance Ranges and Connections

Range	Range Switch	Function Switch	Input Connections	Test Current	Full Scale Voltage
0 to 200Ω	200Ω	OHMS	V-Ω, COMMON	1 mA	200 mV
0 to 2 kΩ	2	OHMS	V-Ω, COMMON	1 mA	2 V
0 to 20 kΩ	20	OHMS	V-Ω, COMMON	100 μA	2 V
0 to 200 kΩ	200	OHMS	V-Ω, COMMON	1 μA	200 mV
0 to 2000 kΩ	2000	OHMS	V-Ω, COMMON	1 μA	2 V
0 to 20 MΩ	20 MΩ	OHMS	V-Ω, COMMON	100 nA	2 V

4.8 DC CURRENT MEASUREMENTS

a. **Review Safety Precautions in paragraph 4.2.**

b. Depress the DC mA function switch.

c. Depress the appropriate current range switch as indicated in Table 4-4. If the current being measured is unknown (but less than 10A), begin with the 20 (10A) switch and connect the red test lead to the 10A jack and the black test lead to the COMMON jack.

4.9 AC CURRENT MEASUREMENTS

a. **Review Safety Precautions in Paragraph 4.2.**

b. Depress ACmA function switch.

c. Depress the appropriate current range switch as indicated in Table 4-5. If the current being measured is unknown (but less than 10A), begin with the 20 (10A) switch and connect the red test lead to the 10A jack and the black test lead to the COMMON jack.

Table 4-5. AC Current Ranges and Connections

Range	Range Switch	Function Switch	Max. Connections	Max. Current Amperes	Remarks
0 to 200μA	200 μA	AC mA	mA, COMMON	2.5	Frequency range: 40 Hz to 10 kHz
0 to 2 mA	2	AC mA	mA, COMMON	2.5	
0 to 20 mA	20	AC mA	mA, COMMON	2.5	
0 to 200 mA	200	AC mA	mA, COMMON	2.5	
0 to 2000 mA	2000	AC mA	mA, COMMON	2.5	
0 to 10A	20 10A	AC mA	10A, COMMON	10	

d. **Remove all power from the circuit being measured and discharge all capacitors.**

e. Open the circuit in which the current is to be measured and securely connect the test leads in series. Insure that the Model 464 is not connected across a voltage source which can exceed ratings of the Instrument.

f. Connect the test leads according to Table 4-5.

g. Apply power to the circuit being measured.

h. The value of the current being measured is indicated on the numerical display.

i. **Remove all power from the circuit being measured and discharge all capacitors.**

j. Disconnect the test leads and reconnect the circuit which was originally opened.

SECTION V

THEORY OF OPERATION

5.1 OVERALL SYSTEM

The basic system block diagram for the Model 464 is shown in Figure 5-1.

5.1.1 Signal Conditioning Section

The parameter being measured is connected to the appropriate input terminals. The corresponding Signal Conditioning circuits convert this parameter into a proportional DC voltage. The conversion is accomplished by the Attenuator, Current Shunts, Resistance Converter, AC-to-DC Converter, and associated switching.

5.1.2 Analog-To-Digital Converter Section

The Analog-To-Digital (A/D) Converter section changes the DC output voltage from the Signal Conditioning section to digital information. Using two Large-Scale Integration (LSI) circuits, the unique A/D converter automatically eliminates zero error.

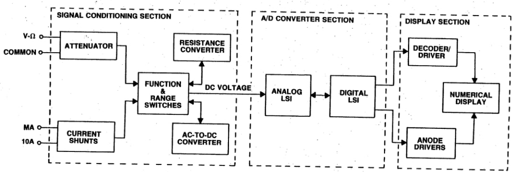

Figure 5-1. Model 464 Basic System Block Diagram

5.1.3 Display Section

Digital information in BCD form from the A/D Converter section is decoded into 7-segment information by the Decoder/Driver. The decoded information, in conjunction with the Anode Drivers, is visually presented on the Numerical Display.

5.2 INPUT CIRCUITS

5.2.1 DC Voltage Measurements

The basic DC voltage measurement circuit is shown in Figure 5-2(A). The DC voltage being measured is connected to the V-Ω and COMMON jacks, attenuated according to the range selected and converted into digital information by the A/D Converter.

5.2.2 The A/D Converter circuit provides two basic full range sensitivities: 200mV and 2V. This feature simplifies the attenuator design. No attenuation is required on the 200mV and 2V ranges. The same attenuator ratio is used on the 20V and 200V ranges. A separate attenuator tap is provided for the 1000 volt range.

5.2.3 AC Voltage Measurement

The basic AC voltage measurement circuit is shown in Figure 5-2(B). The AC voltage being measured is connected to the V-Ω and COMMON jacks, attenuated according to the range selected and applied to the amplifier. The output of the amplifier is converted into DC voltage by an active rectifier and the resulting DC voltage is measured by the A/D Converter.

5.2.4 The AC-To-DC Converter provides two basic full range sensitivities: 200mV and 2V. The converter is average responding but its calibration (gain) is based on the rms value of a sine wave.

5.2.5 The AC-To-DC Converter consists of an input amplifier and a precision half-wave active rectifier. The input amplifier, connected as a source follower, operates as a buffer for the active rectifier. The buffered output is applied as a voltage, E_{in}, to the non-inverting input of the operational amplifier. Negative feedback causes the voltage at the inverting input to follow the non-

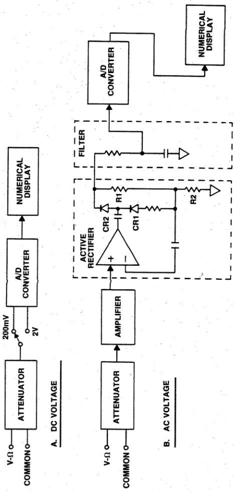

Figure 5-2. Basic Voltage Measurement Circuits

inverting input, causing a current Ein/R2, through R2 to circuit common. Since diodes CR1 and CR2 conduct on alternate half cycles, one-half of the average current flows through R1. The rectified voltage developed across R1 is filtered by the RC filter to produce the DC voltage required for the A/D Converter.

5.2.6 DC Current Measurements

The basic DC current measurement circuit is shown in Figure 5-3(A). The current being measured is connected in series with the mA (or 10A) and COMMON jacks, across an internal precision shunt resistance. The value of the shunt resistance depends on the current range selected. The DC voltage developed across the shunt resistor is measured by the A/D Converter.

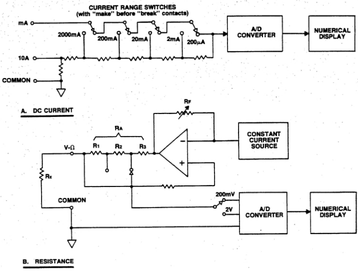

Figure 5-3. Basic DC Current and Resistance Measurement Circuits

5.2.7 The full range sensitivity of the A/D Converter is set for 200mV. The internal shunt resistance for each current equals 200mV divided by the full range current. For example, if the full range current is 200μA, the shunt resistance is 1000 ohms.

5.2.8 AC Current Measurements

The basic AC current measurement circuit is essentially the same as the DC current measurement circuit (refer to paragraph 5.2.6), except that the voltage developed across the internal shunt resistance is measured by the AC voltage measurement circuit.

5.2.9 Resistance Measurements

The basic resistance circuit is shown in Figure 5-3(B). The resistance being measured, Rx, is connected to the V-Ω and COMMON jacks and a constant current is applied through it by the Instrument. The resulting voltage is proportional to the value of Rx.

5.2.10 The operational amplifier bootstraps the constant current source. With the non-inverting input connected to the junction of Ra and Rx such that a constant voltage is maintained across Ra for a given range. The voltage developed is proportional to the value of Rx. For resistance ranges 200Ω through 2000 kΩ, the constant voltage maintained across Ra is 10 volts. In the 20 MΩ range, the feedback resistor, RF, is changed so that a 1 volt potential is maintained.

5.3 ANALOG-TO-DIGITAL (A/D) CONVERTER

5.3.1 The basic block diagram of the A/D Converter is shown in Figure 5-4. The analog-to-digital conversion is accomplished by the quantized Charge-Balance technique. An Auto-Zero circuit minimizes the effects of offset and drift for greater accuracy. Filtering and Over-Voltage Protection circuits are provided at the input to the A/D Converter.

5.3.2 Time Base Counter

An External Clock signal (approximately 18 kHz) drives a Two-Phase Clock Generator. The clock frequency is divided by the Time Base Counter into sampling intervals of 6144 pulses of which 4096

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constitutes the measurement interval and 2048 for the auto-zero interval.

5.3.3 Auto-Zero Interval

During the Auto-Zero interval, the Input Amplifier is switched to circuit common. A pulsed Reference Current is supplied to the Integrator/Comparator by the Control Logic circuit. The Auto-Zero circuit equalizes the Integrator/Comparator input and maintains the equalizing current during the measurement interval.

5.3.4 Measurement Interval

The input voltage is now connected to the Input Amplifier through a switch actuated by the Control Logic circuit. The Integrator/Comparator senses an imbalance which the Control Logic circuit attempts to equalize by pulsing the Reference Current. During the equalization process, the Counter/Latch accumulates a count proportional to the magnitude of the input voltage.

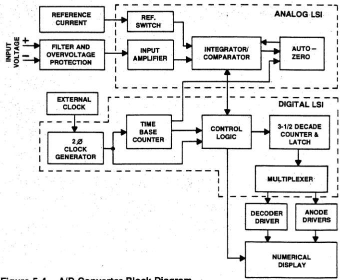

Figure 5-4. A/D Converter Block Diagram

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5.3.5 Digital Information and Multiplexed Display

At the end of the measurement interval, the Latch is up-dated and the Counter is cleared. The Multiplexer routes the BCD and digit outputs into the Decoder/Driver and Anode Drivers. The BCD data are decoded into a 7-segment format which are connected to the cathodes of the display. The digit outputs control the Anode Drivers which energizes the correct digit on the Numerical Display.

5.4 POWER SUPPLY CIRCUITS

5.4.1 AC Line Power

The AC line power supply is shown on Figure 7-1, Schematic Diagram. The incoming AC power is applied to the dual-primary power transformer T1. The two primary windings are connected in series for 240 VAC and in parallel for 120 VAC operation. The secondary windings generate step-down voltages to provide 2 regulated and 2 unregulated DC voltages.

5.4.2 Regulated DC voltages of +12V and −12V are produced by two full-wave rectifiers, followed by two series-type voltage regulators. These regulated voltages are used to supply power to the analog circuits.

5.4.3 A full-wave rectifier, followed by capacitor C25, provides an unregulated +5V supply to all digital integrated circuits and the LED display. An unregulated +15V supply is generated for operating the Resistance Converter.

5.4.4 Battery Power (Model 464D only)

The battery-operated power supply of the Model 464D is shown on Figure 7-1, Schematic Diagram. With the POWER switch ON, the battery is connected to the input of the DC-To-DC converter consisting essentially of T2 and transistors Q14 and Q15 in a multivibrator configuration. The multivibrator signal is coupled by T2 to the bridge rectifier and regulators to generate DC voltages of +12V, −12V, and +15V. The required +5 volt supply is provided by the battery.

5.4.5 The battery is charging whenever the Model 464D is connected to the AC line. A secondary winding from Transformer T1 and the associated rectifier provides power to operate a constant current source for charging the battery. The constant current source, consisting essentially of IC8 and Q19, provides a charging current of approximately 450 milliamperes when the Instrument is OFF. Approximately 50 milliamperes is supplied to charge the battery when the Instrument's POWER switch is set to ON.

5.4.6 When the Model 464D is operated with AC line power (no battery power) the battery-charging constant current source provides the +5V supply required for operation.

SECTION VI

MAINTENANCE

6.1 GENERAL

WARNING

This Instrument contains internal voltages which constitute a SHOCK HAZARD. Review what constitutes a SHOCK HAZARD as explained on page v. Internal adjustments or repairs should be performed only by qualified personnel (preferably a Simpson Authorized Service Center), who understand and can recognize what constitutes a SHOCK HAZARD.

The Simpson 464 is carefully designed and constructed with high quality components. By providing reasonable care and following the instructions in this manual, the user can expect a long, useful service life from his Instrument.

6.2 WARRANTY

The Simpson Electric Company Warranty policy is printed on the inside back cover of this manual. Read carefully before requesting a warranty repair.

NOTE: For assistance of any kind, including help with the Instrument under warranty, contact your nearest Authorized Service Center for instructions. These centers are listed on the last pages of the manual. If you wish to contact the factory directly, give full details of the difficulty and include the instrument model number, serial number and date of purchase. Service data or shipping instructions will be promptly sent to you. If an estimate of charges for non-warranty or other service work is required, a maximum charge estimate will be quoted. This charge will not be exceeded without prior approval.

6.3 SHIPPING

6.3.1 Pack the Instrument carefully and ship it prepaid to the proper destination. Insure the Instrument.

6.4 COVER REMOVAL

The bottom cover can be removed for maintenance purposes by the following procedures:

WARNING

Remove all power and connections to the Instrument before removing the case cover. Do not operate the Instrument with the bottom cover removed.

a. Depress the POWER switch to the OFF position.

b. Disconnect the line cord from the power source and all connections from the Instrument.

c. Pull out the knobs on sides of Instrument and raise the handle towards the rear of Instrument.

d. Turn the Instrument over and remove the four (4) screws in the rubber feet.

e. Lift bottom cover and remove handle.

f. Reverse this procedure when replacing the cover.

6.5 BATTERY INSTALLATION (Model 464D only)

6.5.1 Refer to Table 7-2 for recommended batteries.

CAUTION

Standard carbon zinc or alkaline "D" size cells can be used in an emergency. However, the power line fuse must be removed to prevent charging these cells in the Instrument. These cells do not have provision for pressure relief and can burst when charged. Immediately remove the cells when the emergency is over or when they are discharged and replace with nickel-cadmium cells at your earliest convenience.

6.5.2 Install the cells as follows:

a. Remove bottom cover (refer to paragraph 6.4). Remove the retainer tubings from the battery holder. Insert two cells into each retainer. Then install the combination into the holder. Insure that the cells are installed according to the polarity orientation designated on the battery holder label. **Failure to do so can damage the Model 464D.**

b. Check that the battery contacts are clean and making good connection.

c. Replace the bottom cover.

d. For battery recharging, refer to paragraph 6.6, below.

e. Test the battery according to paragraph 4.3.2.

6.6 BATTERY CHARGING (Model 464D only)

6.6.1 The battery is being charged at full rate when the POWER switch is set to the OFF position and AC power is applied to the *Instrument*. Approximately 16 hours are required to fully charge the battery in this mode of operation.

NOTE: If the battery voltage checks below +4.7 volts, charge the battery with the POWER switch set to OFF for at least 15 minutes before operating the Instrument.

6.6.2 The battery is being "trickle" charged whenever the Instrument is operated by the AC power line.

6.7 BATTERY CARE

6.7.1 Avoid discharging the cells completely. Check the battery voltage periodically using the BATTERY TEST jack (refer to paragraph 4.3.2). Charge the battery whenever the voltage is close to or below +4.7 volts.

6.7.2 Do not operate the Instrument with discharged cells. Make sure to recharge all newly purchased batteries (refer to 6.6.1 above) for at least 15 minutes before operating the Instrument.

6.7.3 Whenever the line cord is not connected and the Instrument is not in use, remember to set the POWER switch to the OFF position.

6.7.4 With nickel-cadmium cells installed in the Model 464D, avoid storing in an area where the temperature exceeds +60°C.

6.8 FUSE REPLACEMENT

6.8.1 The line and current fuses are mounted inside fuseholders on the main P.C. Board as shown in Figure 6-1. Use the following procedure to replace a fuse.

WARNING

Remove all power and input connections to the Instrument before removing bottom cover.

6.8.2 Remove bottom cover as described in paragraph 6.4.

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CAUTION

Do NOT replace a blown fuse with a fuse which has a larger rating or slower time lag characteristic than those specified.

6.8.3 Carefully lift the defective fuse from the holder and replace with appropriate fuse (refer to Table 7-2).

6.8.4 Replace the bottom cover.

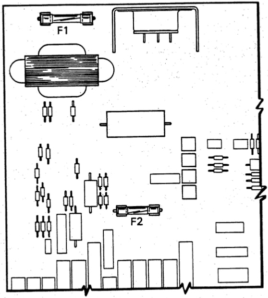

Figure 6-1. Model 464, Fuse Location

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6.9 PREVENTIVE MAINTENANCE

6.9.1 Daily Care

WARNING

Do not attempt to clean this Instrument with the test leads connected to a power source or when it is connected to the AC power line.

a. Immediately clean all spilled materials from the Instrument and wipe dry. If necessary, moisten a cloth with soap and water to clean plastic surfaces.

b. Do not allow the battery to fully discharge. A completely discharged battery generally becomes inoperative and a replacement will be necessary. Check the battery voltage according to paragraph 4.3.2.

c. Whenever possible, avoid exposure or usage in areas which are subject to temperature and humidity exposures, vibration or mechanical shock, dust or corrosive fumes, or strong electrical or electromagnetic interferences.

6.9.2 Monthly Care

Verify Instrument calibration by performing operational checks using known value sources. If the need for calibration is indicated, contact your nearest Authorized Simpson Service Center.

6.9.3 Annual Care

It is recommended that the Instrument be returned annually to a Simpson Authorized Service Center or the factory for a complete overall check and calibration.

6.9.4 Storage

When the Instrument is not in use, store it in a location free from temperature extremes, dust and corrosive fumes, and mechanical vibration or shock.

6.10 TROUBLESHOOTING

6.10.1 If the Instrument does not yield satisfactory results, follow this procedure, before attempting maintenance on the Instrument.

a. Review and comply with the Preliminary Notes and Checks, listed in paragraph 4.3.

b. Check that all switches are positioned correctly for the parameter and range of value being measured and that the measurement situation is within the ratings of the Instrument.

c. If the Model 464D has been operated with battery power, be sure that the cells are charged and properly installed (refer to paragraph 6.5).

d. If the Model 464A has been operated with AC power insure that power source is within the Instrument specifications, and free from excessive fluctuations and transients.

e. Insure that the environment in which the Instrument is being used is within the Instrument specifications.

f. Inspect the device being measured and the measurement test set-up to insure that proper shielding and grounding techniques have been used. Also consider whether the Instrument is significantly affecting the circuit being measured.

6.10.2 If the steps taken in paragraph 6.10.1 do not yield satisfaction, refer to the troubleshooting chart (Table 6-1). Direct all other repair and adjustment needs to a Simpson Authorized Service Center.

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Table 6-1. Troubleshooting Chart

Sympton	Probable Causes	Cure
1. No indication on numerical display when 464D is battery operated. AC operation is OK.	Cells — Discharged, defective, not installed properly, making poor contact, or missing.	Check battery voltage. Refer to para. 4.3.2. If OK contact nearest Simpson Authorized Service Center.
2. LOW intensity on numerical display in battery operation. (464D)	Cells not fully charged.	Check battery voltage. Refer to para. 4.3.2. If battery checks low, remove cover and check that the cells are installed correctly and making good contact. Refer to 6.5. If they are, replace cover and charge battery overnight. Refer to paragraph 6.6.
3. No indication on the numerical display when Instrument is AC line operated (no cells installed).	a. Low or no voltage at power source receptacle. b. Line cord disconnected. c. Defective line cord. d. Line fuse open.	a. Restore correct voltage at power receptacle. b. Connect line cord. c. Repair or replace line cord. d. Replace line fuse. Refer to 6.8.
4. Batteries do not respond to charge. 464D operation OK when connected to AC power.	Cells defective, not installed properly, making poor contact, or missing.	Remove cover and check that cells are installed correctly and making good contact. Refer to 6.5. If they are, check the voltages of the individual cells. Replace those which check significantly lower than normal (1.25 volts).

5. Operation normal on all functions and ranges except AC and DC Current.	Current fuse F2 open.	Replace fuse F2. Refer to 6.8.
6. Indications fluctuate and / or drift, even though indication is OK at 000 with the input terminals shorted, and at 1000 counts when using a stable and low impedance input.	Fluctuations and / or drift are being generated by the device being measured or the measurement test set up.	Use proper shielding, grounding techniques and connections to minimize "pick-up" of unwanted signals due to ground loops, poor connections, and capacitive and/or inductive coupling. Operate Instrument (464 D only) on battery for complete isolation from the power line. NOTE: If the drift and/or fluctuation is coming from the device being measured, no cure is required, the measurement is valid, and the device must be corrected.
7. Indication is OK on battery. However, on AC operation, the reading fluctuates and/or drifts at 0, with the input shorted, and/or at 1000 counts using a stable and low impedance input. (464D)	AC power source is low or fluctuating (including transients).	Correct the power source or use Instrument on battery.
8. Same as 7 above, except indication OK on AC but not battery operation.	a. Battery voltage low.	a. Check battery condition. Refer to para. 4.3.2. If not OK charge battery, refer to para. 6.6.

	b. One or more cells *defective*, not installed correctly.	b. Remove cover and check that cells are stalled correctly and making good contact. If OK, replace all cells temporarily with conventional carbon zinc "D" size cells for checking purposes only. If problem still exists, contact nearest Simpson Authorized Service Center.
9. Slow response. Operation OK when using a low impedance input.	Parameter being measured has a high source impedance.	None required.
10. Accuracy not within specifications when checked with a stable, higher accuracy (at least 5 times better) low impedance (voltage measurements) source.	a. Instrument is out of calibration. b. Instrument not zeroed properly.	Contact nearest Simpson Authorized Service Center.
11. Accuracy of Instrument is within specifications but measurements appears in error.	a. Instrument affects circuit being measured.	a. Study circuit being measured vs. Instrument specifications. Correct indications accordingly.
	b. Common and / or normal mode specifications is being exceeded.	b. Refer to cure in item 6 above.

SECTION VII

ORDERING INFORMATION, SCHEMATIC DIAGRAM, AND AUTHORIZED SERVICE CENTERS

Table 7-1. Items Furnished With Instrument

Quantity	Description	Part No.
1	Test Lead Set: One black and one red insulated lead having probe tips with provisions for screw-on alligator clips (one red and one black supplied).	10-830115
1	Power Cord	5-118916
1	Operator's Manual	5-118430

Table 7-2. Replacement Parts List

Reference Symbol	Description	Part No.
	Battery, "D" size, 1.25V, 4-Ampere-Hrs, Nickel-Cadmium, Eveready Type CH4 Rechargeable, or Equal	
F1	Fuse, Line (for 120V operation): 1/4A 250V Type 3AG, Normal Blow (for 240V operation): 1/8A 250V Type 3AG, Normal Blow	
F2	Fuse, Current, 2.5A, 125V, Type 8AG, Normal Blow	

( ) = Parts used on Model 464A only.
[ ] = Parts used on Model 464D only.
All other parts are common to both Models.

Reference Symbol	Description	Part No.
	AC Line Cord	5-118916
	Pushbutton, Black	5-118378
	Pushbutton, Red	5-118379
	Pushbutton, Gray	5-118086
	Alligator clips (without insulators)	1-115963
	Insulator, aligator clips, red	5-112479
	Insulator, aligator clips, black	5-111169
C1	Capacitor, 3.3 pF, 1 kV	5-117138
C2, 23	Capacitor, Variable, 5.5-60 pF, 100V	5-116235
C3	Capacitor, 390 pF ±5%, 250V	5-118405
C4	Capacitor, 470 pF ±5%, 500V	5-118406
C5	Capacitor, .22μF, ±10%, 630V	5-118449
C6,8,14 15, (18)	Capacitor, 15μF, 16V	5-115534
C7	Capacitor, .01μF, ±5%, 100V	5-117278
C9,10,17	Capacitor, .01μF, ±20%, 50V	5-113215
C11	Capacitor, 47 pF ±10%, 160V	5-115992
C12	Capacitor, .33μF, ±10%, 100V	5-118407
C13	Capacitor, .47μF, 16V	5-115530
C16	Capacitor, .0022μF, ±5%, 100V	5-117201
[C18]	Capacitor, 100μF, 10V	5-117050
C19, 21	Capacitor, .033μF, ±20%, 100V	5-117732
C20	Capacitor, .022μF, ±20%, 100V	5-116188
C22	Capacitor, .1μF, ±20%	5-113612
(C24,26)	Capacitor, 470μF, 25V	5-118408
[C25]	Capacitor, 2200μF, 16V	5-118084
(C25)	Capacitor, 4700μF, 10V	5-118083
[C26]	Capacitor, 10μF, 25V	5-118426
[C27]	Capacitor, 100μF, 25V	5-117737
[C28,29]	Capacitor, 3.3μF, 25V	5-118085
C30	Capacitor, 10μF, 50V	5-116969
C31	Capacitor, 100 pF ±20%, 1kV	5-113217
C32	Capacitor, 330 pF ±20%, 500V	5-112690

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Reference Symbol	Description	Part No.
C33	Capacitor, 100μF, 16V	5-118453
D1, 2	Diode, Silicon, 1N914 Selected	5-117379
D3,8,9 10, [19,20]	Diode, Silicon, 1N914	5-112004
D4,5,6,7	Diode, Silicon, 1N5059	5-113826
(D11,12,13) (14,15) 16 [17,18]	Diode, Silicon, 10D1	5-114005
ZD1	Diode, Zener, 1N936	5-118918
ZD2	Diode, Zener, 1N5239B	5-118917
ZD3	Diode, Zener, 1N4743A	5-112726
ZD4,(5)	Diode, Zener, 1N753A	5-112634
[RECT 1]	Diode, Bridge Rectifier, W005	5-115945
IC1	Integrated Circuit, Op. - Amp., LM301AH	5-115916
IC2	Integrated Circuit, Op. - Amp., LM308N	5-116598
IC3,[8]	Integrated Circuit, Op. - Amp., SN72741P	5-115928
IC4	Integrated Circuit, Timer, NE555V	5-117150
IC5	Integrated Circuit, Analog, LD111	5-117724
IC6	Integrated Circuit, Digital, LD110	5-117723
IC7	Integrated Circuit, 7-Segment Decoder-Driver, DM7447N	5-115927
DS1,2,3	Readout, LED, 7-Segment	5-117338
DS4	Readout, LED, ±1	5-117337
Q1,2,10 11,12,13 18	Transistor, Silicon NPN, 2N4123	5-115931
Q3	Transistor, FET, N-Channel, 2N5458	5-112747
Q4,5,17 (20)	Transistor, Silicon NPN Darlington, 2N5306	5-115938
Q6,7,8,9	Transistor, Silicon PNP, 2N3638	5-114106
[Q14,15]	Transistor, Silicon NPN, GET 2222	5-115934
Q16	Transistor, Silicon PNP, 1N5815	5-117720
Q19	Transistor, Silicon NPN Darlington, D40C1	5-118404
R1	Resistor, 9.90 MΩ ±.25% 2W	5-118897
R2	Resistor, 90 kΩ ±.25%, 1W	5-118897
R3	Resistor, 10 kΩ ±.25%, 1W	5-118897

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Reference Symbol	Description	Part No.
R6	Resistor, 0.897 Ω ±.5%, 1.5W	5-118409
R7	Resistor, 9 Ω ±.5%, 1 Watt	5-118410
R8	Resistor, 90 Ω ±.25%, 1/4 Watt	5-116272
R9	Resistor, 900 Ω ±.25%, 1/4 Watt	5-116273
R10,11,23	Resistor, 470 kΩ ±10%, 1/4 Watt	5-114983
R12	Resistor, 15 MegΩ ±10%, 1/4 Watt	5-118423
R13	Resistor, 100 kΩ ±10%, 2 Watt	5-116883
R14, 17	Resistor, 10 kΩ ±10%, 1/4 Watt	5-113624
R15	Resistor, 22 MegΩ ±10%, 1/4 Watt	5-118424
R16	Resistor, 10 MegΩ ±5%, 1/4 Watt	5-116632
R18, 39	Resistor, 120 kΩ ±5%, 1/4 Watt	5-113627
R19	Resistor, 4.7 MegΩ ±10%, 1/4 Watt	5-118422
R20, 21	Resistor, 10 kΩ ±.25%, 1/4 Watt	5-118413
R22	Potentiometer, 200 Ω ±20%, -2 Watt	5-118078
R24	Resistor, 448 Ω ±.25%, 1/4 Watt	5-118411
R25	Resistor, 4.08 kΩ ±.25%, 1/4 Watt	5-118412
R26	Resistor, 100 kΩ ±10%, 1/2 Watt	1-113949
R27	Potentiometer, 5 kΩ ±20%, 1/2 Watt	5-118080
R28	Resistor, 37.5 kΩ ±.5%, 1/4 Watt	5-118416
R29	Potentiometer, 1 kΩ ±20%, 1/2 Watt	5-118079
R30	Resistor, 4.0 kΩ ±1%, 1/4 Watt	5-117695
R31,32	Resistor, 36 kΩ ±1%, 1/4 Watt	5-118415
R33,34	Resistor, 10 kΩ ±1%, 1/4 Watt	5-114962
R73	Resistor, 330 Ω ±5%, 1/4 Watt	5-116091
R36	Resistor, 470 kΩ ±10%, 2 Watt	5-118421
R37	Resistor, 560 kΩ ±10%, 1/4 Watt	5-114984
R38 [83]	Resistor, 100 kΩ ±10%, 1/4 Watt	5-115514
R40	Potentiometer, 10 kΩ ±20%, 1/2 Watt	5-118081
R41	Potentiometer, 20 kΩ ±20%, 1/2 Watt	5-118082
R42	Resistor, 75 kΩ ±1%, 1/2 Watt	5-116921
R43	Resistor, 100 kΩ ±1%, 1/4 Watt	5-115506
R44	Resistor, 110 kΩ ±1%, 1/4 Watt	5-117519
R45	Resistor, 20 kΩ ±1%, 1/4 Watt	5-116621
R46,65,66	Resistor, 33 kΩ ±10%, 1/4 Watt	5-113875
R47	Resistor, 5.1 kΩ ±5%, 1/4 Watt	5-117714
R35	Resistor, 402Ω ±1%, 1/4 Watt	5-116772

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Reference Symbol	Description	Part No.
R48	Resistor, 15 kΩ ±5%, 1/4 Watt	5-116134
R49	Resistor, 10 Ω ±5%, 1/4 Watt	5-115117
R50,51,52 69,74	Resistor, 100 Ω ±10%, 1/4 Watt	5-114968
R53,54,55 68, [72]	Resistor, 1 kΩ ±10%, 1/4 Watt	5-113871
[R56-62]	Resistor, Network, 100 Ω	5-118094
(R56-62)	Resistor, Network, 68 Ω	5-118425
[R63,64]	Resistor, 100 Ω ±, 1/4 Watt	5-117178
(63,64) [67]	Resistor, 68 Ω ±5%, 1/4 Watt	5-118419
(R67)	Resistor, 47 Ω ±10%, 1/4 Watt	5-114967
R70	Resistor, 220 Ω ±5%, 1/4 Watt	5-117179
[R71]	Resistor, 270 Ω ±10%, 1/4 Watt	5-114969
R75	Resistor, 68 kΩ ±10%, 1/4 Watt	5-115962
R76	Resistor, 750 Ω ±5%, 1/4 Watt	5-116366
R77	Resistor, 22 kΩ ±5%, 1/4 Watt	5-117196
R78	Resistor, 27 kΩ ±5%, 1/4 Watt	5-118431
[R79]	Resistor, 390 Ω ±5%, 1/4 Watt	5-118420
[R80]	Resistor, 18 kΩ ±10%, 1/4 Watt	5-115512
[R81]	Potentiometer, 1 kΩ ±30%, 1/4 Watt	5-114069
[R82]	Resistor, 0.5 Ω 1%, 1 Watt	5-113998
	Switch, pushbutton, 12 Station	5-118077
T1	Transformer, Power	5-118376
[T2]	Transformer, DC-DC Converter	5-118377

OBSOLETE

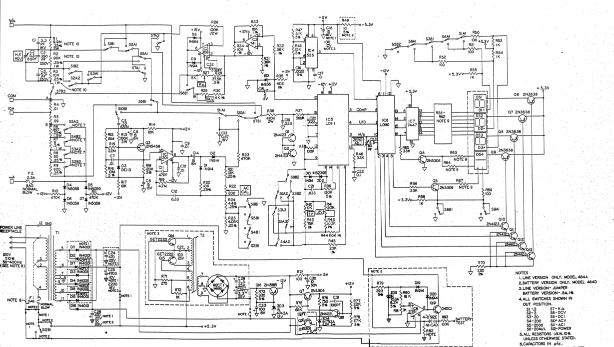

Figure 7-1. Model 464, Schematic Diag

NOTES

1. LINE VERSION ONLY. MODEL 464A
2. BATTERY VERSION ONLY. MODEL 464D
3. LINE VERSION- JUMPER
   BATTERY VERSION-.5Ω.1%
4. ALL SWITCHES SHOWN IN OUT POSITION.

S1 -.2	S7 - KΩ
S2 - 2	S8 - DCV
S3 - 20	S9 - DCI
S4 - 200	S10 - ACV
S5 - 2000	S11 - ACI
S6 - 20MΩ	S12 - POWER

5. ALL RESISTORS 1/4W, 10% UNLESS OTHERWISE STATED.
6. CAPACITORS IN μfd.
7. MAKE BEFORE BREAK CONTACTS.
8. FOR 120V JUMPER PIN 1 TO PIN 2 AND PIN 3 TO PIN 4. F1 = 1/4 AMP. FOR 240V JUMPER PIN 2 TO PIN 3. F1 = 1/8 AMP.
9. LINE VERSION: R56-R64 = 68Ω.5%
   R67 = 47Ω
   BATTERY VERSION: R56-R64 = 100Ω.5%
   R67 = 68Ω.5%
10. R1, R2 AND R3 ARE RATIO MATCHED TO ±.05%.

OBSOLETE