MOTOROLA INC., COMMUNICATIONS DIVISION · INSTRUCTION MANUAL

Model S1051B

MOTOROLA *transistorized voltmeter*

AC

OPERATOR'S HANDBOOK

PRINTED IN U.S.A.

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MOTOROLA
TRANSISTORIZED AC VOLTMETER
MODEL S1051B

AEPD-6203-O(MC6609)

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TRANSISTORIZED AC VOLTMETER

MOTOROLA INC. COMMUNICATIONS DIVISION
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GUARANTEED PERFORMANCE SPECIFICATIONS

MODEL	S1051B AC Voltmeter
MEASUREMENTS	1 millivolt to 300 volts full scale on 12 ranges. -60 db to +50 db on 12 ranges.
ACCURACY	±3% from 20 cycles per second to 1 megacycle (25°C (77°F))
INPUT IMPEDANCE	1 to 300 mv range; greater than 1 megohm shunted by 30 uuf. 1 to 300 volt range; greater than 10 megohms shunted by 15 uuf.
OVERLOAD PROTECTION	VOLT range: Maximum of 550 volts (sum of the d-c and a-c peak voltages) MILLIVOLT range: Maximum of 110 volts rms continuous; 220 volts rms for 10 seconds or less; 600 volts d-c.
NOISE	Less than 0.2 mv meter deflection in open circuit input on the 1 mv scale. Less than 0.1 mv meter deflection in short circuit input on the 1 mv scale.
METER CALIBRATION	Linear voltage scales: 0-1 and 0-3 (calibrated to rms values of a sine wave). Voltages ranges: 1, 3, 10, 30, 100, 300 steps DB scale calibration: -12 to +2 Zero level: 1 milliwatt in 600 ohms.
METER	0-50 microampere movement
TRANSISTOR COMPLEMENT	(7) 2N231
POWER SUPPLY	1 - 6.5 volt Mercury Battery (Mallory No. TR-135).
WEIGHT	Approximately 6 pounds
DIMENSIONS	5" wide x 6" high x 10" long (approx.)

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE.

(Pages iii and iv are omitted due to irrelevancy)

CONTENTS

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1. INTRODUCTION

A fully transistorized a-c voltmeter offers many advantages not found in a-c vacuum tube voltmeters. Small physical size, light weight and a single battery with an operating life of over 400 hours permits complete portability for field use. Freedom from a-c power lines reduces the effects of noise and harmonic frequencies on the meter reading. The absence of heat producing elements, such as tubes and transformers, lessens the need for frequent recalibration and increases component life.

2. DESCRIPTION

a. Functions

The Model S1051B Transistorized AC Voltmeter is a battery operated instrument capable of accurately performing the following functions:

(1) AC voltage measurement from 0.1 millivolt to 300 volts in a frequency range of 20 cycles per second to 1 megacycle.

(2) Power measurements from -72 to +52 dbm when measured across 600 ohm impedances (0 dbm = 1 milliwatt into 600 ohms).

(3) Comparative power measurements from -72 to +52 db (when measured at the same impedance level).

b. Instrument Characteristics

This instrument is similar to many other a-c voltmeters in that the meter movement responds to average values of applied voltages. The meter scale is calibrated to read the rms value of a sinusoidal waveform. When the input waveform departs from a pure sine wave, the meter indication will be in error by the ratio of the average value to the rms value of the incoming waveform.

c. Portability

Although primarily designed for laboratory use, this instrument being self-powered and housed in a sturdy case is quite applicable for portable use without sacrificing the accuracy or versatility of a laboratory instrument. A detachable metal cover protects the front panel from damage that might occur in portable use. Clips for storing the meter cable or other accessories are mounted on the inside of the cover.

3. METER CALIBRATION

The meter is calibrated in two linear a-c voltage scales, one decibel scale and a battery condition scale. It uses a 0-50 microampere movement with non-linearity less than 1% of full-scale deflection. Damping is adjusted to eliminate "overshoot" for convenience in reading the pointer indication. The meter scales and applications are as follows:

a. AC Voltage Scales

The two linear scales (black) are used to measure rms values of a-c voltages. The upper scale is graduated to a full-scale value of 1.0 and the lower scale is graduated to a full-scale of 3.2. All a-c voltages from 0.1 millivolt to 300 volts rms are read directly from these scales using the full scale factors appearing on the range selector switch positions.

b. Decibel Scale

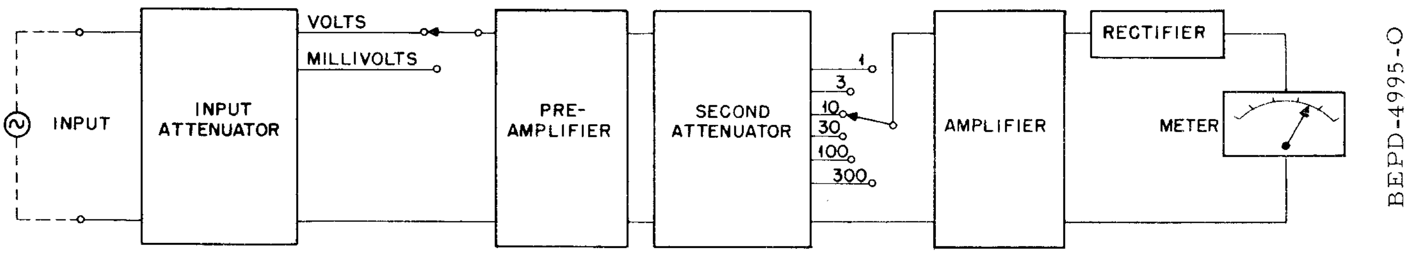
The DECIBEL scale (red) is used for dbm measurement when measuring power levels into a 600 ohm impedance or comparative db levels when measured at the same impedance level. The scale is calibrated from -12 to +72 and readings are obtained by using the algebraic sum of the range selector switch position and the meter pointer indication.

c. Battery Condition Scale

The BATTERY O.K. scale (red) is the small scale above and to the right of the upper a-c voltage scale. It is used to obtain an indication of battery condition under load. The meter pointer indication within the scale limits is a relative indication of battery condition.

4. CONTROLS AND INPUT TERMINATIONS

All controls and input terminations used for measurement are located on the recessed front panel of the instrument.



Block Diagram

a. Range Selector Switch

This is a 12 position switch used to select the proper voltage or decibel range. The correct switch position is determined by the level applied to the input.

b. OFF-BATT. -ON Switch

This switch permits a check of the internal battery condition under load in addition to turning the instrument on or off. The meter is connected to the battery under a simulated load when the switch is placed in the BATT. position.

c. Input Terminations

Two binding posts are mounted on a molded polystyrene base selected for its low loss characteristics at high frequencies. These "six-way" binding posts are used to make electrical connections with single and double pin banana type plugs, tipped plugs, spade lugs, alligator clips and bare wire.

d. Meter Cable

The SKN6001A Meter Cable Kit is available as an optional accessory. It is a 30" shielded cable terminated at one end in a standard two-pin banana plug. The probe end of the cable is terminated in two insulated alligator clips.

5. CIRCUIT DESCRIPTION

Refer to the block diagram for general information and the schematic diagram for detailed wiring information.

a. Input Attenuation

Two precision resistor attenuators are used to reduce the input level. The input attenuator (used only on ranges above 1 volt) reduces the input level by 60 db. A second attenuator at the output of the pre-amplifier is used to accomplish additional attenuation in 10 db steps. A three section potentiometer (R13A, B and C) permits adjustment for minor loading variations or resistance changes of the second attenuator.

b. Pre-amplifier

The pre-amplifier presents a high input impedance necessary to prevent circuit loading and resultant erroneous readings in many applications. Two transistors (Q1 and Q2) are connected in a "bootstrap" configuration. The normally low input impedance of transistor amplifiers is increased through the use of feedback to the high level required for accurate measurement. Two protection diodes (CR1 and CR2) are connected in the base circuit of the input transistor (Q1) to protect the instrument from excessive input voltages. A maximum of 550 volts peak (sum of the a-c and d-c voltages) may be applied on any VOLT range without damage to the instrument. A maximum of 110 volts rms continuous or 220 volts rms for 10 seconds or less can be applied on any MILLIVOLT range without damage.

c. Amplifier

A buffer stage (Q3) prevents excessive loading of the second attenuator in addition to voltage amplification. The input impedance of the buffer stage presents a fixed load for the second attenuator regardless of operating frequency or transistor characteristics. Resistor R23 shunts the input impedance of transistor Q3, which is raised to more than 150K by the use of feedback and determines the input impedance of the stage almost exclusively.

Two cascaded amplifier stages, the first consisting of Q3, Q4 and Q5 and the second consisting of Q6 and Q7, perform the main voltage amplification. Large amounts of a-c and d-c feedback are used to insure stable operation over the wide bandwidth of the instrument.

A variable gain control (R26) in the emitter circuits of Q3 and Q5 permits adjustment of the net gain of the first three transistors (Q3, Q4 and Q5) for calibration purposes. A variable resistance (R19) in the base circuit of Q3 permits adjustment of the operating bias for transistors Q3, Q4 and Q5. Capacitors C2 and C24 are used for high frequency compensation. Resistor R33 and capacitor C14 constitute a low frequency decoupling circuit between the second pair of transistors (Q6 and Q7) and the preceding stages. A thermistor (RT1) in the collector circuit of Q3 maintains constant d-c operating characteristics in all three stages of the amplifier for temperatures up to 50° C (122°F).

d. Meter Circuit

The output of Q7 is applied to a full wave bridge rectifier consisting of two high frequency diodes (CR3 and CR4). A 0-50 microampere meter movement (M1) is connected across the output of the rectifier to measure the resultant d-c current. Signal current from the meter circuit is fed back to the amplifier to obtain gain stability and meter linearity over the entire bandwidth.

6. OPERATION

a. Mechanical Meter Zero

A screwdriver adjustment, used to mechanically zero the meter, is located on the meter cover. If the meter pointer does not rest directly in line with the 0 line of the voltage scales when the OFF-BATT.-ON switch is in the OFF position, turn this adjustment left or right until the pointer is directly in line with the 0 line.

b. Battery Check

Place the OFF-BATT.-ON switch in the BATT. position. A new battery will give a meter indication near the upper limits of the BATTERY O.K. scale. After a few hours of operation, meter indication will be approximately mid-scale. If the meter indication just reaches or falls below the lower limits of the scale, the accuracy of the instrument will be affected and the battery must be replaced. Refer to the MAINTENANCE paragraph of this manual for detailed information.

c. AC Voltage Measurement

(1) Place the OFF-BATT.-ON switch in the ON position.

(2) A rapid check of the condition of the instrument may be performed by placing the range selector switch in the 1 MILLIVOLT position. The meter indication should be anywhere from 0.2 to full or off-scale deflection depending on the proximity of stray electric fields from a-c power lines.

(3) Place the range selector switch in a VOLTS or MILLIVOLTS position corresponding to an expected meter indication in the upper 2/3 of the meter scale. Readings in this portion of the scale are the most accurate and ranges should be selected to accomplish this whenever possible.

NOTE

When in doubt as to expected voltage levels, good practice is to place the range selector switch in the least sensitive (highest voltage) range and progressively increase the sensitivity (switch to lower voltage ranges) until a reading in the upper 2/3 of the scale is obtained.

(4) Connect the input terminals across the voltage source to be measured.

WARNING

The GND terminal is connected to the instrument case and extreme caution should be exercised when connecting this terminal to high potentials (referenced to ground) to minimize shock hazard to operating personnel. When high d-c potentials are present, connect a large coupling capacitor in series with this terminal and a 1 megohm resistor between this terminal and referenced ground of the circuit being measured.

d. Power Measurements

Power measurements in terms of db or dbm are made in the same manner as a-c voltage measurements except that the meter indication is read from the DECIBEL scale. When making measurements in terms of dbm, the measurements must be made across a 600 ohm impedance (0 dbm = 1 milliwatt into 600 ohms). Comparative power level measurements in terms of db may be made by noting the difference in db readings obtained when each measurement is made across the same value of impedance. The correct level in db or dbm is the algebraic sum of the meter indication on the DECIBEL scale and the range selector switch DECIBEL position.

e. Battery Conservation

The instrument should be turned off when not in use to increase the life of the battery. Accuracy will not be affected by using the instrument immediately after turning it on as there is essentially no "warm-up" period required. If the instrument has not been used for extended periods (6 weeks or longer) a five minute stabilization period is recommended before use.

f. Examples of AC Voltage and Power Measurements

The following table lists a number of meter indications and their respective voltage and power levels.

Range Selector Switch Position	Scale	Meter Indication	Level
300 VOLTS	0-3.2	2.1	210 volts a-c rms
10 VOLTS	0-1.0	.64	6.4 volts a-c rms
3 MILLIVOLTS	0-3.2	2.6	0.0026 volts a-c rms
1 MILLIVOLTS	0-1.0	.72	0.00072 volts a-c rms
+50 DECIBELS	DECIBEL	+1	+51 decibels
+20 DECIBELS	DECIBEL	-5	+15 decibels
-60 DECIBELS	DECIBEL	-8	-68 decibels
-40 DECIBELS	DECIBEL	+2	-38 decibels

7. TEMPERATURE LIMITATIONS

As with most precision measuring equipment, this instrument has certain temperature limitations. Accurate readings are obtained in normal temperatures. Avoid operation and storage in temperatures above 50°C (122°F). Storage in temperatures less than -40°C or -40°F should also be avoided. The following table will provide an idea of the accuracy of the instrument as influenced by temperature.

Temperature	Tolerance	Frequency
0°C (32°F) to 40°C (104°F)	±3%	20 cps to 1 mc
50°C (122°F)	+3, -5%	20 cps to 1 mc
-10°C (14°F) to -20°C (-4°F)	±5%	20 cps to 500 kc
	+5, -10%	500 kc to 1 mc

8. APPLICATIONS

a. General

A complete understanding of instrument capabilities and effects on various circuits is necessary to obtain optimum accuracy in difficult measurements. This instrument measures average voltage levels of sinusoidal waveforms and the meter scale is calibrated in rms levels. The meter reading may be in error when the instrument is used to measure other than sinusoidal voltage waveforms. The instrument will accept voltage peaks up to twice the rms value of the input at full scale deflection without waveform clipping.

The curves of figures 1 and 2 illustrate some of the effects of the harmonic content of non-sinusoidal waveforms on meter readings. It can be noted from these curves that the meter will always read lower than the true rms value when measuring waveforms having a second harmonic content. The meter may read higher or lower than the true rms value when measuring waveforms having a third harmonic content.

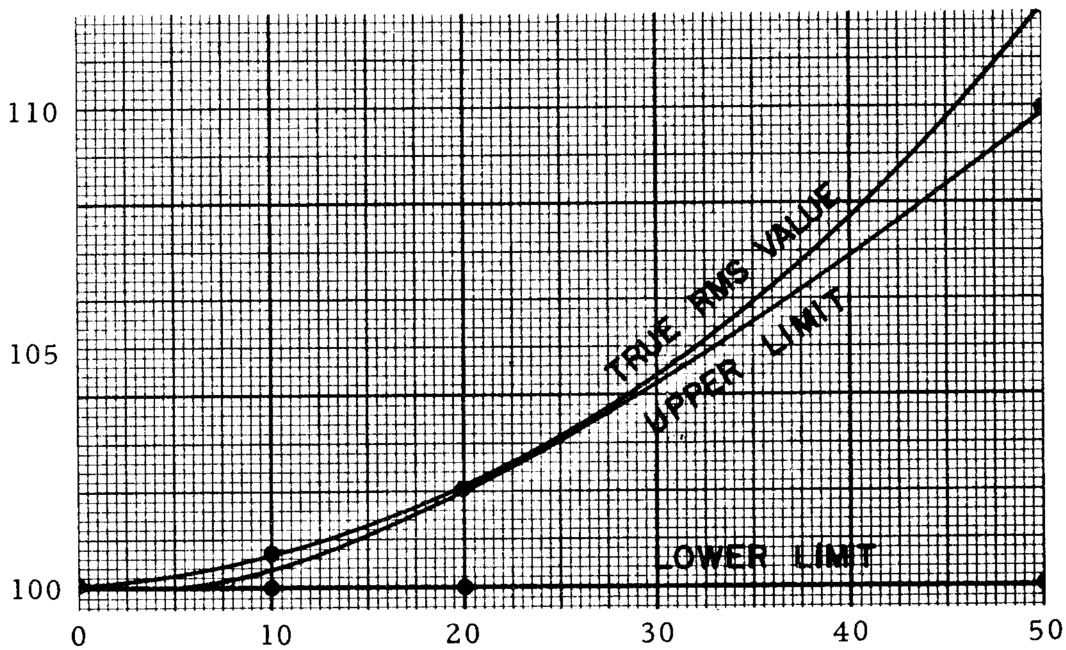
b. Typical Applications

A brief outline of typical applications for the a-c voltmeter is included to show the versatility of an instrument of this type. Unique uses for this instrument will be found as capabilities become more evident.

(1) Audio Frequency Measurements

Low level audio voltages generated piezo-electric and magneto-strictive in

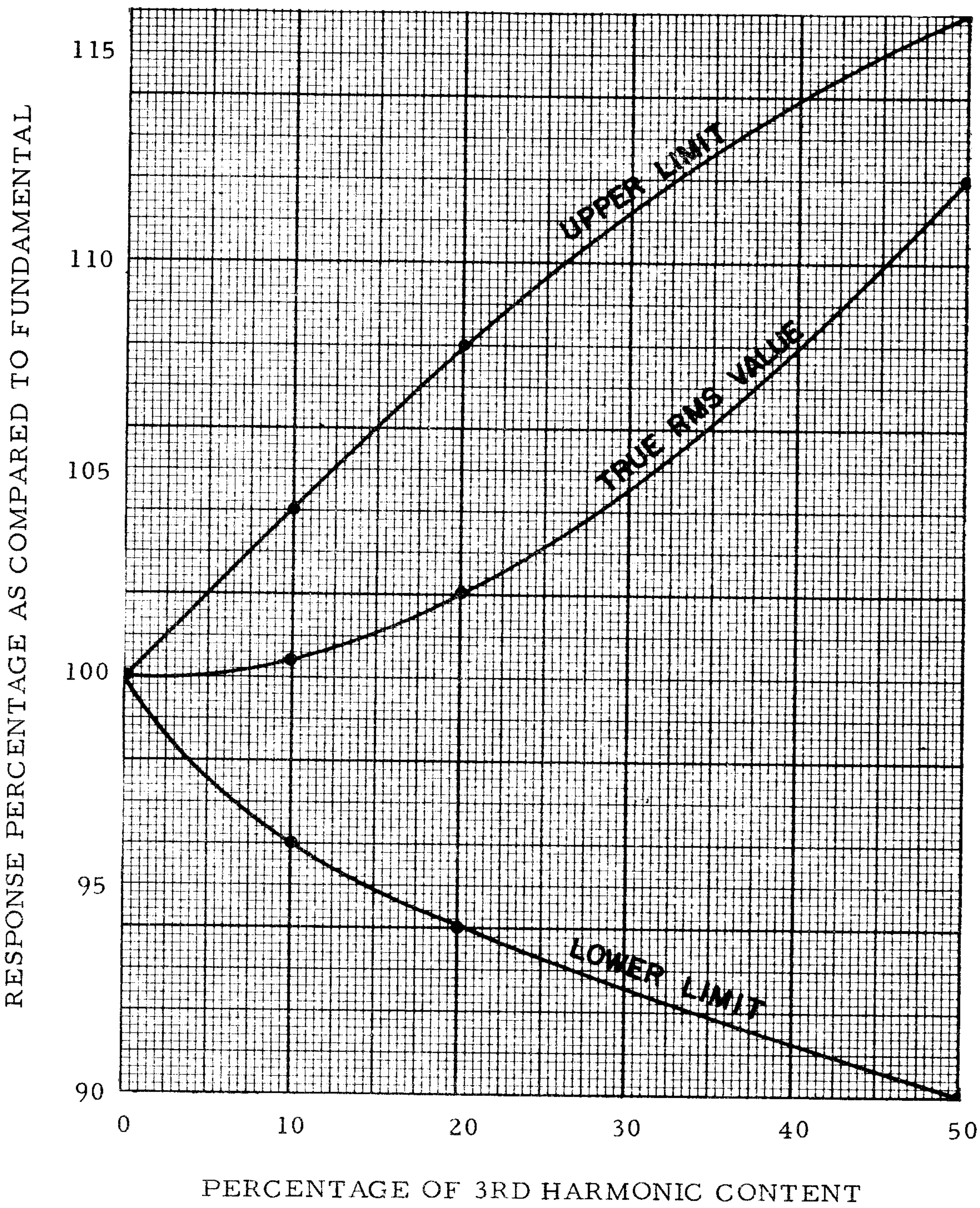
AC VOLTMETER RESPONSE TO 2ND HARMONIC



NOTE: METER READINGS MAY VARY BETWEEN UPPER AND LOWER LIMITS DEPENDING ON PHASE RELATIONSHIP OF FUNDAMENTAL AND HARMONIC.

Figure 1.

AC VOLTMETER RESPONSE TO 3RD HARMONIC



NOTE: METER READINGS MAY VARY BETWEEN UPPER AND LOWER LIMITS DEPENDING ON PHASE RELATIONSHIP OF FUNDAMENTAL AND HARMONIC.

Figure 2.

AEPD-4998-O

electro-mechanical devices (phonographic cartridges and microphones) may be accurately measured on the lower ranges of the meter.

Voltage levels in audio and ultra-sonic amplifiers using either electron tubes or transistors may also be measured without disrupting the circuit under test.

Output voltages from power amplifiers, such as P. A. loudspeaker systems, may be measured across low impedance speakers and high impedance distribution lines without any loss of accuracy of the measuring instrument. However, do not exceed the maximum overload voltages as specified in the GUARANTEED PERFORMANCE SPECIFICATIONS Chart included in this manual.

Hum levels of power supplies may also be measured. When d-c voltages in excess of the instrument rating (550 volts -- sum of the a-c peak and d-c) are present, a 0.1 microfarad capacitor should be connected in series with the INPUT terminal and a 10 megohm resistor connected between the INPUT and GND. terminals. Use a capacitor with a higher d-c voltage rating than that of the power supply being measured.

(2) Radio Frequency Measurements

The a-c voltmeter will accurately measure voltage levels in i-f and r-f amplifiers, mixers, detectors, oscillators and modulators using either electron tubes or transistors. Measurements at these higher frequencies should be performed using very short direct leads between the voltmeter and the circuit under test. This will avoid the capacitive shunting effects which are inherent in shielded cables and long test leads.

The input resistance and shunt capacity of the instrument must be considered when measuring voltages at radio frequencies. The loading effect is most predominant on high impedance tube circuits (especially on tuned circuits). The influence is considerably less on low impedance transistor circuits, where the shunt capacity of the instrument is normally a small part of the tuned circuit being measured.

The isolation from an a-c line makes the use of this instrument as a null indicator in a-c bridges very important. The high sensitivity and low internal noise allows an accurate balance of the bridge circuit to be made. Due to the wide frequency response of the instrument, it is important that the oscillator supplying the bridge be completely free from harmonics.

9. CALIBRATION

Accuracy of the instrument can be maintained by periodic calibration. This should be accomplished only by qualified personnel having adequate facilities. If desired, the instrument may be returned to the factory for calibration. Refer to the FOREWORD section of this manual for detailed information.

10. MAINTENANCE

a. Servicing

This instrument should be serviced by personnel qualified in maintaining laboratory test equipment. It is an accurate, sensitive instrument and should be treated as such. When qualified personnel or adequate equipment are not available, the instrument should be returned to the factory for service or calibration.

b. Battery Replacement

(1) Remove the large plug-button from the bottom of the instrument housing to gain access to the battery case.

(2) Remove the screwdriver slotted plug and the attached spring from the bottom of the battery case.

(3) Remove the battery.

(4) Insert a new mercury battery (Mallory No. TR-135 or equivalent), negative end first, in the battery case. (See note in Parts List)

(5) Replace the spring, plug, and plug-button.

(6) Check the battery condition and polarity by placing the OFF-BATT.-ON switch in the BATT. position. Meter indication should be in the upper portion of the BATTERY O.K. scale. If the meter deflects to the left off-scale, reverse the position of the battery in the case.

NOTE

The Mallory No. TR-135R battery may be used in place of the TR-135 but has a shorter operating life (approximately 350 hours).

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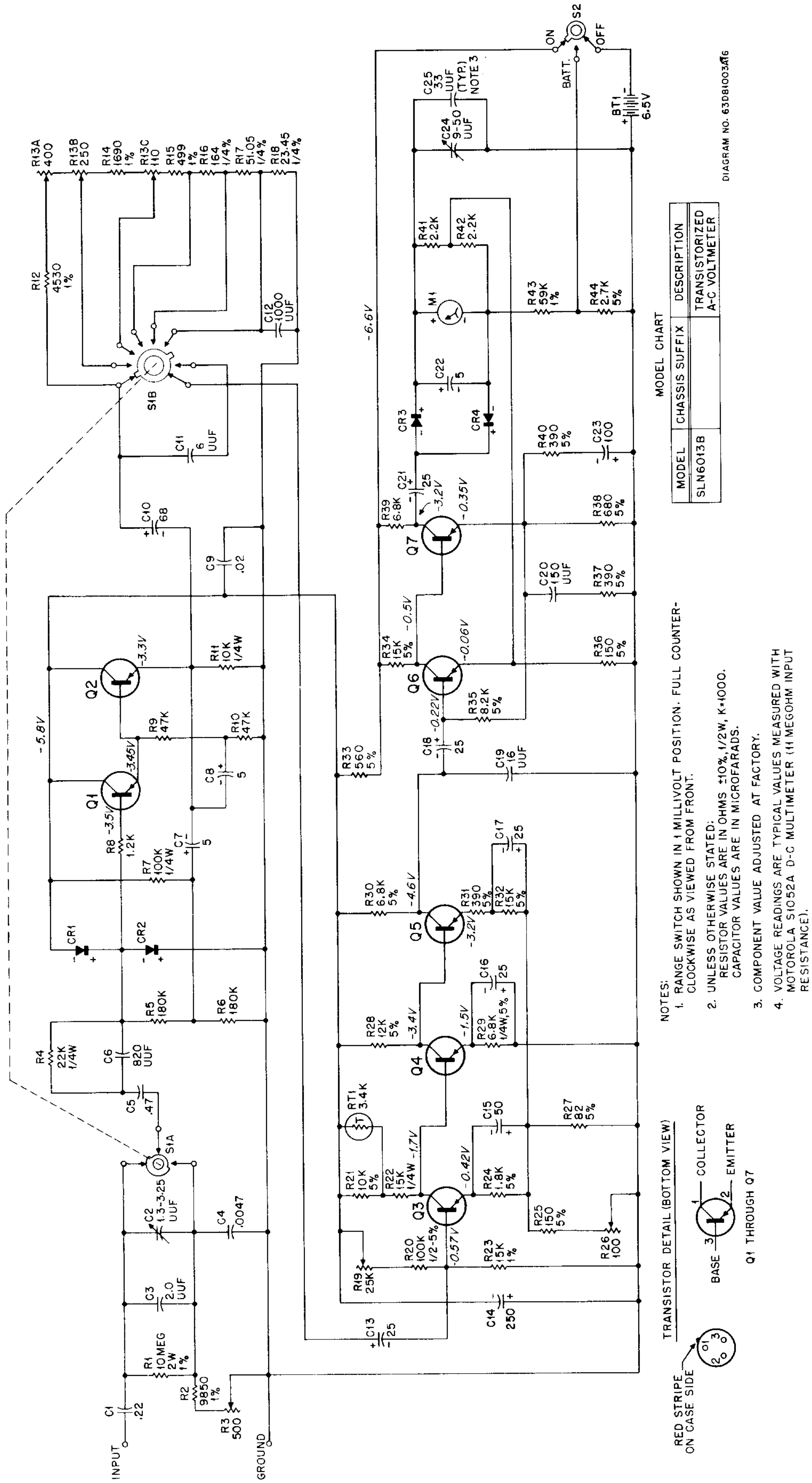

NOTES:
1. RANGE SWITCH SHOWN IN 1 MILLIVOLT POSITION. FULL COUNTER-CLOCKWISE AS VIEWED FROM FRONT.
2. UNLESS OTHERWISE STATED: RESISTOR VALUES ARE IN OHMS ±10%, 1/2W, K=1000. CAPACITOR VALUES ARE IN MICROFARADS.
3. COMPONENT VALUE ADJUSTED AT FACTORY.
4. VOLTAGE READINGS ARE TYPICAL VALUES MEASURED WITH MOTOROLA S1052A D-C MULTIMETER (11 MEGOHM INPUT RESISTANCE).

MODEL CHART

MODEL	CHASSIS SUFFIX	DESCRIPTION
SLN6013B		TRANSISTORIZED A-C VOLTMETER

Model S1051B
Transistorized AC Voltmeter
Schematic Diagram
Motorola No. 63D81003A16-O
2/1/61-UM

LEGEND

ppm/°C = parts per million/°C
NPO = ±0 ppm/°C
N750 = -750 ppm/°C
N1500 = -1500 ppm/°C
c/o = consists of

PARTS LIST for Schematic Diagram 63D81003A16-O

REFERENCE SYMBOL	MOTOROLA PART No.	DESCRIPTION
		BATTERY, mercury: See note
BT1	60B863919	6.5 volts; 5 cell
		CAPACITOR, fixed: unless otherwise stated;
C1	8C865794	.22 uf ±20%; 600 v
C2	19B82684B01	variable; 1.30-3.25 uuf; 850 v
C3	21K857336	2.0 uuf ±.25 uuf; 500 v; NPO
C4	8C867238	.0047 uf ±10%; 400 v
C5	8K861614	.47 uf ±10%; 100 v
C6	21B837745	820 uuf ±10%; 500 v
C7	23C82601A11	5 uf +33-10%; 25 v
C8		same as C7
C9	21K832502	.02 uf +60-40%; 250 v
C10	23K865795	68 uf +100-10%; 6 v
C11	21K840848	6 uuf ±.5%; 500 v
C12	21K847601	1000 uuf ±5%; 500 v
C13	23C82601A01	25 uf +150-10%; 25 v
C14	23D82394A03	250 uf +100-10%; 25 v
C15	23C82601A05	50 uf +150-10%; 25 v
C16		same as C13
C17		same as C13
C18		same as C13
C19	21K868383	16 uuf ±5%; 1000 v; N1500
C20	21K840047	150 uuf ±5%; 500 v
C21		same as C13
C22		same as C7
C23	23C82601A09	100 uf +150-10%; 25 v
C24	20C82860B01	variable; 9-50 uuf; 350 v; N750
C25	21R131261	33 uuf ±5%; 500 v; NPO
		SEMI-CONDUCTOR DEVICE, diode: (NOTE 1)
CR1	48B864199	silicon
CR2		same as CR1
CR3	48B82691B01	germanium
CR4		same as CR3
		METER, multi-scale:
M1	72D863754	c/o; 0-1, 0-3 volts; -10 to +2 db; 0-50 ua
		TRANSISTOR: (NOTE 1)
Q1	48K124382	p-n-p
Q2		same as Q1
Q3		same as Q1
Q4	48K124381	p-n-p
Q5		same as Q4
Q6.		same as Q4
Q7		same as Q4
		RESISTOR, fixed: ±10%; 1/2 w; unless otherwise stated;
R1	6D82672B04	10 meg ±1%; 2 w
R2	6D82672B05	9850 ±1%
R3	18C82692B01	variable; 500 ohms ±20%; 1/4 w
R4	6K128685	22K; 1/4 w
R5	6R6444	180K
R6		same as R5
R7	6K129226	100K; 1/4 w
R8	6R6393	1.2K
R9	6R6048	47K
R10		same as R9
R11	6K129225	10K; 1/4 w
R12	6D82475B38	4530 ±1%
R13	18C82675B01	variable; 3 section; consists of;
R13A		400 ±20%
R13B		250 ±20%
R13C		110 ±20%
R14	6D82475B39	1690 ±1%
R15	6D82475B40	499 ±1%
R16	6D82672B03	164 ±.25%
R17	6D82672B01	51.05 ±.25%
R18	6D82672B02	23.45 ±.25%
R19	18K848202	variable; 25K ±20%; 2/10 w
R20	6R5553	100K ±5%

REFERENCE SYMBOL	MOTOROLA PART No.	DESCRIPTION
		RESISTOR, fixed: ±10%; 1/2 w; unless otherwise stated: (Continued)
R21	6R5556	10K ±5%
R22	6K127805	15K; 1/4 w
R23	6D82475B37	15K ±1%
R24	6R488095	1.8K ±5%
R25	6R5645	150 ±5%
R26	18C82676B01	variable; 100 ±20%; 0.2 w
R27	6R2083	82 ±5%
R28	6R2075	12K ±5%
R29	6R129237	6.8K ±5%; 1/4 w
R30	6R2001	6.8K ±5%
R31	6R400804	390 ±5%
R32	6R5726	15K ±5%
R33	6R400058	560 ±5%
R34		same as R32
R35	6R400490	8.2 ±5%
R36		same as R25
R37		same as R31
R38	6R5651	680 ±5%
R39	6R6428	6.8K
R40		same as R31
R41	6R6069	2.2K
R42		same as R41
R43	6D82475B41	59K ±1%
R44	6R5652	2.7K ±5%
		THERMISTOR:
RT1	6K864427	3.4K ohms ±10% @ 37.8°C
		SWITCH, rotary:
S1	40C82687B01	2 section; 2 poles-12 positions; shorting type
S2	40B863922	1 pole-3 positions; non-shorting type
		NON-REFERENCED ITEMS
	1V80710A13	FRONT PANEL ASSY. (riveted)
	36K868905	KNOB, control: (white dot)
	46B865778	POST, binding: BLACK
	46K865779	POST, binding: RED
	14K865780	INSULATOR, binding post: 2 req'd.
	42B82673B01	HOLDER, battery: incl. hdwe
	36B82479B01	KNOB, control: range selector switch
	1V80710A94	CIRCUIT BOARD ASSY. (riveted)
	26C82980B01	SHIELD, cover
	55A82436B01	HINGE, front cover: 2 req'd.
	55A879706	CATCH, strike
	3S131660	SCREW, self-tapping: for hinge and catch
	1V80709A38	FRONT COVER ASSY. (riveted)
	15D82533B02	HOUSING ASSY.
	38A82978B01	BUTTON, plug
	75A82467B01	MOULDING, rubber: for front cover

NOTES:

1. Replacement transistors or diodes must be ordered by Motorola part number only for optimum performance.

The battery may be one of the following brands and types: Eveready E135, Mallory TR-135, or Ray-O-Vac T-135. This is a 7-volt mercury battery rated at 1000 mAh and is 0.662" diameter and 3.245" long.

END OF DOCUMENT