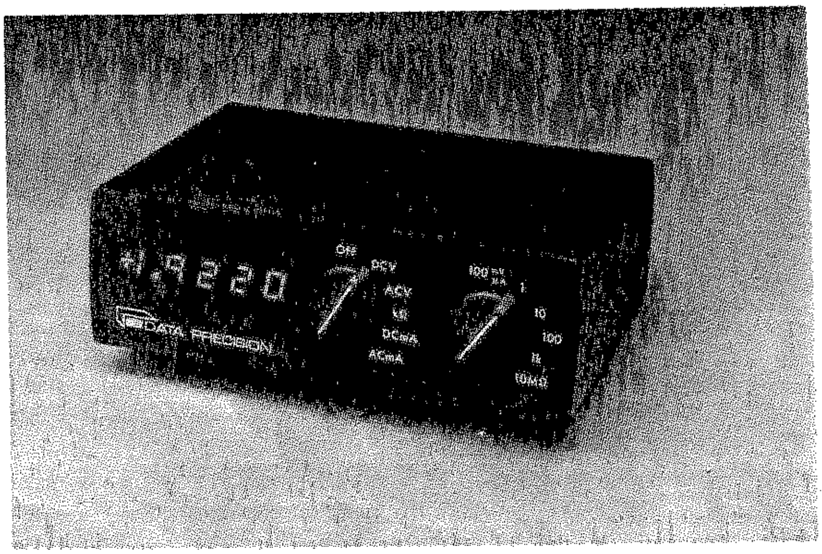
Miniature
Portable
4-½ Digit
TRUE RMS
Digital Multimeter

MODEL 248

Specifications
Operation
Theory of Operation
Maintenance
Parts Lists
Schematics



FRONTISPIECE- MODEL 248 DMM

3rd Issue, November 1978

PROPRIETARY NOTICE

The information contained in this publication is derived in part from proprietary and patent data of the Data Precision Corporation. This information has been prepared for the express purpose of assisting operating and maintenance personnel in the efficient use of the Model **248** *Digital Multimeter, and publication of this information does not convey any rights to reproduce it or to use it for any purpose other than in connection with the installation, operation, and maintenance of the equipment described herein.*

Chapter 1

INTRODUCTION

1.1 GENERAL

a. Data Precision Model 248 4½ digit multimeter (DMM) (frontispiece) is a miniature, rugged, battery-powered (or line-charged battery), portable meter for measuring DC or AC voltages, DC or AC currents, and ohmic resistances with 0.005% resolution in 25 ranges with 100% overrange. The Model 248 like its predecessor Model 245, uses the field-proven Tri-Phasic^{TM} analog-to-digital conversion, Isopolar^{TM} reference, and Ratiohmic^{TM} resistance measurement technique. In addition, the Model 248 incorporates true RMS sensing on AC inputs.

b. The Model 248 DMM is complete, including carrying case, wrist strap, test probes, battery pack with rechargeable batteries, charger with integral line cord, and this complete instruction manual. Performance-extending accessories are available and are listed in paragraph 1.4.

1.2 OPERATING & DESIGN FEATURES

a. Model 248DMM is operated simply by selecting the measuring function with one front-panel rotary switch and an appropriate range with the other. The measured input signal including sign and decimal point is displayed on 7-segment planar LED characters. All measured values are direct reading as determined by the selected function and range. Out-of-range inputs (overload) are indicated by a blanked display (decimal point and polarity sign, if appropriate, remain lighted).

b. A nominal full scale sensitivity of 100mV, 1 Kohms, or 100 microamps is available for voltage, resistance, or current measurements, respectively, providing a resolution of 10 microvolts, 100 milliohms, and 10 nanoamperes. Measurements up to 100% overrange may be made on each range scale (except for voltage on the highest range) with the same high accuracy as for in-range measurement on each scale. Model 248 DMM incorporates protection circuitry to permit maximum input signals (within specifications) to be applied indefinitely on any selected range, without damage.

c. A fully-charged battery pack will supply 6 hours of in-specification operation; it can be recharged fully overnight (12 hours). Moreover, the batteries are always being recharged when the battery charger is connected, whether the meter is turned on or off. Power consumption is less than 1 watt from the battery and slightly more than one watt from AC mains when operating the charger. Battery drain and parts count are minimized by the use of a proprietary LSI/CMOS chip which performs all the logic functions required by the A/D converter.

1.3 SPECIFICATIONS (For 1 year, without recalibration)

1.3.1 DC Volts

Range	Full Scale	Resolution
100mV	± 199.99mV	10µV
1	± 1.9999V	100µV
10	± 19.999V	1mV
100	± 199.99V	10mV
1k	± 1000.0V	100mV

Input Impedance: 10MΩ all ranges.

Maximum Voltage: ±1000V, all ranges.

Accuracy: (24 hrs., 23°C ±1°C): ±0.03% inp ±1 lsd
(1 year, 23°C ±5°C): ±0.05% inp ±1 lsd
Add ±0.00001% (0.1 ppm) of inp/volt on 1k range.

Temperature Coefficient: (0°C to 40°C, all ranges): (±0.003% inp ±0.001% f.s.)/°C.

Common Mode Voltage: 500 VDC (or peak AC) max when connected to AC power power line.
1000 VDC (or peak AC) max when on battery operation (for safety).

Common Mode Rejection Ratio:
(with 1000 ohm source impedance unbalance)
AC line operation: >120dB @ dc.
>100dB @ 50Hz and @ 60Hz
Battery operation: Essentially infinite @ dc
>120 dB @ 50Hz and @ 60Hz

Normal Mode Rejection Ratio: 50 dB @ 50Hz and @ 60 Hz

1.3.2 AC Volts (True RMS Sensing)

Range	Full Scale	Resolution
100mV	199.99	10µV
1	1.9999	100µV
10	19.999	1mV
100	199.99	10mV
500VAC*	500V*	100mV

*See maximum input voltage limits below.

At frequencies greater than 1kHz with display greater than 10% of full scale.

To obtain optimum resolution and stated accuracy:
1. Decrease range from maximum to obtain overrange indication.
2. Select next highest range.

Input Impedance: 10MΩ in parallel with 75pF or less.
Sensing and Calibration: True RMS
Accuracy: (1 year @ 23°C ±5°C).

Frequency*	Inaccuracy
30Hz	±(1% input + 0.5% f.s.)
50 Hz to 500 Hz	±(0.4% input + 0.2% f.s.)
2kHz to 20kHz	±(1.0% input + 0.2% f.s.)

*Interpolate linearly between frequency end points.

Temperature Coefficients (0°C to 40°C, all ranges):

Frequency*	Coefficients
50 Hz to 500 Hz	± (0.02% input + 0.02% range)/°C
2kHz to 20kHz	±(0.1% input + 0.02% range)/°C

*Interpolate linearly between frequency end points

Maximum input voltage (sinewave)

30Hz to 10kHz:	500 VRMS
>10kHz	Decreasing to 250 VRMS @ 20KHz

Settling Time: 2.5 seconds max. to ±0.1% of final reading for full-scale step input change.

1.3.3 Resistance

Range	Full Scale	Resolution	Maximum Test Current
1	1.9999kΩ	100mΩ	1.8mA
10	19.999kΩ	1Ω	330μA
100	199.99kΩ	10Ω	35μA
1k	1999.9kΩ	100Ω	3.5μA
10MΩ	19.999mΩ	1000Ω	0.35μA

Accuracy (1 year, @ 23°C ±5°C):

Range	Inaccuracy
1, 10, 100	±(0.07% input + 1 l.s.d.)
1k	±(0.1% input + 1 l.s.d.)
10MΩ	±(0.25% input + 1 l.s.d.)

Temperature Coefficient (0°C to 40°C):

Range	Coefficient
1, 10, 100	±(0.005% input + 0.001% range)/°C
1k	±(0.01% input + 0.001% range)/°C
10M Ω	±(0.02% input + 0.005% range)/°C

Measuring Configuration: 2-wire

Maximum Open Circuit Voltage: 3.5 Volts

Maximum Input Voltage: 250 VRMS AC or DC

Settling Time: 0.7 + (0.3) (Resistance in MΩ)

1.3.4 DC Current.

Range	Full Scale	Resolution
100μA	±199.99μA	10nA
1	±1.9999mA	0.1μA
10	±19.999mA	1μA
100	±199.99mA	10μA
1k	±1999.9mA	100μA

Maximum Current: Limited to 2A by series fuse(250V) located in red probe
Nominal Full Scale Voltage Across Shunts: 100mV
Accuracy (1 year, @ 23°C ±5°C): ±(0.3% input + 1 l.s.d.)

Range	Inaccuracy
100μA, 1, 10	±(0.1% input + 1 l.s.d.)
100, 1K	±(0.2% input + 1 l.s.d.)

Temperature Coefficient (0°C to 40°C):

Range	Coefficient
100μA, 1, 10	±(0.01% input + 0.001% f.s.)/°C
100, 1K	±(0.02% input + 0.001% f.s.)/°C

1.3.5 AC Current (True RMS Sensing)

Range	Full Scale	Resolution
100μA	199.99μA	10nA
1	1.9999mA	100nA
10	19.999mA	1μA
100	199.99mA	10μA
1k	1999.9mA	100μA

Maximum Current*: Limited to 2A by series fuse (250V) located in red probe.
*CAUTION: Protection is defeated if fused probe is not used.

Nominal Full Scale Voltage Across Shunts: 100mVRMS

Accuracy (1 year, @23° ±5° C):

Frequency*	Inaccuracy
30Hz	±(1.5% input + 0.5% f.s.)
50Hz to 500Hz	±(0.75% input + 0.2% f.s.)
2kHz to 20kHz	±(1.5% input + 0.2% f.s.)

*Interpolate linearly between frequency end points.

At frequencies greater than 1kHz, with display greater than 10% of full scale.

Temperature Coefficients (0° to 40°C):

Frequency*	Coefficient
30Hz to 500Hz	±(0.03% input + 0.02% f.s.)/°C
2kHz to 20kHz	±(0.1% input + 0.02% f.s.)/°C

*Interpolate linearly between frequency end points.

To obtain optimum resolution and stated accuracy;

1. Decrease range from max. to obtain overrange indication.
2. Select next highest range.

1.3.6 All Measuring Modes

Reading Rate: 2.5 readings/second

Polarity: Automatic plus (+) or minus (–) displayed for all dc measurements

Overload: Indicated by blanking of all digits; decimal point and polarity (if appropriate) remain lighted.

Power Supply: Battery pack with 6 NiCd batteries. Recharging requires approximately 12 hours. Battery charger operates from 105-125V (47 to 400Hz). Model 248E operates from 220-250V (47 to 400Hz). Charged battery provides up to 6 hours of operation.

Power Consumption: 0.75W battery operation

Low Battery Indication: Decimal point blinks @ 2.5/second for approximately 5 minutes before discharge.

Environment:

Temperature Range: Operating, $0^{\circ}C$ to $40^{\circ}C$
Storage, $-25^{\circ}C$ to $+50^{\circ}C$

Humidity: 80% RH, $0^{\circ}C$ to $40^{\circ}C$, noncondensing

Physical:

Size: 5½" w x 1¾" h x 3½" d. (13.97 x 4.45 x 8.89 cm)

Weight: 1.3 lb. net; 3 lb. packed for shipping (0.63 kg)

1.4 Accessories (Supplied as Standard shown by *)
(Supplied for Model 248E shown by **)

Name	Data Precision Model No.
Bench Stand	B40
Battery Module (Spare)	CP50
Test Leads (Spare) (Set of two) (Fuse, 3AG, 2amp Fast-Blo) (Part No. 25-500002)	T4*
Charger/Line Cord (105-125V)	L15*
Charger/Line Cord (220-250V)	L30**
High Voltage Probe (to 40kV)	V40A
Current Probe to 150 amp	IP150
Leather Case	WE8
Adaptor, Std. Banana to Mini Banana	MB2
Rack Mount	R35

Chapter 2

OPERATION & CALIBRATION

2.1 GENERAL

a. Model 248 4½ digit Multimeter has been shipped with a fully charged battery pack, and should be usable immediately upon opening the box and attaching the probe leads.

b. This chapter contains:

(1) an inventory list of what you should find upon opening your packing carton;

(2) a complete description of the operating controls and indications;

(3) a step-by-step procedure for operating the instrument in any of its 6 measuring functions.

(4) a procedure for determining when to recalibrate the meter; and

(5) application notes to help obtain the measurement accuracies of which the meter is capable.

2.2 UNPACKING & REPACKING

a. Model 248 is shipped in a molded protective fitted container. This manual has been packed in a recess at the top of the outer protective layer, and should be read before attempting to use the meter. When the protective box is opened, you should find the following items inside the flexible fitted carrying case:

(1) Model 248 4½ digit Multimeter with attached wrist strap and battery pack module inserted;

(2) Line cord with attached battery charger unit; (Charger L15 for 105-125V) (Charger L30 for 220-250V);

(3) Two probes (Red probe fused with 2A (250V) fuse; (Alligator clips & spare fuse.)

(4) Certificate of Conformance and copies of authenticated Factory Test Data Sheets;

(5) Warranty Card.

b. Carefully examine these articles, noting especially the matching serial numbers of the instrument and the test data. Inspect the packing case and the instrument for any signs of damage during shipment and report immediately to the carrier. Fill out and return the warranty card to register your instrument and to establish your warrantied service interval.

c. Accessories, such as bench stand, spare charger, spare battery pack, or high voltage probes, may have been ordered. These will be shipped in their own containers.

d. Retain the packing material for reshipment.

e. When shipping Model 248 DMM, place the instrument in its protective carrying case, including test probes and battery charger. Use foam liners and pack in original shipping carton, if available.

If original shipping carton is no longer available, wrap the instrument (in its carrying case as above) with a foam-type insulation or air bubble plastic and pack in a suitable carton. Use sufficient stuffing to keep the unit securely positioned in the carton.

f. If the Model 248 DMM is to be kept stored without use for any appreciable time (6 months or more), the batteries should be recharged every 6 months.

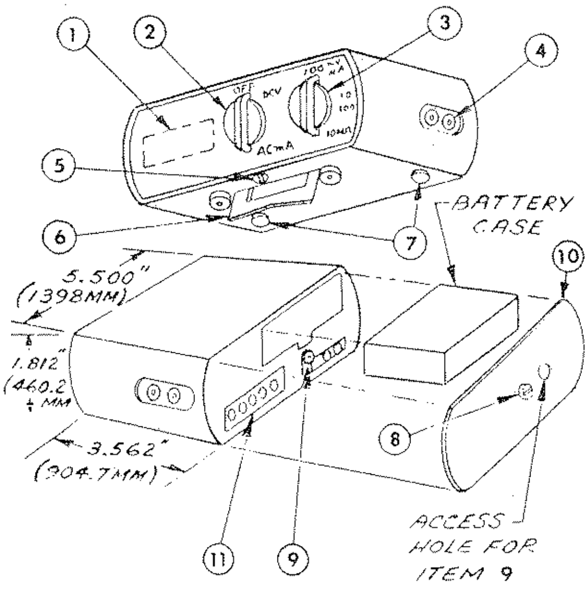


Fig. 2-1. Outline Dimensions & Features

2.3 KEY POINTS ON YOUR MODEL 248 DMM (Figure 2-1)

Fig. Ref.	Item	Functional Description
1.	Display Area	Automatic polarity indication; decimal digits plus overrange "1"; and range-scale selected decimal point display.
2.	Function Switch	Rotary 6-position switch. Selects one of five measuring functions or disconnects battery power (OFF).
3.	Range Switch	Rotary 6-position switch. Selects one of six full scale display values and corresponding decimal points for voltage, current, and resistance measurements.
4.	COM, HI	Receptacles for probe leads, common and high.
5.	Assembly Screw	Slotted screw fastens meter assembly to case.
6.	Flip-Down Tilt Leg	Recessed hinged leg to support meter in tilt position.
7.	Non-skid pads	2 pads to prevent meter from sliding on smooth surfaces.
8.	Screw	Holds rear cover in place.
9.	Charger Input	Receptacle for charger input.
10.	Rear Cover	Removable cover to permit access to calibrating adjustments, and to remove battery.
11.	Adjustments	7 calibrating adjustments.

2.4 OPERATING PROCEDURES

2.4.1 General

Operate your multimeter in the following sequence for most efficient use:

a. If line power is to be used, attach battery charger output to meter at rear panel connector; then plug in battery charger to appropriate AC power line. See power data on charger label. Do not remove battery pack. Battery pack must always be installed for proper operation.

b. Turn the instrument on by selecting the desired measurement function with Function Switch. . .DCV, ACV, etc.

c. Select the appropriate full scale range. . .1K, 100, 10, etc.

d. Connect test leads to meter and apply probes to circuit under test.

e. Read display.

f. Select range for highest resolution capability.

2.4.2 Applying Power

a. The Model 248 4½ digit multimeter may be operated from power supplied by the internal battery module containing six rechargeable NiCd batteries. The batteries will supply up to six hours of in-spec operation when fully charged. Completely discharge the batteries before recharging. Recharging requires approximately 12 hours. The meter may also be operated from AC line power, where available, without disconnecting the batteries. Use the AC charger and integral connecting cable supplied with the instrument. The standard Model 248 is shipped with a charger that operates from 105-125V AC; Model 248E is shipped with a charger intended for 220-250V AC. When the line cord and battery charger are connected, the batteries are always charging, even when function switch is in the off position. A protective circuit prevents overcharging the batteries. For extended field use without access to charging power, an extra battery module is recommended.

b. Low battery power is indicated by a blinking decimal point in the display, and approximately 5 minutes of useful battery power remains when the display first starts to blink.

2.4.3 Selecting Measuring Function

The left-hand seven-position rotary Function Switch makes the required internal connections to measure DC volts, AC volts, Kilohms (3.5V excitation), DC milliamperes, or AC milliamperes. The OFF position disconnects battery power from the circuitry but does not disconnect the charging circuit, if AC power is connected. The switch positions are as shown in Table 2-1.

2.4.4 Selecting Range

The right-hand rotary Range Switch selects the full scale sensitivity of the measurement and simultaneously positions the decimal point for direct reading in the selected units. The switch positions and the full-scale readings are shown in Table 2-2. Note that the highest scale position provides for 10MΩ for resistance measurements, 500 VAC for ACV measurements, 1000 DCV on DCV measurements, and 1000 mA on current measurement (DCmA and ACmA).

CAUTION

When making voltage measurements, exercise care that the source signal does not include high voltage spikes which could be injurious to personnel or equipment.

2.4.5 Connecting the Inputs

Connect the probes: red probe lead to the HI receptacle and the black probe lead to the COM receptacle of the meter. Measurements made at the sensing ends of the probes will be the value of the HI input with respect to the COM input. If the meter reads + 17.725 volts DC, then the HI (red-lead) is 17.725 volts more positive than the COM (black-lead) terminal.

Table 2-1 Function Switch Selections

FUNCTION SWITCH POSITION (clockwise from OFF)	PARAMETER MEASURED
DCV	DC voltages up to 1,000 volts.
ACV	Up to 500 VRMS of true RMS AC voltage, from 30Hz to 10KHz, decreasing linearly to 250V at 20KHz.
kΩ	Resistance up to 20 megohms with maximum open-circuit voltage of 3.5V. Able to withstand connected external voltage of 250 VRMS AC or DC.
DCmA	Direct Current in milliamperes, up to 2,000mA, protected by 2-ampere fuse rated at 250V in red input probe.
ACmA	Alternating Current in milliamperes. Up to 2,000mA of true RMS inputs, protected by 2-ampere fust (250V) in red input probe.

2.4.6 Reading the Display

a. DC polarities are automatically indicated on the display, and reflect the polarity of the HI signal with respect to the COM.

b. Overrange values up to 100% above the selected range will be measured and displayed. The maximum indication is 19999 with the appropriate decimal point location. (See exceptions for maximum voltages per specifications.)

Table 2-2 Range Switch Selection

Switch Position Marking (Clockwise from top)	Nominal Range	Overrange Full Scale Value	Units		
			Voltage	Current	Resistance
100(mV, μA)	100.00	199.99	mV	μA	–
1.0	1.0000	1.9999	V	mA	kΩ
10	10.000	19.999	V	mA	kΩ
100	100.00	199.99	V	mA	kΩ
1K/500VAC	1000.	(Note 1)	V	mA	kΩ
10MΩ	10.000	19.999	–	–	MΩ

(Note 1): See specification para 1.3 for overrange limits on these scales.

c. Overload measurements of more than 100% above the selected range are indicated by a blanking of all digits, leaving only the polarity of overload and decimal point display lighted. For example, if the applied signal is more than +19.999 volts on the 10 volt full scale range, only the + sign and the decimal point will appear.

d. Values on the display are interpreted directly in engineering units defined by the setting of the function switch and scaled by the setting of the range switch. The table below illustrates the interpretation of various displayed values for appropriate range scales and function modes.

Displayed Value	Function	Range	Interpretation
+1.2345	DCV	1	1.2345 volts positive DC
1.2345	kΩ	1	1.2345 kilohms
12.345	kΩ	10	12.345 kilohms
1234.5	kΩ	1K	1,234.5 kilohms or 1.2345 megohms
12.345	kΩ	10MΩ	12.345 megohms
+ .	DCV	10	Input is greater than +19.999 VDC
.	kΩ	10MΩ	Input is greater than 19.999MΩ

2.5 CALIBRATION

a. The Model 248 Digital Multimeter is factory calibrated and burned-in prior to shipment, and is designed to remain in calibration for a minimum of 1 year before the recalibration procedure should be required. The complete set of factory test data sheets for each instrument is shipped with the meter, and may be referenced to determine the need for calibration.

NO ZERO ADJUSTMENT IS EVER REQUIRED ON ANY MEASUREMENT FUNCTION OR RANGE SCALE AND NONE IS PROVIDED

b. When calibration is required, test standards of the ranges and accuracies listed below should be used to eliminate any test standard uncertainty.

Parameter	Range	Accuracy Tolerances
DC Voltage	0 to 10V	±0.005%
AC Voltage		
@ 500Hz	0 to 10V RMS	±0.01%
@ 10kHz	0 to 500.0V RMS	±0.02%

c. Calibration Adjustments are accessible through the rear panel, behind the removable cover plate in the lower left corner. Lift out the cover plate by inserting a small tool in the hole and lifting out. The circuit reference designations are stamped on the rear panel for each of the seven adjustments.

d. Perform the adjustments in the sequence tabulated below. Apply test input standards of amplitude and frequency as close as possible to the values listed in the table. Adjust the designated control until the display is the input (or the designated reading). If available test standards do not develop the listed values, then the closest value to the specified input should be used and the control adjusted accordingly. It is desirable to use signals at least 50% of the full scale value for the specified range.

CALIBRATION SEQUENCE

Step	Function Select	Range Select	Test Input	Adjust for Input/or Record
1.	DCV	1	+1.9000 VDC	R31 for +1.9000
2.	DCV	100mV	+100.00mVDC	R36 for + 100.00
3.	ACV	1	1.0000V @ 100Hz	R18 for 1.0000
4.	ACV	100mV	100.00mV @ 100Hz	R12 for 100.00
5.	ACV	1K	500V @ 10KHz	C4 for 500.0
6.	ACV	100	50V @ 10KHz	C10 for 50.00
7.	ACV	100	100V @ 10KHz	Record Display
8.	ACV	10	10V @ 10KHz	Record Display Adjust C6 until Display is 2/3 between Step 7 and value first recorded in Step 8.
9.	ACV	10	Same as Step 8	C4 for 10.000
10.	Repeat Steps 7, 8, and 9.			

2.6 APPLICATION NOTES

2.6.1 General

Optimum performance is obtained from your Model 248 by observing a number of precautions in establishing the test measurement conditions. The few hints included in these paragraphs are only indicative of the types of measuring environment problems which may influence the meter performance. It is suggested that the user record his own application aids as he determines them.

2.6.2 Avoiding Ground Loops (Making Grounded Measurements)

If the battery charger/line cord is connected, a potential difference may exist between the "ground" of the power source and the "ground" of the measured circuit. This difference of ground potentials may set up ground-loop currents and affect the measured values although the instrument will reduce their effects significantly (CMRR = 120dB, NMR = 50B). The ground loop effects can be avoided almost completely by operating the meter on batteries.

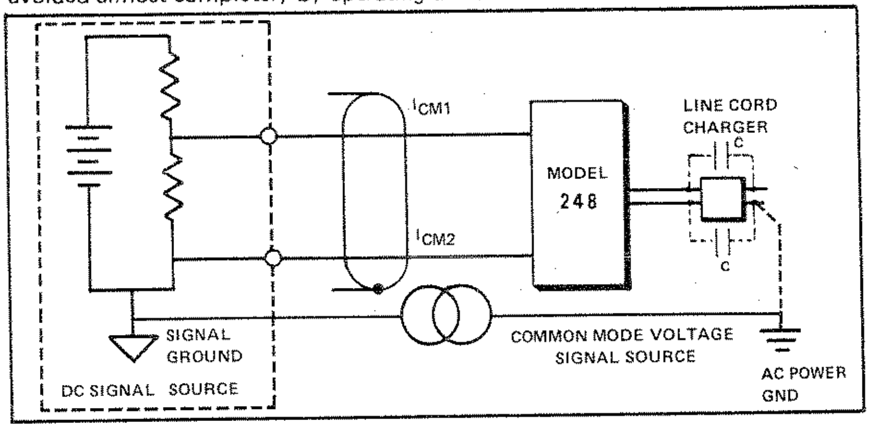


Fig. 2-2. Ground Loop Voltage Generation

2.6.3 Making "Floating" Measurements

In a floating measurement, such as in figure 2-3, it is possible to introduce a common mode voltage by reactive coupling through the AC power line when that source of Model 248 power is connected. As in paragraph 2.6.2, although this effect is small, it may be avoided almost completely by disconnecting the AC power source and reverting automatically to battery power.

2.6.4 Making High Resistance Measurements

a. When making measurements of very high impedance sources, as when required to measure resistance on the 10MΩrange, the input circuit may be susceptible to noise. The effect of voltage-producing noise fields on the probe leads may be sufficient to introduce significant changes in the least significant digit of the display.

b. Measurement errors may be kept to a minimum under these circumstances by keeping the leads as short as possible (do not use any extensions on the probes), and by twisting the probe leads so as to equalize any field effects on the signal input leads.

NOTE: It is good practice to twist probe leads whenever possible in order to equalize any field effects on the the signal input leads.

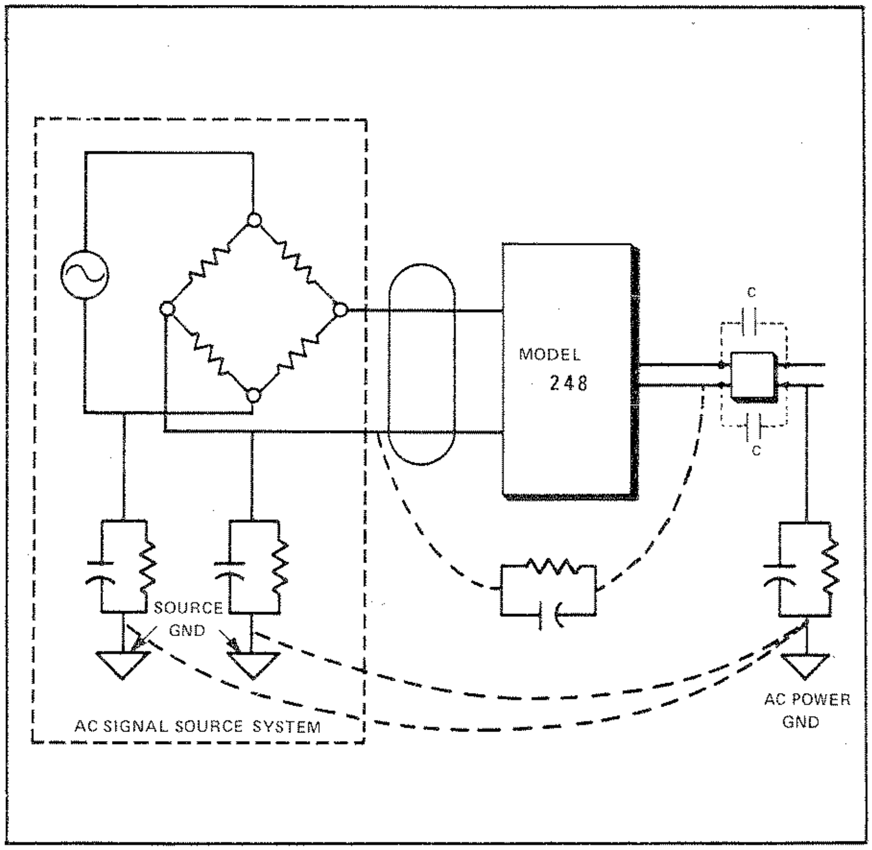


Fig. 2-3. Induced AC Common Mode Voltages

2.6.5 Making Very Low Voltage Measurements

Problems may arise when measuring very low voltages because of the differences in temperature of the probe contact points. Both probes are plated brass, and if the HI probe is in contact with copper in a high ambient temperature (for example, in a computer tape drive mechanism), while the COM probe is grounded at a very much cooler steel cabinet frame, then a difference in emf of several hundred microvolts may result, changing the least significant digit. In order to minimize such errors, connect the probes wherever possible at approximately the same temperature.

2.6.6 Making AC Measurements of Complex Waveforms

To obtain optimum performance of Model 248DMM, use the range indicated in Table 2-4 when measuring waveforms whose complexity is described by the crest factor, CF (CF = Peak Voltage ÷ RMS Voltage). All selections are subject to the requirement that ac voltage must not exceed 750 V-peak to avoid instrument damage.

TABLE 2-4

FOR CREST FACTOR	SELECT MODEL 248DMM RANGE
Up to 2.5	For displayed RMS values up to maximum possible on the selected range.
2.5 to 5.0	For displayed RMS values up to 100% of nominal range, (50% of maximum possible on the selected range).

2.6.7 Making DCV Measurements in the Presence of AC Interference

Input dc voltages are frequently measured in circuits that inject an ac voltage in series with the unknown dc input signal. These "normal mode" interference signals are rejected by the Model 248 circuitry in accordance with the NMRR specifications in Chapter 1. The extent to which the ac component of the dc signal is attenuated depends upon the frequency of the ac interference. At 50 and 60 Hz, the ac signal amplitude is attenuated by a factor of at least 300 (50dB).

Chapter 3

PRINCIPLES OF OPERATION

3.1 INTRODUCTION

Model 248 DMM is triggered internally to initiate a 3-phase measurement cycle. During Phase 1 the meter circuits are automatically servoed to determine the correction for the accumulated zero offsets in the analog integrator loop. In Phase 2 the signal to be measured, which has been conditioned according to the type of signal (AC, DC, or Ohms) and selected range scale, is connected in series with the zero offset correction to the dual slope A/D converter integrator which integrates the conditioned input for a fixed time interval of 100 milliseconds. After the fixed time interval of Phase 2, Phase 3 begins, in which the input signal is disconnected from the A/D converter, and in its place a reference signal of opposite polarity and fixed magnitude is connected in series with the zero offset correction. The integration of the reference signal continues in Phase 3 until this second ramp of the dual ramp A/D converter reduces the voltage on the integrating capacitor to zero. The zero level on the integrating capacitor is sensed and indicates the End of Conversion (EOC) if it occurs in 200 msec or less during Phase 3. If there has not been an EOC signal within 200 msec in Phase 3, the meter interprets this as an overload condition. It quickly ends Phase 3 via a fast time discharge and initiates Phase 1 to restart the conversion cycle. The fast time constant introduced into the capacitor discharge circuit assures that the auto-zeroing integration in Phase 1 will start from zero conditions after an out-of-range input. The overload sense circuit also initiates the development of logic control signals for the overload display.

3.2 OVERALL BLOCK DIAGRAM

As shown in Fig. 3-1, the meter consists of the following major functional sections:

a. Input Signal Conditioners (Excitation, Dividers, Shunts, AC/DC Converter)

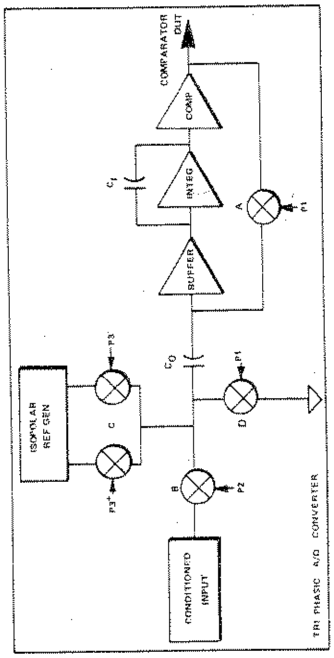
b. Tri-Phasic^{TM} Analog-to-Digital Converter.

c. Digital Logic Programmer and Master Timing Oscillator.

d. Isopolar Reference Generator.

e. Display (Decoder and Scanner).

f. Power Supply (Including DC/DC Converter and Reference).



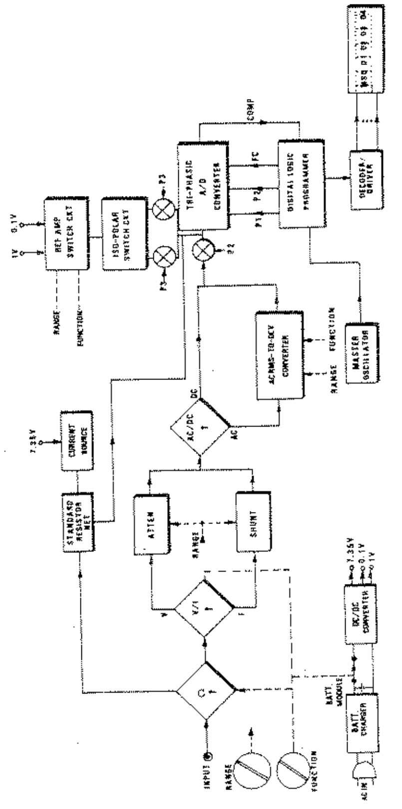


Fig. 3-1. Overall Block Diagram

3.2.1 Input Signal Scaling

a. The output count n, of the Tri-Phasic A/D converter is determined by the formula

$$n = K\frac{V_{COND}}{V_{REF}}$$

where n = The count accumulated in the output register during Phase 3

V_{COND} = The conditioned voltage amplitude input to the A/D during Phase 2.

V_{REF} = The reference voltage amplitude input to the A/D during Phase 3.

K = scaling constant, determined by the timing clock counter input to the accumulating register.

Thus, as shown in Figure 3-1, the digital value will be scaled by the combined effects of the input voltage attenuator or current shunt, the gain through the AC/DC converter (for AC inputs), the selected reference voltage amplitude, and the gain of the A/D. Table 3-1 summarizes the relationship of the gain factors for each range and in each function mode.

b. An input voltage signal is conditioned by the voltage attenuator and an input current by a current shunt. The development of a conditioned voltage across an unknown input resistance is described in some detail in a subsequent paragraph.

3.2.2 A/D Converter

The analog section of the Tri-Phasic Analog-to-Digital Converter includes an input buffer stage, integrator, and comparator, connected as shown in a very simplified schematic of Figure 3-1. They function as follows during the three phases of Tri-Phasic operation.

a. Phase 1

During Phase 1 the analog section automatically zeros the unit to correct for the zero offsets inherent within the analog functioning elements. During this phase, switch A and switch D are closed, removing the conditioned input, and grounding the input to the high input impedance unity gain amplifier. As a result, the closed loop servos the output of the A/D comparator to near-zero. At

TABLE 3-1
MODEL 248
GAIN FACTOR TABLE

Measure Mode	Range Selected	Input Atten/Shunt	AMP + AC to DC RMS to DCV	Selected DC Ref Voltage Amplitude	A/D Input AMP
DCV	.1	1:1	NOT USED	0.1	10:1
	1	1:1		1	1:1
	10	1:10		1	1:1
	100	1:100		1	1:1
	1K	1:1000		1	1:1
ACV	.1	1:1	10:1	1	1:1
	1	1:1	1:1	1	1:1
	10	1:10	1:1	1	1:1
	100	1:100	1:1	1	1:1
	1K	1:1000	1:1	1	1:1
ACmA	.1	1:1	10:1	1	1
	1	1:10	10:1	1	1
	10	1:100	10:1	1	1
	100	1:1000	10:1	1	1
	1K	1:100000	10:1	1	1
DCmA	.1	1:1	NOT USED	0.1	10:1
	1	1:10		0.1	10:1
	10	1:100		0.1	10:1
	100	1:1000		0.1	10:1
	1K	1:10000		0.1	10:1

that time a voltage will have been developed across the memory capacitor, C_O which balances the sum total of all the individual offsets generated within the loop, and the servo loop "sees" a zero error signal.

b. Phase 2

At the start of Phase 2, switches A and D open, and switch B closes. In the open position of switches A and D, the analog section retains the offset voltage on memory capacitor C_O as a correcting value which will be combined algebraically with the input signals and the values integrated in Phase 2 and Phase 3.

Switch B, which remains closed during Phase 2, connects the input signal conditioner output to the buffer amplifier. The buffer output is integrated for a fixed time of 100 milliseconds as controlled by the digital logic. The voltage developed across the integrating capacitor C_I is therefore proportional to the magnitude of the input signal, and the output of the high-gain comparator amplifier will be at a saturation level of opposite polarity to the conditioned input voltage.

c. Phase 3

At the start of Phase 3, switch B opens, removing the conditioned output signal from the unity gain amplifier. At the same time (start of Phase 3), the polarity sense function of the digital section determines the polarity of the comparator output and transmits a control signal to the Isopolar reference switching network, thereby connecting the correct polarity of the reference voltages through Switch C to the unity gain amplifier for integration during Phase 3. The reference voltage integrated during Phase 3 decreases the voltage across integrating capacitor C_I until the output of the high gain comparator changes polarity. This change in comparator output polarity indicates end of conversion and is sensed in the logic to indicate the end of Phase 3 and the start of Phase 1. The cycle repeats.

If the charge on C_I is not reduced to zero in the time interval allowed for full overrange measurements, the digital control logic initiates the overload actions in the multimeter, as explained later. It should be noted that the zero offset is generated and the storage capacitor charge is updated in each conversion cycle. Also, note that the stored voltage representing the corrected zero is introduced into the analog section for both the unknown integration and the reference integration, thereby removing the zero effects from both the charging and the discharging actions on C_I.

The timing relationships of the Triphasic conversion cycle are summarized in Figure 3-2.

3.2.3. Digital Logic Programmer

a. All of the logic circuitry to develop the phase timing control signals for the A/D converter are incorporated in one CMOS integrated circuit. This component receives the 400 kHz master oscillator pulse chain from which it derives the control signals for the start of Phase 1, the start of Phase 2 (100 milliseconds later) and the start of Phase 3 (100 milliseconds after the start of Phase 2). It also receives the A/D comparator output from which it derives the control signals to select the polarity of the reference for Phase 3 signal integration and the control signal that ends Phase 3.

b. The logic chip also generates the control signal for the fast discharge of the integrating capacitor, if applicable, and the control signals that cause the overload indication in the display.

c. The digitized value of the conditioned multimeter input is time multiplexed in BCD format on four parallel lines to the Decoder Driver, while the corresponding digit address is transmitted to the address scan element.

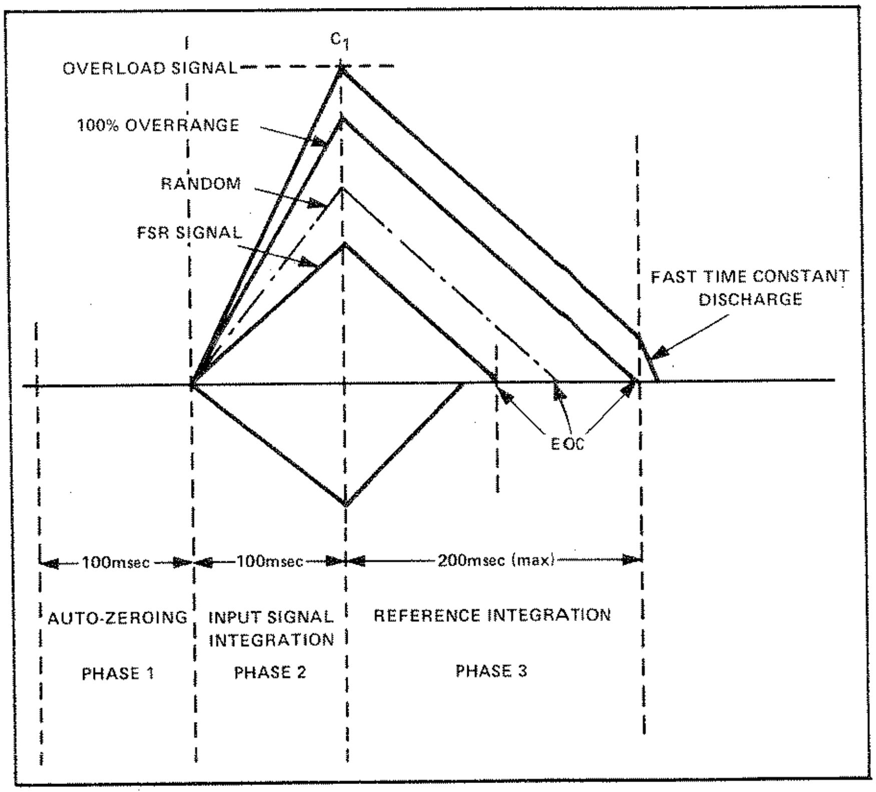


Fig. 3-2. System Timing Waveforms

3.2.4. Decoder/Driver

The digitized value of the conditioned input is converted from the BCD format into 7-segment display code in a CMOS Decoder/Driver. The Decoder/Driver outputs provide adequate current to drive directly the segment of each digit display. The decoder unit also receives the blanking control output from the digital programmer (paragraph 3.2.3) and responds with the blanked display format of an overload indication.

3.2.5. Display

The display consists of four full decades of seven-segment characters, a fifth element which may take a character of "1" or remain blank, and an element for indicating the polarity of the input signal. The decimal point position is controlled directly by the manual range selection, and may be located in any one of five positions.

3.2.6. Reference Generator

The Iso-polar™ reference generator provides a precise 1.0 or 0.1 volt level to be connected to the analog input for Phase 3 operation. The selection of 1.0 or 0.1 voltage level is accomplished by the mode selection. The Iso-polar action obtains positive or negative references with equal magnitudes.

3.2.7. DC/DC Converter & Power Supply

a. Power for the meter is obtained from a nominal 7.5 volt battery supply which is connected as a negative voltage source. A plug-in battery charger, provided as standard equipment, maintains the voltage whenever the charger is connected to line power, whether or not the meter is on. The DC/DC converter is connected to the battery supply only when the meter is turned ON, and develops nominal +7.5 volts for the analog circuitry. The -6.8 volts for the digital logic and for the analog amplifier units are supplied directly by the battery.

b. The reference voltage generator regulates the +7.5 volt output of the DC/DC converter, and develops both the +1 and 100mV reference potentials for use in the A/D conversion. The isopolar reference circuitry determines the appropriate polarity of these levels before connection to the A/D converter in Phase 3. The regulation circuitry also monitors the level of the negative supply and causes the decimal point to blink when a low-battery condition exists.

3.3. INPUT SIGNAL CONDITIONING

3.3.1. Voltage Divider

a. Model 248 DMM scales all ac and dc voltages in a frequency-compensated voltage divider, as shown in the fold-out reference schematic. Parts of the divider are also used as the reference resistance for the Ratiohmic resistance measurement. The decimal point location automatically tracks the decade selection effected by the range switch.

b. Resistance elements of the divider are contained in a single resistor network, A4, that has been trimmed during manufacture to within 0.03% relative and absolute accuracy. No external resistive trimming is required. Capacitive elements that trim the network for specified frequency response are mounted external to the resistor network. As noted in the reference illustration, C3, C5, and C8 are trimmed by C4, C6, and C10, respectively for the separate decades, while C11 is trimmed by bleeding some current through C39 from the full input via C2.

3.3.2. DCV Signal Conditioning

When the Function Switch is in the DCV position, the output of the voltage attenuator is capacitive-coupled (C20 - 47µF) to the A/D converter during Phase 2 of the 3-phase conversion cycle. Resistor R19 and capacitor C17 form a simple input filter for all dc input signals.

3.3.3. ACV Signal Conditioning (Reference Fold Out)

a. When the Function Switch is in the ACV position, the output of the voltage divider is connected to the AC/DC converter. The AC/DC converter consists of a true RMS to DCV unit preceded by an amplifier of selectable gain (1:1 or 1:10).

b. The AC/DC converter is connected in the circuit through contacts on one wafer of the mode switch when positioned to ACV or ACmA, and receives the output of the voltage attenuator or current shunt, respectively. The gain of amplifier Z1 is either unity or 10:1, determined by the configuration of the feedback circuit that is controlled by the selected function mode and range. A gain of 10:1 is set up for all ranges when in ACmA measurements, or when the .1 RANGE is selected for ACV measurements. The 10:1 divider ratio is obtained by resistors R13 and R14 and trimmed by series potentiometer R12 for calibration purposes.

c. The ac output of Z1 is capacitor-coupled to Z2, in which it is converted to a dc voltage and scaled such that 1VRMS at Z2-1 produces 1VDC at Z2-8. The scaling of Z2 is adjusted by R18 for calibration.

3.3.4. Current Shunt & Current Input Conditioning

a. When in either DCmA or ACmA position, the Function Switch connects the input signal to a decade current shunt (R24 through R28). Shunt values are selected so that the output will be 100mV for nominal range inputs. Diode ring CR1 through CR4 provides a protection against overload input to keep the shunt voltage outputs within ± 3.5V.

b. When in DCmA position, the Function Switch capacitor-couples the shunt output to the A/D converter, as for DCV operation.

c. When in ACmA position, the Function Switch connects the shunt output to the AC/DC converter and the AC/DC converter output to the A/D input as for ACV operation.

3.3.5. Resistance Measurement Signal Conditioning

a. In the Data Precision Ratiohmic technique of resistance measurement, the resistance to be measured is connected in series with a selected standard resistance and driven by a source voltage so that the voltage input to the A/D for Phase 2 and the voltage input to the A/D for Phase 3 are derived from the action of the same current in the circuit. Because the Tri-Phasic technique digitizes the ratio of the two voltages (see paragraph 3.2.1), the exact value of the current is not significant in determining the results, only its stability over the measurement cycle. Figure 3-3 is a simplified schematic illustrating the Model 248 operation when in Resistance measurement mode.

b. As shown in Figure 3-3, selection of kΩ by the Function Switch applies a nominal 3.5 V as the reference voltage. The reference voltage is applied across the series-connected unknown resistance and the range-selected precision standard resistance. (The standard resistance is selected from the voltage-divider precision resistor network described previously in paragraph 3.3.1.) The voltages for Phase 2 and Phase 3 are generated by the current, I_S, whose value is determined by the series combination of the two resistances.

c. The voltages connected to the A/D input are controlled by the switch closures of Q6, Q7, Q8 and Q9. During Phase 1, C19 is charged to the value $V_S + V_X$ by the closing of Q6 and Q9. The input to the A/D is zero because of the closing of Q9. During Phase 2, Q6 and Q9 open, Q8 closes, and the input to the A/D is V_X. During Phase 3, Q8 opens, and **Q7** closes connecting the high side of C19 to V_X. The low side of C19 is thus $V_X - (V_X + V_S)$, or $-V_S$, and that value is the input to the A/D. The dual slope integration digitizes the ratio V_X/V_S. But $V_X = I_S \cdot R_X$, and $V_S = I_S \cdot R_S$, so that the measured value is the ratio R_X/R_S, as required. (Q5 remains open for all phases.)

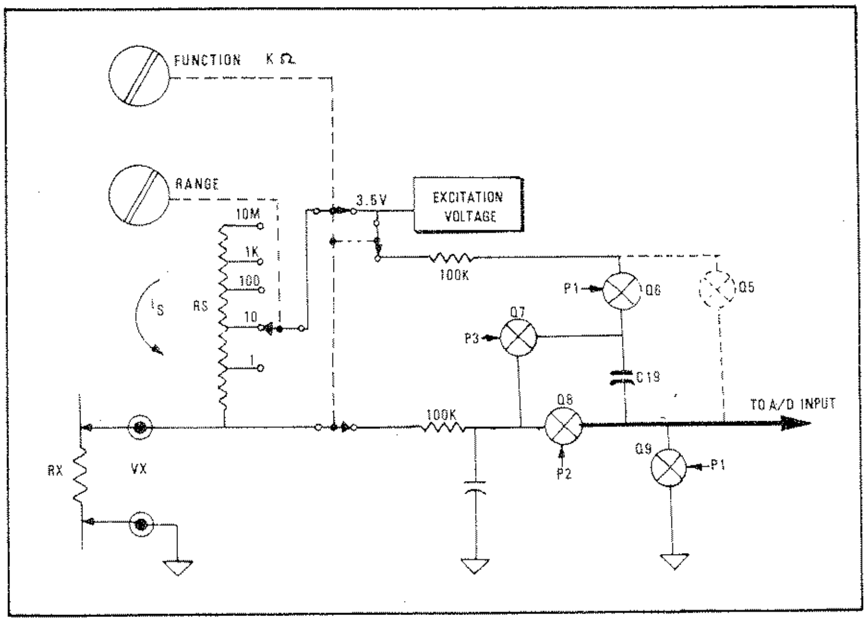


Fig. 3-3. Resistance Measurement Signal Conditioning

d. Figure 3-4 is a simplified schematic of the circuitry that generates the excitation voltage used for resistance measurement. The two pass transistors Q1 and Q2 and diode CR1 are used to develop the nominal 3.5 volts to excite the series input of resistance to be measured and range-selected precision standard resistance. The pass transistors provide a breakdown limit of 2 x 250V peak for protection of the specified 250 VRMS value, while FET transistor Q3 is connected as a voltage clamp on the input to Q1.

3.4. Tri-Phasic A/D Converter

a. The fold-out reference schematic identifies the A/D circuitry containing active elements Z3, Z4, and Z5. Amplifier Z3 is connected as a programmable gain non-inverting amplifier, whose gain is determined by the switched components in the feedback circuit. In DCmA and in the .1 Range of DCV measurement function the 18K and 2K resistors of the A1 network are connected as a

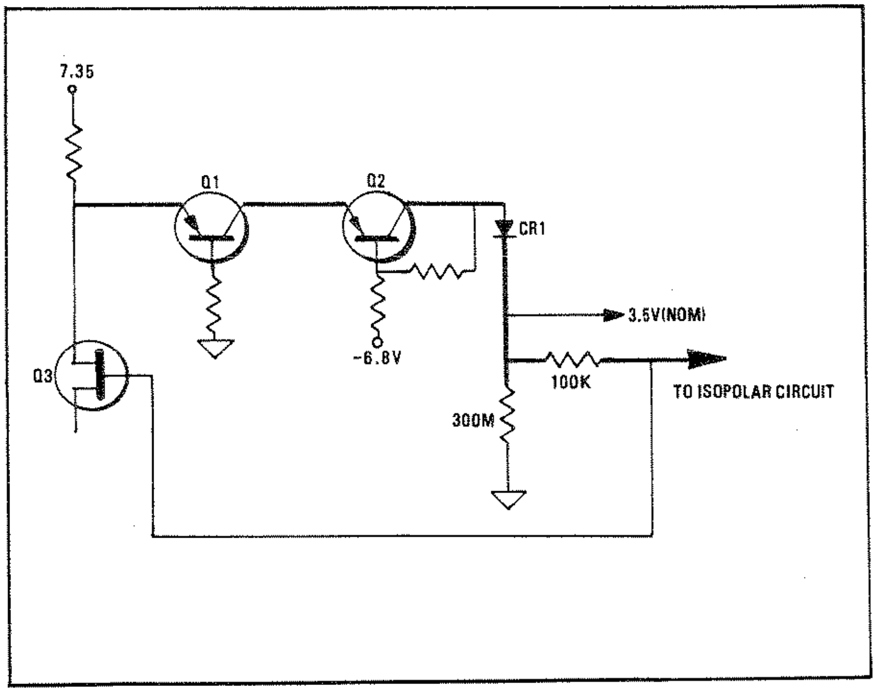


Fig. 3-4. Resistance Voltage Excitation

voltage-divider to ground with a 1:10 feedback ratio. Amplifier Z4 is connected as an integrator with C22 = 1μF and the 50K resistor of network A1 determining the charging current. Amplifier Z5 is connected as a high gain comparator, sensing the polarity of the Z4 output with respect to ground.

b. During Phase 1, Q11 is closed, connecting the comparator output to the A/D input, and servoing any non-zero signals generated in the active elements to charge capacitor C20 with a voltage balancing the non-zero effects. If the prior conversion is overload, digital logic programmer Z6 transmits the FC signal to close Q12 and to provide a path from comparator output to the integrator capacitor. This action delivers a high level charging current to reduce the remaining voltage on C22 to zero before the start of Phase 2.

c. During Phase 2, Q8 is closed, connecting the conditioned input to the A/D converter. If the measuring function is DCmA (any Range) or DCV (Range .1) then nominal full scale input will be 100mV at the input to Z3. The gain around Z3 will be 10:1, so that the integrating capacitor will be charged with the same current as for nominal 1V full scale inputs. Scaling for 100mV inputs then takes place by using the .1 VDC reference voltage during Phase 3.

d. During Phase 3, Q8 opens, removing the conditioned signal input, while the closing of Q7 applies a negative reference, or of Q5 applies a positive reference to the A/D converter. The reference magnitude is determined by the Function Switch and Range Switch selections as previously shown in Table 3-1. The charging path for C22 remains set up as for Phase 2, and the circuit reduces the voltage on C22 while the digital counter in Z6 digitizes the measured value. Phase 3 lasts until comparator Z5-7 indicates the zero crossing of the C22 voltage by a change in polarity of the Z5-7 output. The comparator output change is sensed in digital logic Z6 and results in the generation of the Phase 1 control signals to start the next conversion.

3.5 ISOPOLAR REFERENCING

a. Figure 3-5 is a simplified schematic of the complete circuit in the fold-out reference. The function Switch and Range Switch combination selects either +1.0 V or + 0.1 V according to the conditions of Table 3-1.

b. During Phase 1, Q6 and Q9 are closed, charging C19 to the 100mV or 1V reference value. During Phase 3, if a negative reference is required (positive conditioned input) Q7 closes, placing the high side of C19 at ground level. As a result, the negative side of C19 is negative by the magnitude of the voltage on C19. If a positive reference is required (negative conditioned input), then Q5 is closed, connecting the positive reference as input to the A/D converter.

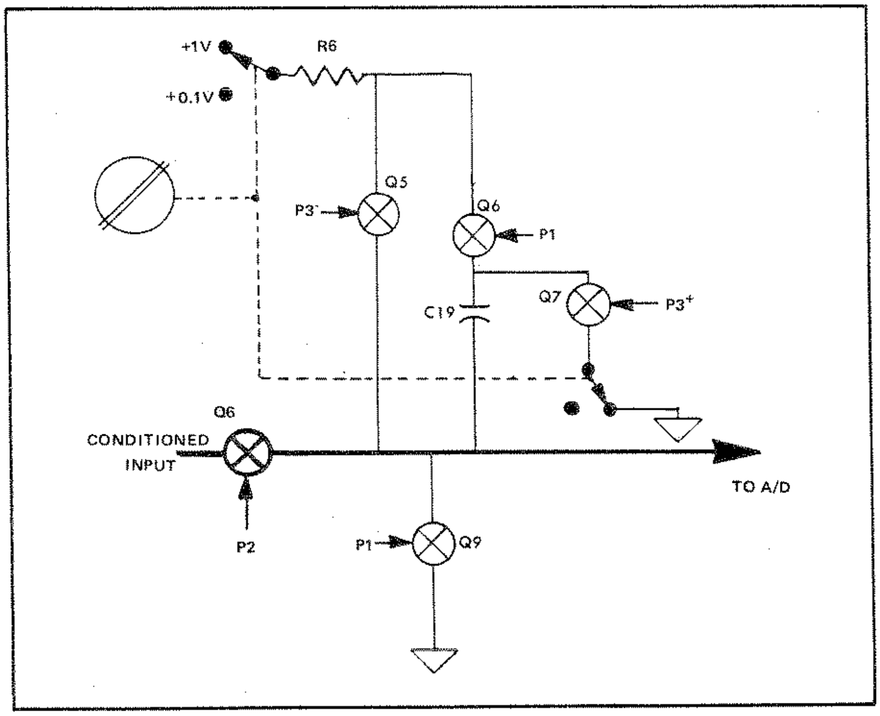


Fig. 3-5. Isopolar Reference Voltage Generation

3.6 DIGITAL LOGIC PROGRAMMER & MASTER OSCILLATOR

a. The digital logic programmer circuitry is contained entirely on one CMOS solid state component, Z6. It contains (Fig. 3-6):

4 Decade Counter and the MSD flip-flop
Latching BCD Output Register
Clock Generator
A/D Phase Signal Generator and Fast Charge Control
Polarity and Overload Detection Logic

b. In addition to the phase control signals described earlier, digital logic Z6 outputs the latched register BCD values series by digit parallel by bit on 4 BCD output lines. The digit address for the BCD data is indicated as a high level on one of 4 parallel lines, while separate output lines indicated the binary value of the MSD (0 or 1), and the polarity (binary + or –). The binary overload condition is also indicated on a separate Z6 output line.

c. The master clock oscillator circuit containing resonator Y1 oscillates at 400 kHz. This frequency is counted down by 4 to obtain a basic counting rate of 100 kHz so that the carry from the 4-decade counter represents an interval of 100 milliseconds for Phase 1 and Phase 2 timing. An MSD divide-by-two flip flop at the output of the 4-decade counter is used to sense the MSD of 10^4 counts, and, when digitizing an overload input to the A/D, senses 2 X 10^4, from which the blanking control and FC control signals are developed.

d. Decoder/Driver Z7 receives the latched outputs in BCD format, time multiplexed on 4 parallel lines successively for each of the four full decades. It converts these to appropriate seven-segment outputs for the LED display digits.

e. Figure 3-7 is a summary of the timing relationships of the waveforms generated in Z6. Conditions for converting an in-range A/D positive input are shown in the upper portion and for an overload negative input in the lower portion of the illustration. The SIGN output of Z6 is always produced; whether the polarity is displayed is determined by an enabling signal controlled by the setting of the front-panel Function Switch.

3.7 DISPLAY

The display is assembled on a separate PC card. It contains the five display digits, including sign and decimal points, current limiting resistors for the segment drivers of the four full decades, transistor driver circuits for the most significant "1" (when appropriate), and for the polarity (plus or minus). Digit address enabling signals multiplex the full decade digits DS102, DS103, DS104, and DS105; a control signal from the main PC board assembly enables the polarity display when in DCV or DCmA measuring function. Range-selected control signals drive the decimal point in the appropriate decade through limiting resistors.

3.8 DC/DC CONVERTER & POWER SUPPLY

a. The DC/DC Converter is a switching regulator type, triggered by a 100 KHz pulse train from the digital programmer. Transistors Q17 and Q18 switch the current through L1 and CR8. When Q17 is off, the current in L1 continues to flow through CR8 and charges capacitor C27 and C28.

b. Amplifier Z6 and reference zener CR7 are connected in a voltage regulator circuit that results in a regulated +7.35V with respect to COM. Voltage divider networks R31, R32, R33, R34, R36, R37 and R38 are used to develop the +1V and +0.1V reference levels for the Phase 3 A/D integration. R31 and R36 are the calibrating adjustments for these voltages.

c. Amplifier Z5 is connected as a comparator in which the battery voltage level is compared with a reference derived from the zener CR7 and the divider network. For low battery levels transistor Q19 is turned on and off by the Phase 1 waveform, providing a blinking signal for the decimal point at a 2½ per second rate, corresponding to the conversion rate.

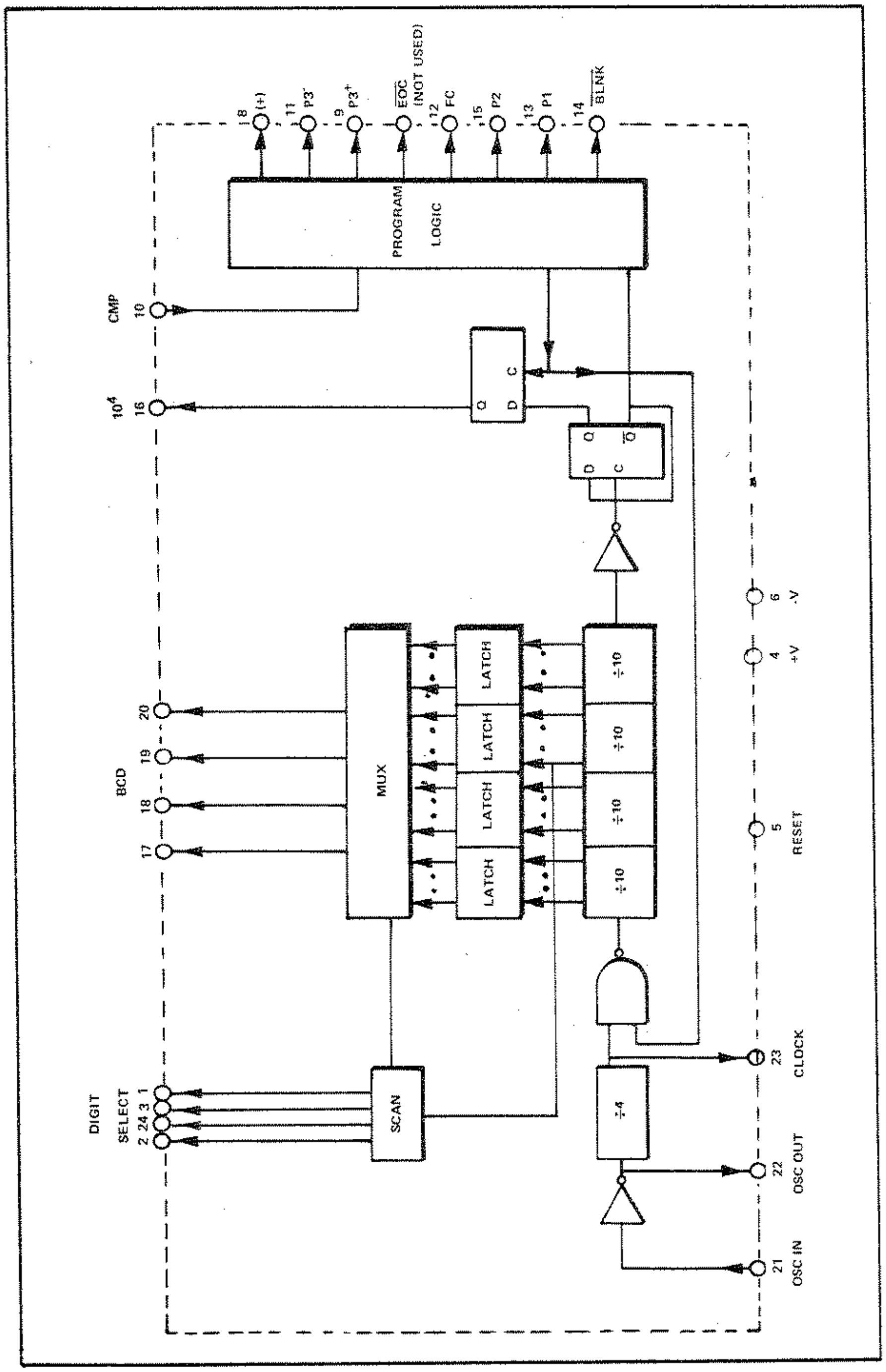


Fig. 3-6. Digital Logic Block Diagram

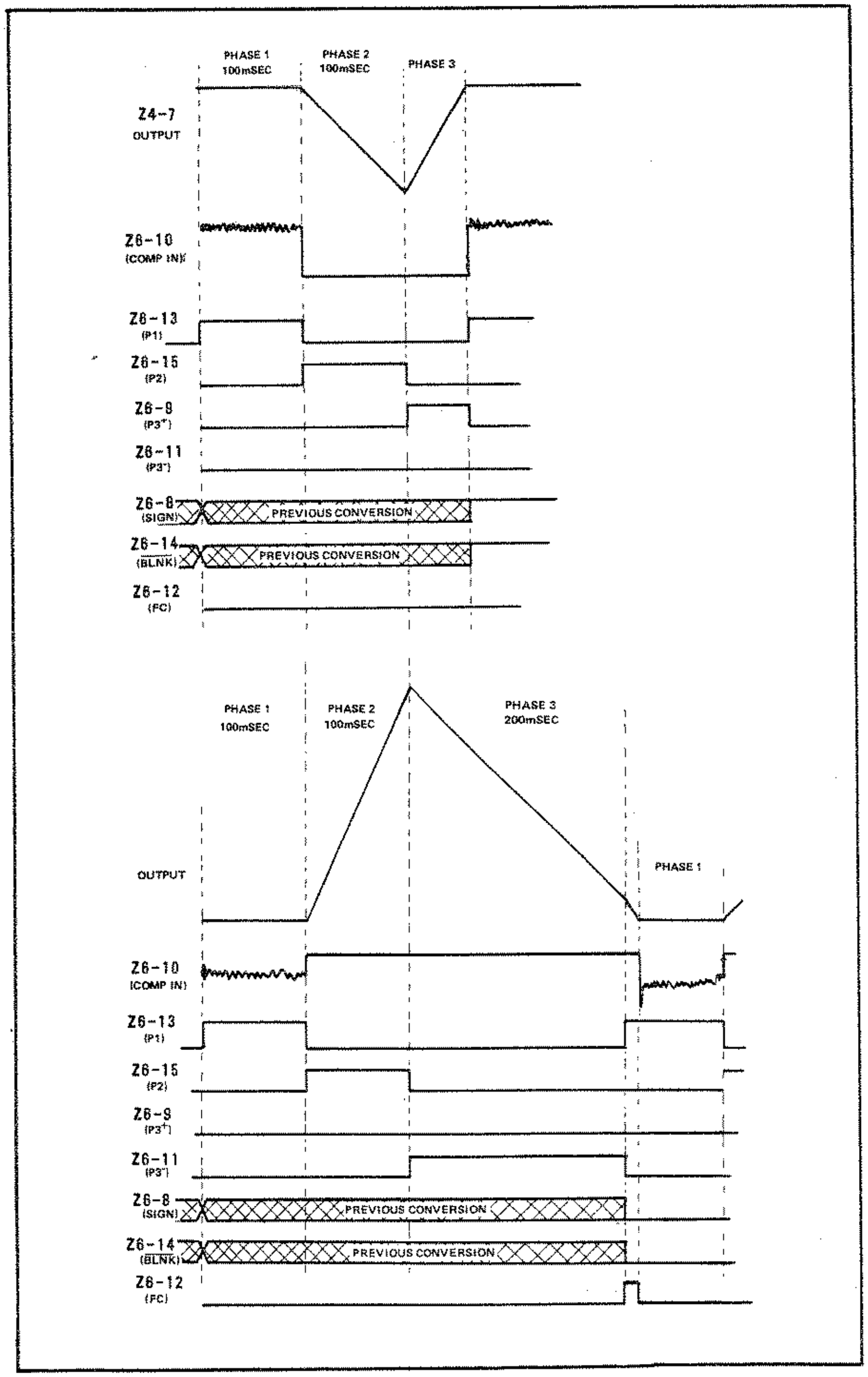


Fig. 3-7. Digital Logic Timing Waveforms

NOTES

Chapter 4

MAINTENANCE

4.1 GENERAL

CAUTION

> Your Multimeter is covered by a one-year warranty and should be referred to the factory for maintenance within the warranty period. Attempts to make any extensive repairs within the warranty period may invalidate the warranty. If repairs are needed after the warranty period, only qualified technicians should attempt to effect such repairs and should use test instruments and standards calibrated within the accuracy and tolerances of the specifications.

4.2 TROUBLE-SHOOTING FLOW CHART

Should the meter performance indicate a possible need for repair, a well-defined strategy should be used to isolate the cause of trouble. This is illustrated in Figure 4-1. It inidicates a sequence of steps in terms of standard symbols and defines a program of actions based on a philosophy of positive maintenance. The positive approach isolates to the faulty sections by verifying proper operation of the remaining instrument sections.

4.3 TEST POINTS

The test sequences identified in the chart of Figure 4-1 are described in step-by-step detail in the paragraphs that follow. In performing the tests detailed in these paragraphs, the maintenance technician is directed to make measurements at designated test points which have been placed at significant portions in the circuit. The special test points are identified by E-reference numbers, and their locations on the printed circuit board are shown in Figure 4.2. Other test points designated in the test procedure paragraphs may be pin terminals of circuit components, and technicians should refer to component data sheets for the pin terminal locations as well as to Figure 4-2. Use caution in attaching test leads to avoid accidental shorting of adjacent components. The use of EZ Mini Hook ^{R} , or equivalent is suggested to aid in making good connections.

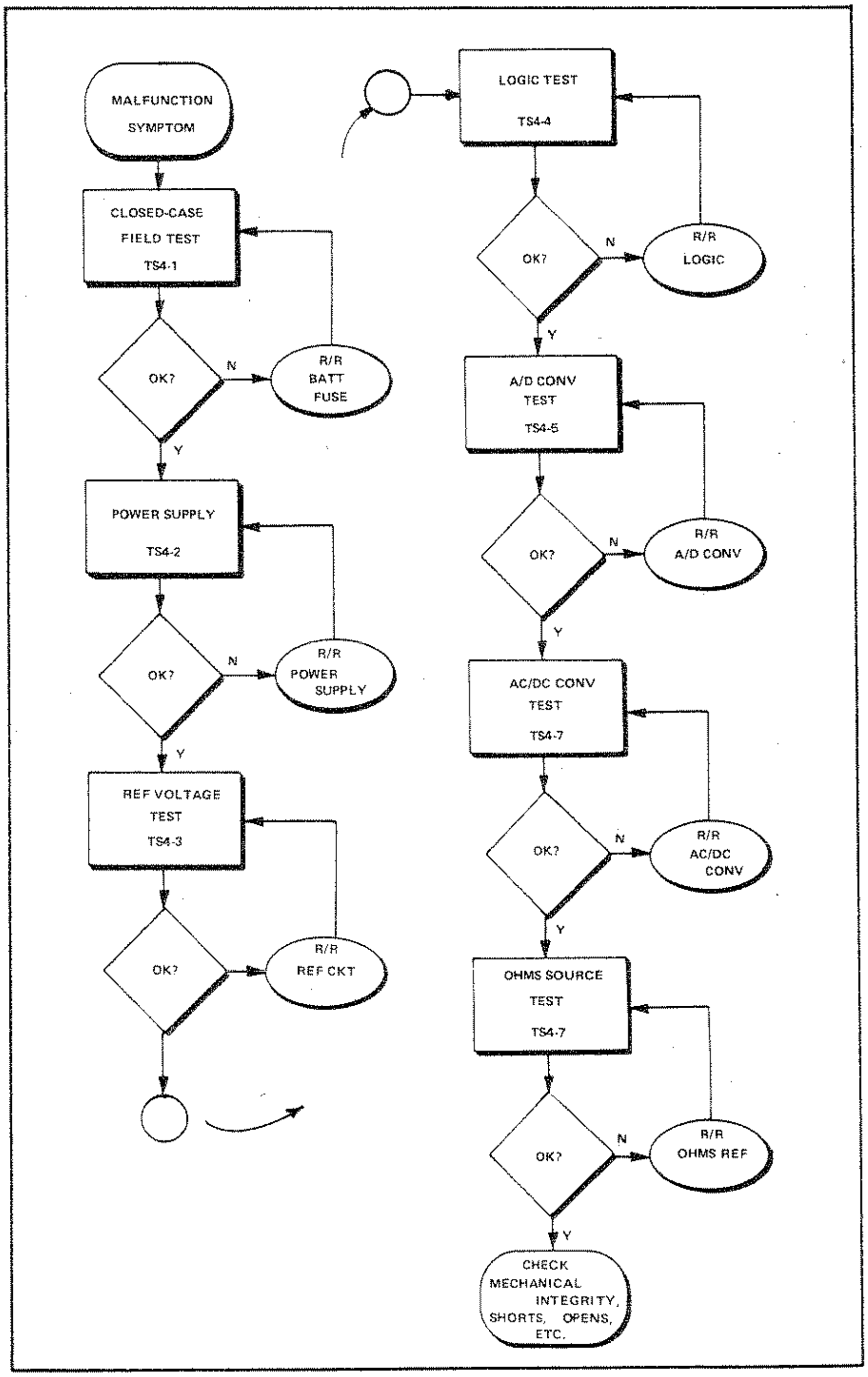


Fig. 4-1. Overall Test Strategy

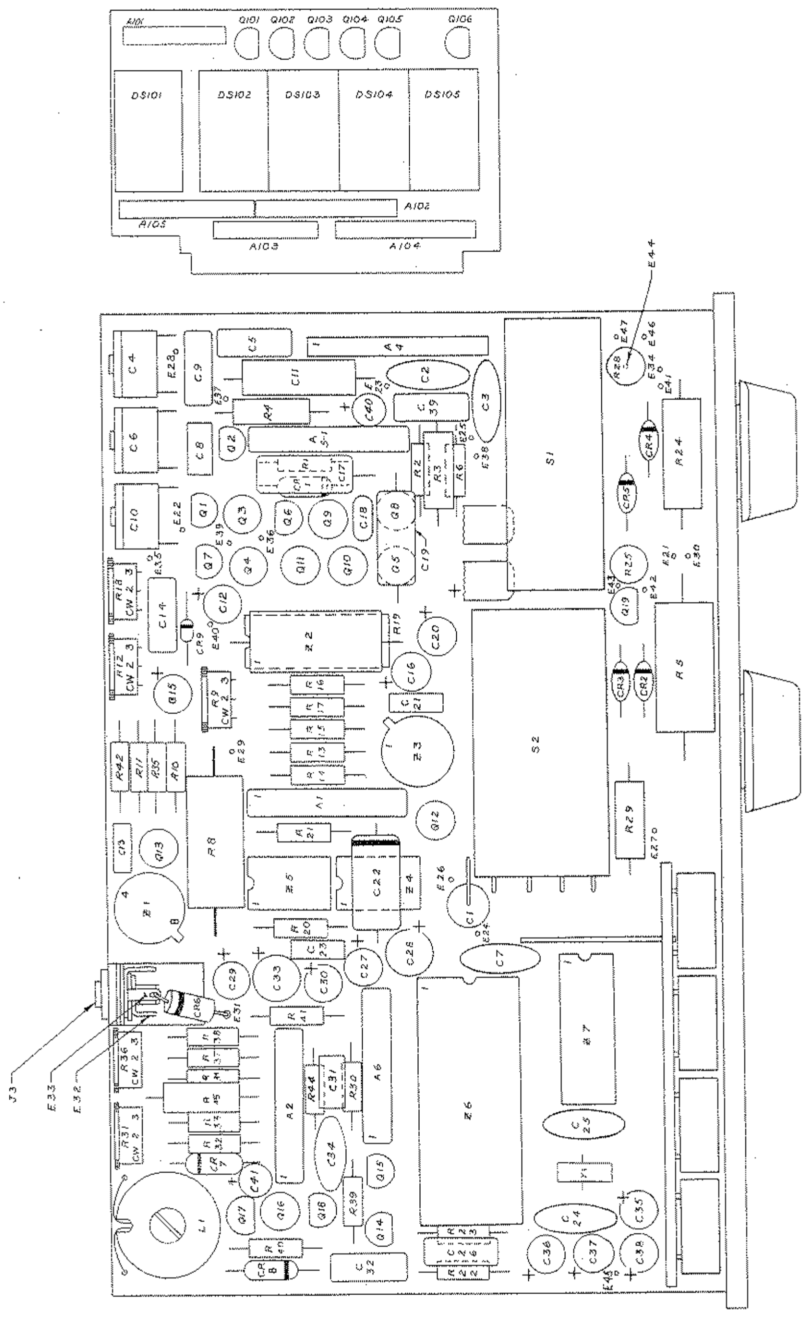


Fig. 4-2. Model 248 Main Assembly

4.4 CLOSED-METER TESTS (FIELD MAINTENANCE) TS4-1

a. The first test sequence is performed with the "cased" meter. The sequence is fully detailed in the illustration of Figure 4-3.

b. The multimeter may exhibit certain battery performance below rated characteristics that are only temporary operational effects typical of battery usage patterns. Such below-specification performance can be corrected easily and in a minimum of time.

Memory. If the meter is used in a series of repeated partial charge and discharge cycles that use only a small portion of the available battery capacity, the battery will become conditioned to deliver only slightly more than normal end-of-discharge voltage capacity when called on to perform in an extended discharge cycle.

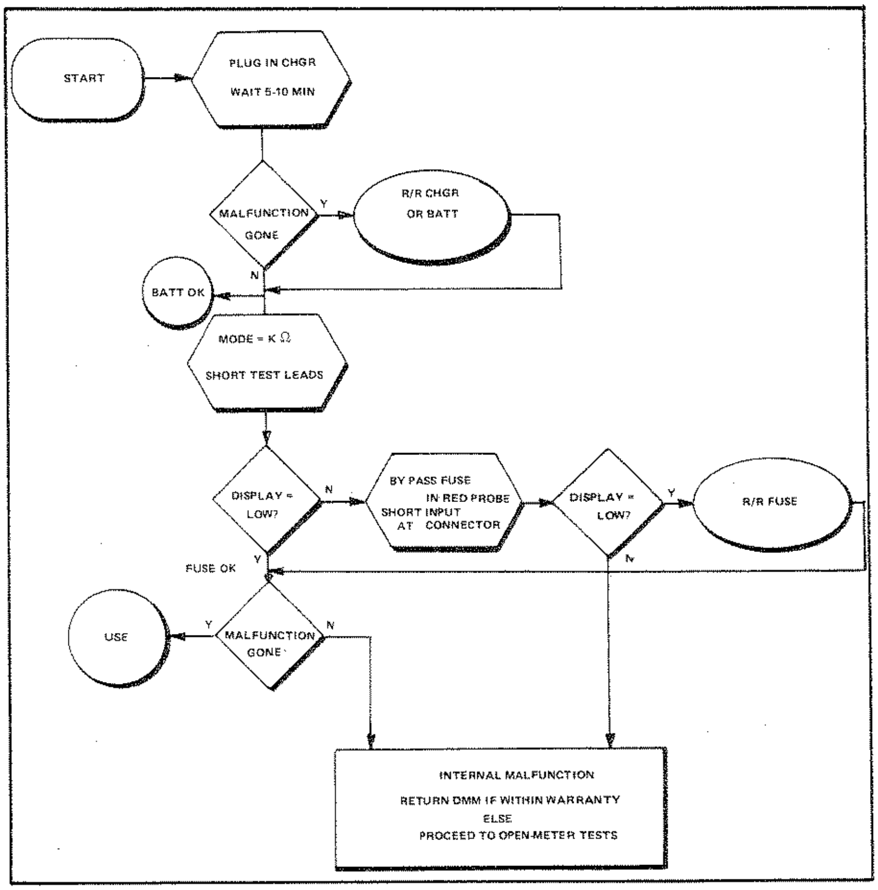


Fig. 4-3. Test TS4-1, Closed Meter Testing

To correct this condition, subject the battery to a deep discharge, and then recharge to full capacity. This will erase the "memory" pattern.

Sustained Overcharge. If the meter is kept on "high voltage charge" for long periods of time without discharge interruptions, the battery may not deliver normal voltage at the end of the first sustained discharge operation thereafter.

To correct, proceed as for the memory effect described above; discharge the battery, then recharge to full capacity.

4.5 OPEN-METER TEST/MAINTENANCE

4.5.1 General

If the multimeter does not perform correctly after the tests of TS4-1 are satisfactorily completed, then it is likely that repairs to an internal assembly are required. The sequence of such tests is indicated in the overall strategy of Figure 4-1, and is identified by a TS number for further reference. Each test sequence paragraph includes the designation of test points, the indicators of proper performance, the circuits that are checked when proper performance is observed, and the circuits that should be examined in greater detail when indications of improper performance are recorded. Refer to the fold-out schematic in the back of this manual for complete circuit details, and to Chapter 6 for replacement parts identification.

4.5.2 Removal of Meter Assembly from Case (See Figure 2-1)

a. The meter assembly is contained on one main PC board. To remove this board from the case:

(1.) Remove the battery module;

(2.) Remove the fastening screw from the case underside;

(3.) Carefully withdraw the meter assembly from the case through the front. Place on insulating surface. Major assemblies are pointed out in Figure 4-2.

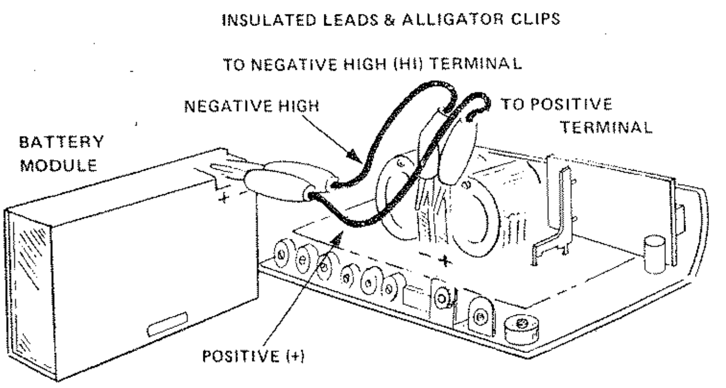
b. To insure specified accuracy, the meter must be recalibrated each time it is removed and replaced in its case. See Chapter 2 for recalibration procedures.

4.5.3 Applying Power to the Meter Assembly

Power for the multimeter may be obtained by connections to the battery pack with jumpers as shown in Figure 4-4. Be sure that a fully charged battery pack is available for these trouble-shooting test sequences. The battery charger may be connected after the battery has been connected to the circuit.

WARNING

Be sure to maintain the proper polarity relationships as shown in Figure 4-4. Improper polarity connection, even if momentary, may result in major component damage. The battery module should be connected before connecting the charger input because the battery acts as a necessary filter for the charger circuit.



WARNING
CROSSED POLARITIES WILL CAUSE IRREPARABLE DAMAGE TO COMPONENTS!!!

Fig. 4-4. Connecting Battery Module to Assembly

4.6 TEST EQUIPMENT

Test instruments and reference standards needed for the trouble shooting analysis should have the following characteristics:

Parameter	Range	Accuracy	Measure/Generate* M/G
DC Voltage	-10V to +10V	±.01%	M/G
AC Voltage	1 kHZ 100mV 150KHz 1 VRMS 10KHz 200 VRMS 100 VRMS 10 VRMS 1 VRMS	± 0.1%	M/G
Timing Waveforms	Oscilloscope 5MHz BW	± 5%	M
Resistance	0 to 10 MΩ	± 0.05%	M/G

*Measure = indicates test instrument. Generate = indicates source instrument.

4.7 POWER SUPPLY TEST TS4-2

a. Select KΩ Function and 10MΩ Range.

b. Check dc voltages at points and in sequence shown in the tabular presentation below. Measurements should be made between the indicated point and case reference. The latter is easily available at the metal support bracket securing the display assembly to the main assembly PC board. See Figure 4-2 for designated test point location and Figure 4-4 for the bracket location.

Test Point	Measure Value	Indicated Proper-Functioning Circuit
CR8-Cathode	+7.2V to +7.5V	DC/DC Converter Reference Zener
Battery-Negative	-7.1V to -6.6V	Negative Supply Regulator

c. Ground the positive battery electrode by momentarily connecting a jumper from that electrode to COM input. Check to see that the display presents the blinking decimal point of a low battery condition while the battery is thus shorted. If satisfactory performance is observed the Z5 circuitry is functioning properly.

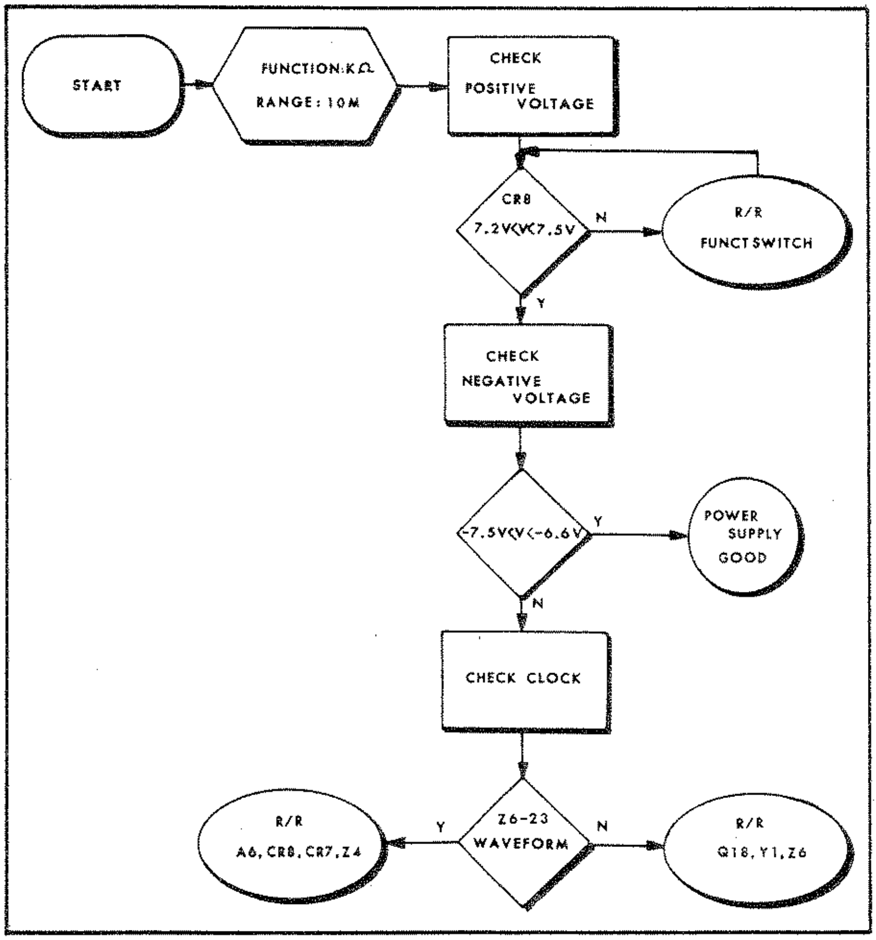
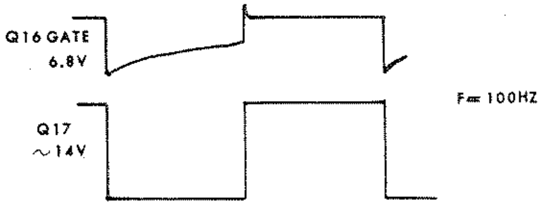


Fig. 4.5. Test TS4-2, Power Supply Trouble Shooting

d. Check waveform at Z6 pin 23. Proper functioning of master oscillator circuit (Y1) and count-down section of Z6 are indicated by observing a 100kHz square wave at amplitude of 4V p-p.

e. Check switching components Q16, Q17, and Q18 for waveforms as shown below.



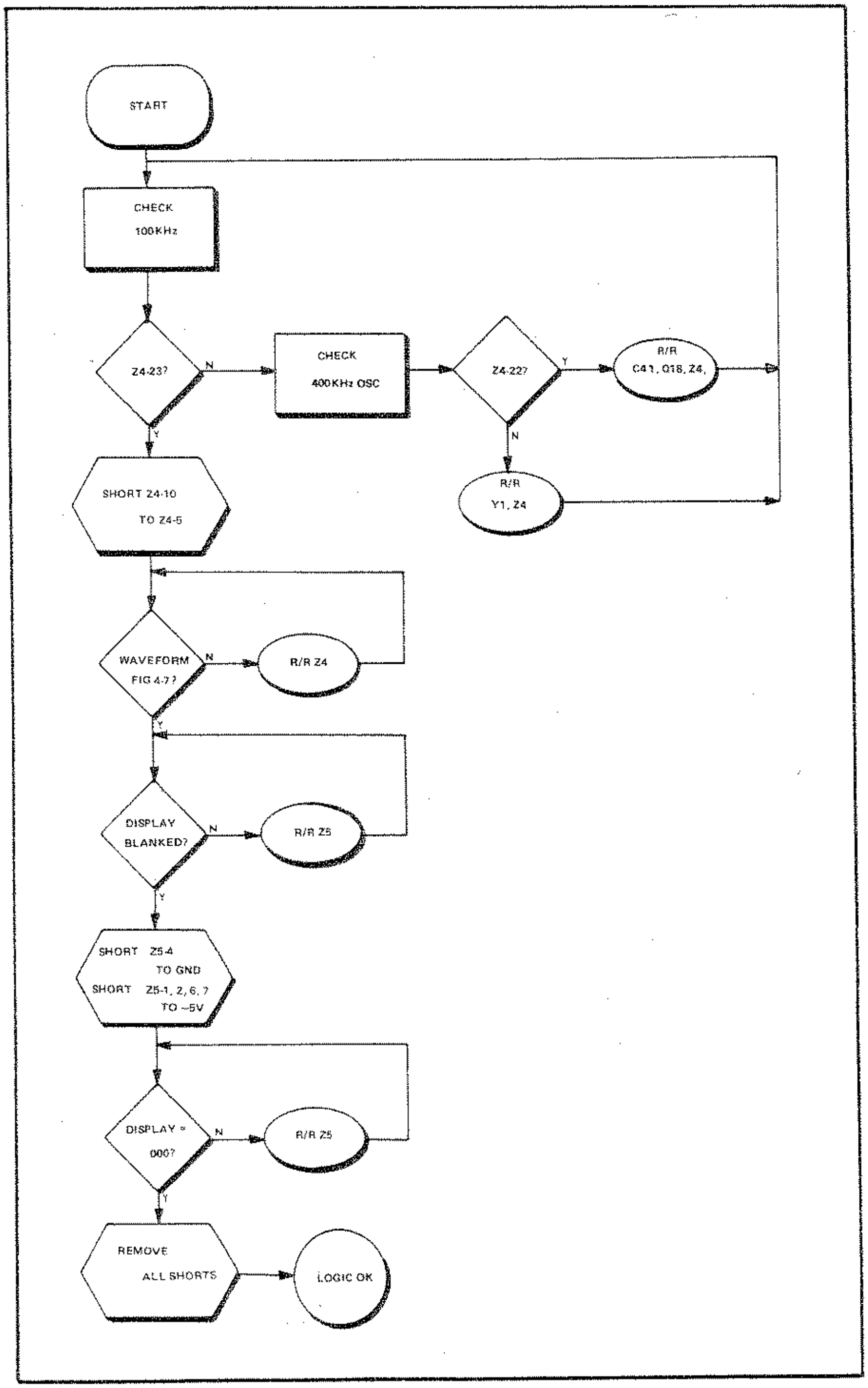


Fig. 4-6. Test TS4-3, Digital Logic

4.8 DIGITAL LOGIC TS4-3

All the digital logic functions are essentially implemented in two CMOS chips, Z6 and Z7. The separate and sometimes independent functions performed by these LSI circuits are checked as shown in Figure 4-6. Proceed as shown below. (A simplified block diagram of Z-6 is shown in Figure 3-6.)

4.8.1 Time-Base Generation

Check 100kHz Clock. Waveform at Z6-23 should have 6.8V p-p amplitude. If not, trace from origin at master timing oscillator and Z6.

4.8.2 Program Logic

a. Connect Z6-10 to Z6-5. Simulates overload input.

b. Observe waveforms at Z6 outputs and compare with those illustrated in Figure 4-7. If satisfactory, then Z6 is functioning properly.

4.8.3 Decoder/Driver Logic

a. Observe display. If indication is of an overload input (blanked digits), then Z7 function is partially checked.

b. Short Z4 to ground (and connect Z7-7, Z7-1, Z7-2, and Z7-6 to Z7-5 (–6.8V). This action simulates a zero value out of the counter of Z4.

c. Observe display. If indication is 0000, Z7 is functioning properly.

d. Remove all shorting jumpers.

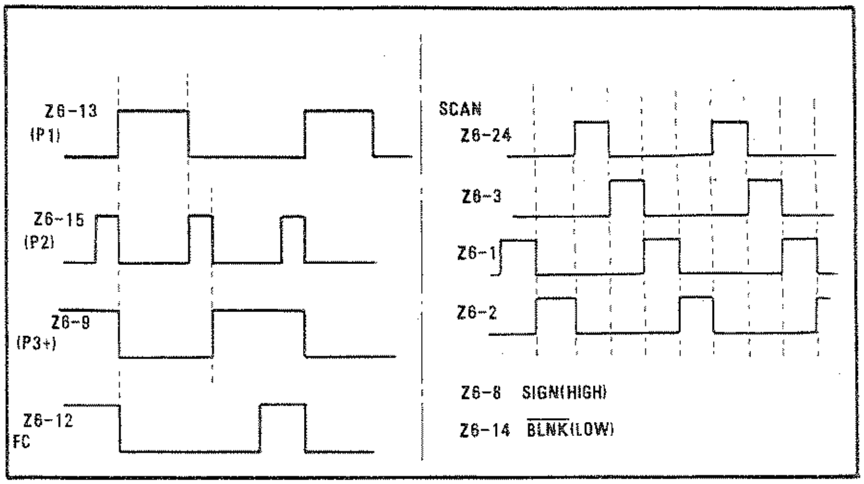


Figure 4-7. Program Logic Waveforms

4.9 A/D CONVERTER & SIGNAL CONDITIONERS TS 4-4

4.9.1 Analog A/D

a. Select DCV measuring function

b. Connect Z6-10 to Z6-5 and synchronize oscilloscope to positive going edge of P1 waveform by connecting to Z6-13. Observe waveform development in Z6 as shown in Figure 3-7.

4.9.2 AC/DC Signal Converter

a. Select ACV function.

b. Apply 100mVRMS @ 1kHz to V_X Hi and V_X COM.

c. Observe waveform at output of Z1-6 by placing scope at junction of R12 and Z1-6 pin. Performance of Z1 is satisfactory when output waveform is 10 times input.

d. Check operation of AC/DC true rms converter Z2 by observing output of Z2-8. DC voltage at Z2-8 should be 1 volt for 1VAC output of Z1-6. Check waveform shape to see that crest factor is not exceeded if test generator output appears to be a complex waveform.

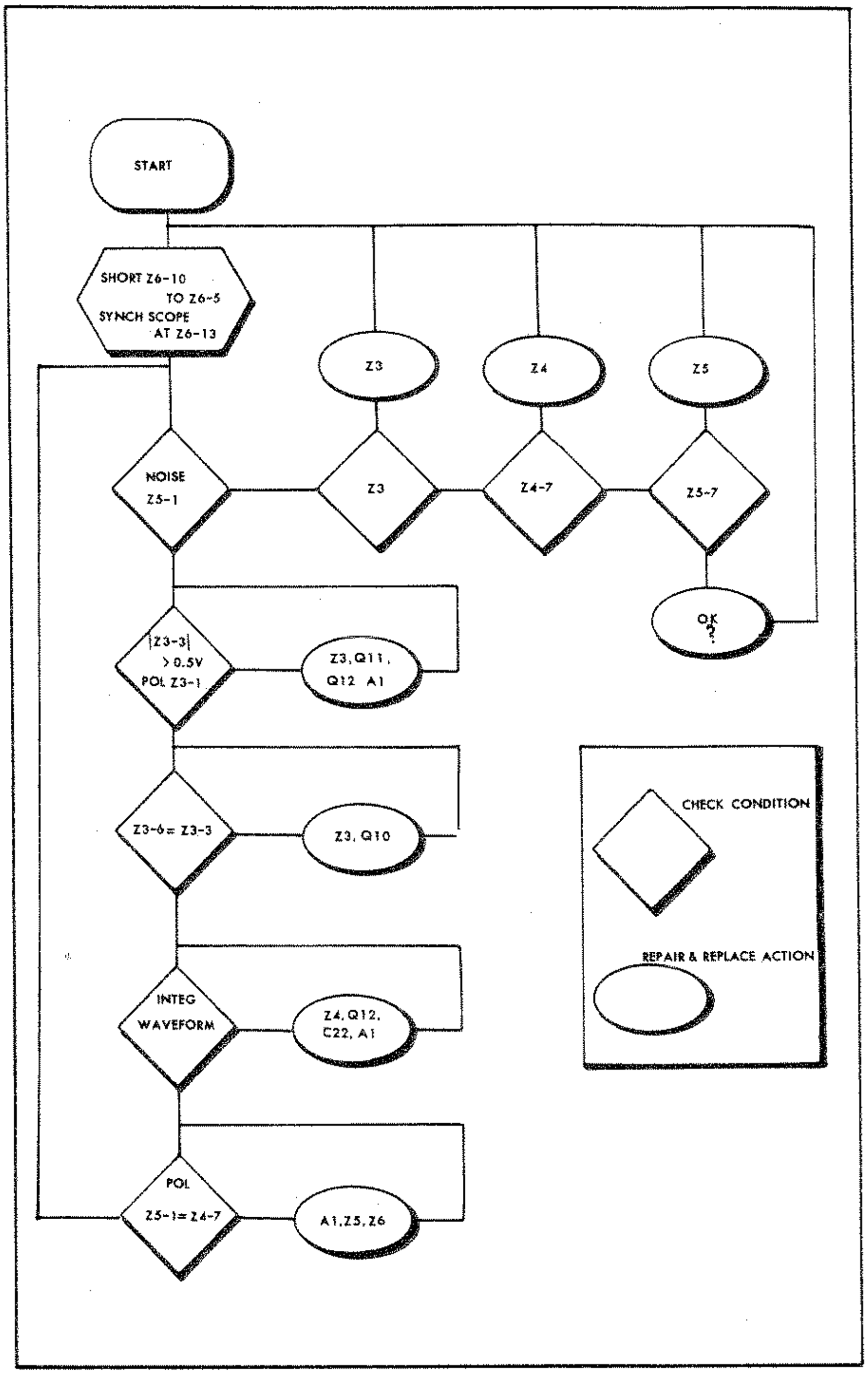


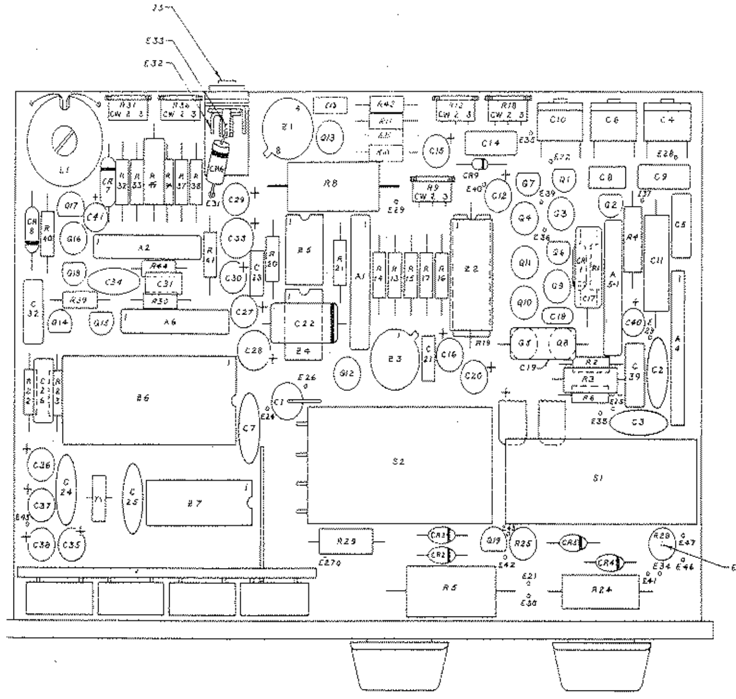
Fig. 4-8. TS4-4 A/D Converter and Signal Conditioning

Chapter 5

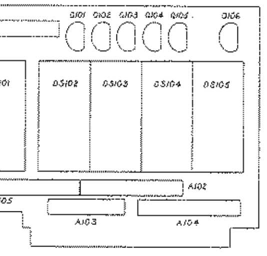
PARTS LIST
(Replaceable Parts)

REF. SYMBOL	DESCRIPTION	DATA PREC. PART NO.
A1	RES NETWORK	22-48-1062
A2	RES NETWORK	22-48-1063
A4	INPUT ATTENUATOR	22-48-1085-02
A5	RES NETWORK	22-731002
A6	RES NETWORK	22-731001
A101	RES NETWORK, 1K, 6 PIN SIP	22-741000
A102, 104	RES NETWORK, 390Ω, 8 PIN SIP	22-751000
A103	RES NETWORK, 390Ω, 6 PIN SIP	22-741001
A105	RES. NETWORK, 2K, 8 PIN SIP	22-751001
J3	JACK	25-700010
C1	CAP, .022uF, 400V, 10%	23-510015
C2	CAP, 5pF, 1KV, 10%	23-111000
C3	CAP, 16pF, 1KV, 5% SELECTED	23-110006-A
C4, 6, 10	CAP, 10-60pF, VARIABLE	23-810003
C5	CAP, 75pF, DM15	23-311008
C7	CAP, 270pF, 1KV, 10%	23-110036
C8	CAP, 1000pF, 100V, 5%, DM10	23-311002
C13	CAP, 12pF, 1KV (OPT. FSV.)	23-111002
C11	CAP, .01uF, 50V, 2%, POLYCARB	23-510024
C21, 23	CAP, 10pF, DM10	23-310002
C27, 29, 41	CAP, 15uF, 10V, 20%, TANT	23-441003
C15	CAP, 4.7uF, 35V, 20%, TANT	23-441052
C17	CAP, .056uF, 50V, 10%	23-510020
C26	CAP, .001uF, 150V, 20%	23-118201
C22	CAP, 1uF, 50V, 10% SELECTED	23-510001-A
C20, 40	CAP, 47uF, 6.3V, 20%, TANT	23-441053
C24	CAP, 68pF, 1KV, 10%	23-110019
C25	CAP, 39pF, 1KV, 10%	23-110014
C32	CAP, 270pF, 5%, DM15	23-311022
C28, 30, 33	CAP, 68uF, 15V, 20%, TANT	23-442004
C31	CAP., 1uF, 50V, 20%	23-142003
C34	CAP, 100pF, 1KV, 10%	23-111072
C35, 36, 37, 38	CAP, 6.8uF, 20%, 20V MIN.	23-441005
C12	CAP, 1uF, 35V, 20%, TANT	23-441001
C14	CAP, 30pF, 500V, 5%, DM15	23-311005
C16	CAP, 3.3uF, 16V, 20%, TANT	23-441007
C19	CAP, ,68uF, 50V, 10%	23-510019
C39	CAP, 51pF, 500V, 5%, DM15	23-311006
CR1, 6	DIODE, IN4004	24-104004
CR4,5	DIODE, A14U, 2.5AMP, 25PIV	24-102001
CR7	DIODE REF ZENER	24-48-1001
CR9, CR8	DIODE, IN4148	24-110001
CR2,3	DIODE, A14U, SELECTED	24-48-1154
DS101	POLARITY INDICATOR(5082-7736)	25-227736
DS102- DS105	SEVEN SEGMENT INDICATOR (5082-7740)	25-227740
L1	INDUCTOR, 7mH	25-48-1083
Q1, 2	TRANSISTOR, MPSA93	24-240A93

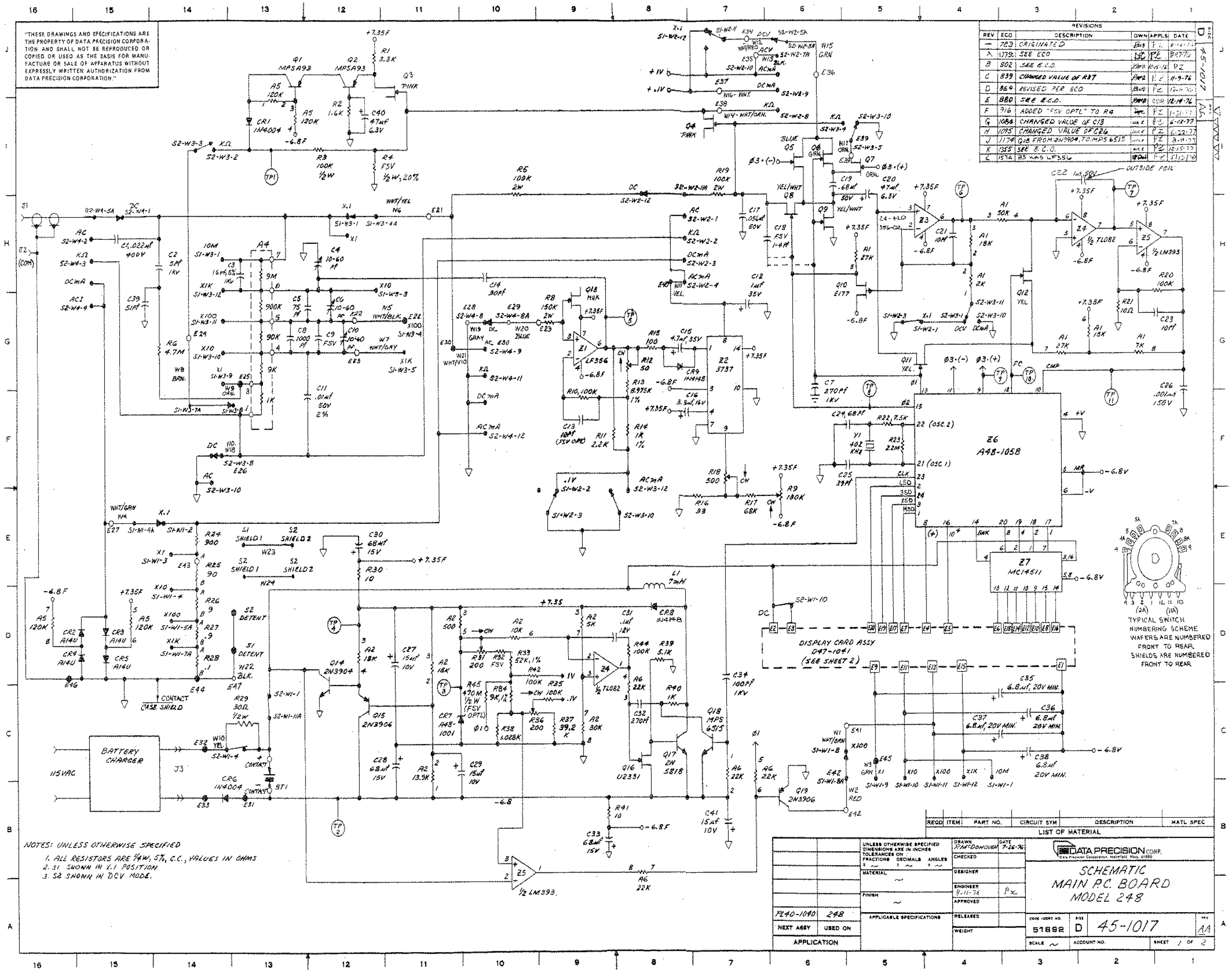
Q3, 4, 13	TRANSISTOR, FET	24-48-1014-01
Q5,	TRANSISTOR, FET	24-48-1014-02
Q6, 7	TRANSISTOR, FET	24-48-1014-03
Q8, Q9	TRANSISTOR, FET, YEL/WHT	24-48-1014-09
Q11, Q12	TRANSISTOR, FET	24-48-1014-05
Q10	TRANSISTOR, P CHANNEL FET	24-210177
Q14	TRANSISTOR, 2N3904	24-233904
Q17, Q101-Q106	TRANSISTOR, 2N5818	24-235818
Q15, 19	TRANSISTOR, 2N3906	24-243906
Q16	TRANSISTOR, U2331	24-48-1074-01
Q18	TRANSISTOR, MPS6515	24-236515
R1	RESISTOR, 3.3K, 1/4W, 5%	22-023329
R2	RESISTOR, 1.6K, 1/4W, 5%	22-021629
R3	RESISTOR, 100K, 1/2W, 5%	22-031049
R4	RESISTOR, 1/2W, 20%, FSV	T22-03***7
R5, 19	RESISTOR, 100K, 2W, 5%	22-051049
R6	RESISTOR, 4.7M, 1/4W, 5%	22-024759
R8	RESISTOR, 150K, 2W, 5%	22-051549-A
R10, 2035,42,44	RESISTOR, 100K, 1/4W, 5%	22-021049
R11	RESISTOR, 2.2K, 1/4W, 5%	22-022229
R12	RESISTOR, 50Ω, TRIM POT	22-674500
R13, 14	RESISTOR SET	22-48-1069-2
	RESISTOR, 8.975K (-1) (R13)	
	RESISTOR, 1K (-2) (R14)	
R18	RESISTOR, 500Ω, TRIM POT	22-674501
R21, 30, 41	RESISTOR, 10Ω, 1/4W, 5%	22-021009
R22	RESISTOR, 7.5K, 1/4W, 5%	22-027529
R23	RESISTOR, 2.2M, 1/4W, 5%	22-022259
R33, 34, 38	RESISTOR SET	22-48-1069-1
	RESISTOR, 9K (-1) (R34)	
	RESISTOR, 1.028K (R38)	
	RESISTOR, 52K (R33)	
R15	RESISTOR, 100Ω, 1/4W, 5%	22-021019
R9	RESISTOR, 100K, TRIM POT	22-674104
R16	RESISTOR, 33Ω, 1/4W, 5%	22-023309
R17	RESISTOR, 68K, 1/4W, 5%	22-026839
R36, 31	RESISTOR, 200Ω, TRIM POT	22-674201
R37	RESISTOR, 39.2K, 1%, RN55C	22-343922
R39	RESISTOR; 5.1K, 1/4W, 5%	22-025129
R40	RESISTOR, 1K, 1/4W, 5%	22-021029
R24	RESISTOR, 900Ω	22-68-1015-01
R25	RESISTOR, 90Ω	22-68-1015-02
R26	RESISTOR, 9Ω	22-68-1015-03
R27	RESISTOR, 9Ω	22-68-1015-04
R28	RESISTOR, 1Ω	22-68-1015-05
R29	RESISTOR 30Ω, ½W, 5%	22-033009
R45	RESISTOR, 470M, ½W, 20% (FSV OPT.)	22-034777
S1	SWITCH, RANGE	PL40-1112
S2	SWITCH, FUNCTION	PL40-1111
Y1	RESONATOR, 402KHz	25-141000
Z1	INTCKT, LF 356H, YEL. DOT SELECTED	24-48-1118
Z3	INT CKT LF 356 H BLUE DOT SELECTED	24-68-1033
Z2	INT CKT 3737	24-303737
Z4	INT CKT TL082	24-400082
Z5	INT CKT LM393	24-400393-A
Z6	INT CKT LSI, CMOS, A/D LOGIC	24-48-1058
Z7	INT CKT MC 14511	24-L14511



MAIN CARD ASSEMBLY



DISPLAY CARD ASSEMBLY



NOTES: UNLESS OTHERWISE SPECIFIED

1. ALL RESISTORS ARE ¼W, 5%, C.C., VALUES IN OHMS
2. S1 SHOWN IN X.1 POSITION
3. S2 SHOWN IN DCV MODE.

"THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF DATA PRECISION CORPORATION AND SHALL NOT BE REPRODUCED OR COPIED OR USED AS THE BASIS FOR MANUFACTURE OR SALE OF APPARATUS WITHOUT EXPRESSLY WRITTEN AUTHORIZATION FROM DATA PRECISION CORPORATION."

REVISIONS

REV	ECO	DESCRIPTION	DWN	APPLS	DATE
—	723	ORIGINATED	BW	PZ	8-22-76
A	1779	SEE ECO	DC	PZ	9-27-76
B	802	SEE E.C.O.	PWD	10-15-76	PZ
C	839	CHANGED VALUE OF R37	PWD	PZ	11-9-76
D	864	REVISED PER ECO	BW	PZ	12-1-76
E	880	SEE E.C.O.	PWD	CDR	12-14-76
F	916	ADDED "FSV OPTL" TO R4	[illegible]	PZ	1-31-77
G	1084	CHANGED VALUE OF C13	WKK	PZ	6-13-77
H	1095	CHANGED VALUE OF C26	WKK	PZ	6-22-77
J	1174	Q18 FROM:2N3904, TO:MPS 6515	WKK	PZ	8-18-77
K	1355	SEE E.C.O.	WKK	PZ	12-15-77
L	1574	Z3 WAS LF356	[illegible]	PZ	5/10/78

REQD	ITEM	PART NO.	CIRCUIT SYM	DESCRIPTION	MATL SPEC

LIST OF MATERIAL

NEXT ASSY	USED ON
PL40-1040	248

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± ~ DECIMALS ± ~ ANGLES ± ~
MATERIAL ~
FINISH ~
APPLICABLE SPECIFICATIONS

DRAWN P.McDonough DATE 7-26-76
CHECKED
DESIGNER
ENGINEER 9-11-76 PZ
APPROVED
RELEASED
WEIGHT

DATA PRECISION CORP.
Data Precision Corporation, Wakefield, Mass. 01880

SCHEMATIC
MAIN P.C. BOARD
MODEL 248

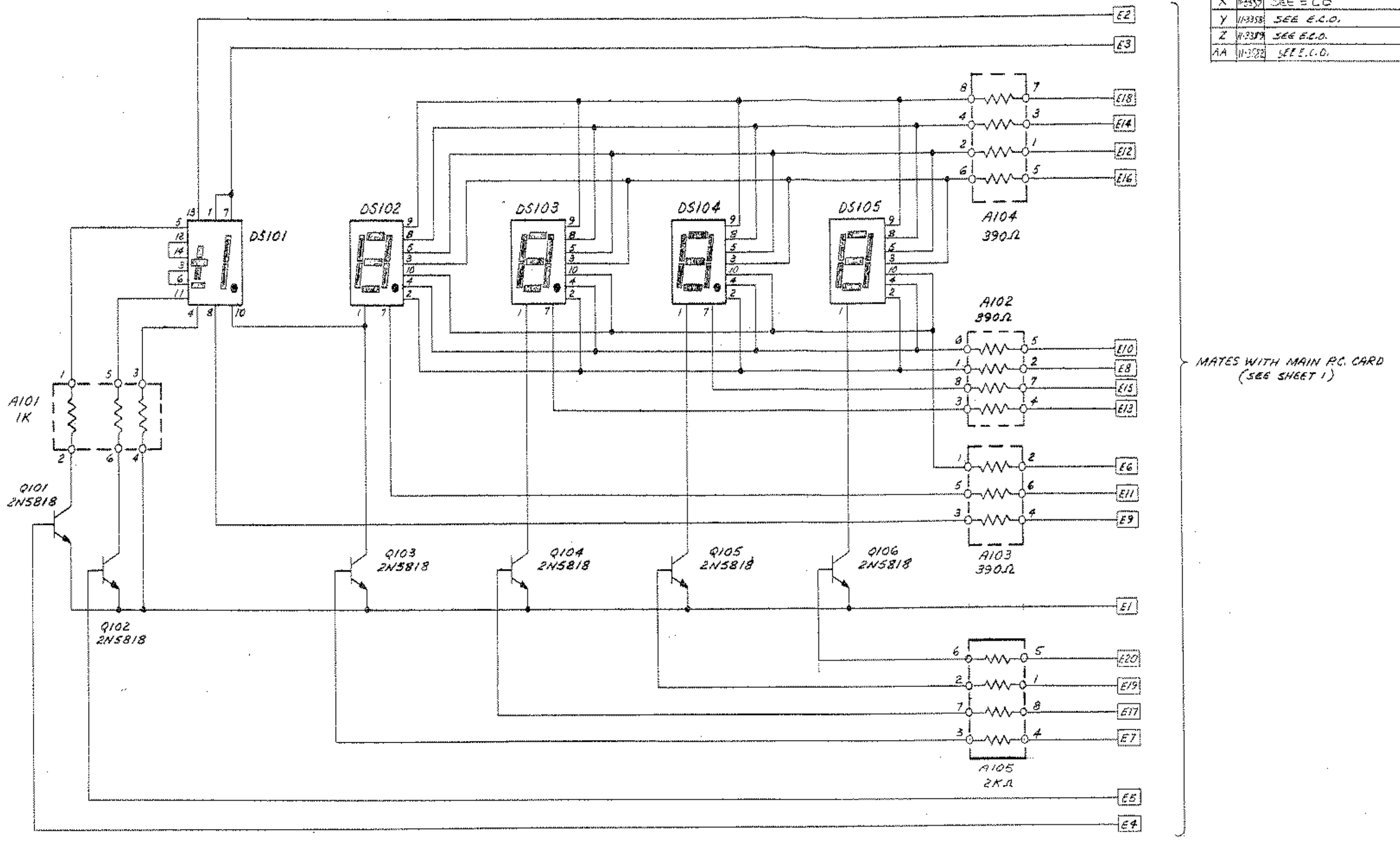
CODE IDENT NO. 51892
SIZE D
45-1017
REV AA
SCALE ~
ACCOUNT NO.
SHEET 1 OF 2

"THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF DATA PRECISION CORPORATION AND SHALL NOT BE REPRODUCED OR COPIED OR USED AS THE BASIS FOR MANUFACTURE OR SALE OF APPARATUS WITHOUT EXPRESSLY WRITTEN AUTHORIZATION FROM DATA PRECISION CORPORATION."

REVISIONS

REV	ECO	DESCRIPTION	DWN	APPLS	DATE
M	1582	CHG Q14 FROM 2N5818 TO 2N3904	PMD	PC	5-16-78
N	1738 1784	ADD C18 OPT'L MTG. R37 WAS 36.5K	BAV	PC	10-16-78
P	1909	C40 WAS 15uf, 10V	PMD	P.C.	1-8-79
R	1950	ADDED TEST POINTS & R45	[illegible]	CSR	[illegible]
S	1970	SEE E.C.O	[illegible]	CSR	[illegible]
T	11-1003	SEE E.C.O.	[illegible]	[illegible]	7-7-79
U	11-3045	SEE E.C.O	KN	[illegible]	9-11-79
V	11-3165	SEE E.C.O.	PMD	[illegible]	2-14-80
W	11-3125	ADDED A105	[illegible]	CSR	[illegible]
X	11-3339	SEE E.C.O	[illegible]	[illegible]	9-18-80
Y	11-3358	SEE E.C.O.	PMD	[illegible]	10-3-80
Z	11-3389	SEE E.C.O.	PMD	CSR	11-5-80
AA	11-3582	SEE E.C.O.	D.G.	[illegible]	6-19-81

SIZE D 45-1017 REV AA



REQD	ITEM	PART NO.	CIRCUIT SYM	DESCRIPTION	MATL SPEC

LIST OF MATERIAL

NEXT ASSY	USED ON
PL40-1041	248

APPLICATION

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES
TOLERANCES ON
FRACTIONS ± ~ DECIMALS ± ~ ANGLES ± ~
MATERIAL
FINISH
APPLICABLE SPECIFICATIONS

DRAWN P. McDONOUGH DATE 7-26-76
CHECKED
DESIGNER
ENGINEER
APPROVED
RELEASED
WEIGHT

DATA PRECISION CORP
Data Precision Corporation, Wakefield, Mass. 01880

SCHEMATIC
DISPLAY BOARD
MODEL 248

CODE IDENT NO. 51682 SIZE D 45-1017 REV AA
SCALE ~ ACCOUNT NO. SHEET 2 OF 2