Instruction Manual

Model 93AD

True RMS Voltmeter

93AD
f-579

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Model 93AD

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CHAPTER I

EQUIPMENT DESCRIPTION

1.1 INTRODUCTION

The Model 93AD furnishes true rms voltage measurements of sine, complex, pulse and random waveforms over a voltage range of 300 μV to 300 V, and a frequency range of 10 Hz to 20 MHz. With the dBm options, the overall range is -68 to +60 dBm. The exact dBm range will depend upon the reference impedance chosen.

The digital display uses light-emitting diodes for clear, unambiguous readings. A small edge meter, calibrated in dB over a 12 dB range, is mounted beside the digital display. While this is useful for comparative dB readings, its major usefulness is for peaking or nulling indications, an application for which a digital display is usually found confusing. In addition to the 3-digits-plus-1 voltage readout, the LED display offers decimal point, over- and under-range indicators, mode (volts or dBm) and polarity (for dBm option instruments).

The Model 93AD is designed for easy integration into external test systems; full BCD output (8,4,2, 1), using standard positive logic, TTL compatible, is supplied as standard. In addition to the BCD outputs, an analog output is furnished, supplying up to 10 volts dc for full-scale reading on each range with a linearity of ±0.3% of fs and a source resistance of ≅ 5 Ω. Command inputs are provided for remote control of all essential functions.

Both bandwidth and response time of the instrument are selectable, either panel switched or remotely, to suit the measurement requirements. The input impedance of the 93AD as supplied is 2 MΩ in parallel with 25 pF or less; a high-impedance probe (Model 93-1A) is available as an optional accessory. This probe has an input impedance of 10 MΩ in parallel with 11.5 pF or less. The signal-input BNC connector, normally mounted on the front panel, may be mounted on the rear panel as an option (Model 93AD-08) to fit a particular installation. Autoranging (Model 93AD-01) is another optional feature.

The Model 93AD is of completely solid-state design, including the chopper; this contributes to the reliability, stability, light weight and compact size of the instrument. The chopper operates at 94 Hz, reducing the susceptibility to line-frequency-related fields and enhancing the low-noise quality of this design.

The mechanical design of the 93AD is simple and rugged, with easy access provided to all components. The extensive use of plug-in printed circuit board construction makes maintenance and adjustment relatively simple procedures. The sturdy bail provided serves as a comfortable carrying handle for the instrument, and as an adjustable mounting foot to tilt the case for easy viewing when it is at bench level.

Packaged in a compact half-rack case, the 93AD may be rack-mounted, singly or in pairs, with an optional rack-mounting kit (Model 92-1A or 92-1B).

1.2 SPECIFICATIONS

1.2.1 Range

	Voltage fs	*dBm 1 mW, 600 Ω
11	300 V	+50
10	100 V	+40
9	30 V	+30
8	10 V	+20
7	3 V	+10
6	1 V	0
5	300 mV	-10
4	100 mV	-20
3	30 mV	-30
2	10 mV	-40
1	3 mV	-50
0	1 mV	-60

*with dBm option instruments

Lowest calibrated voltage level = 300 μV

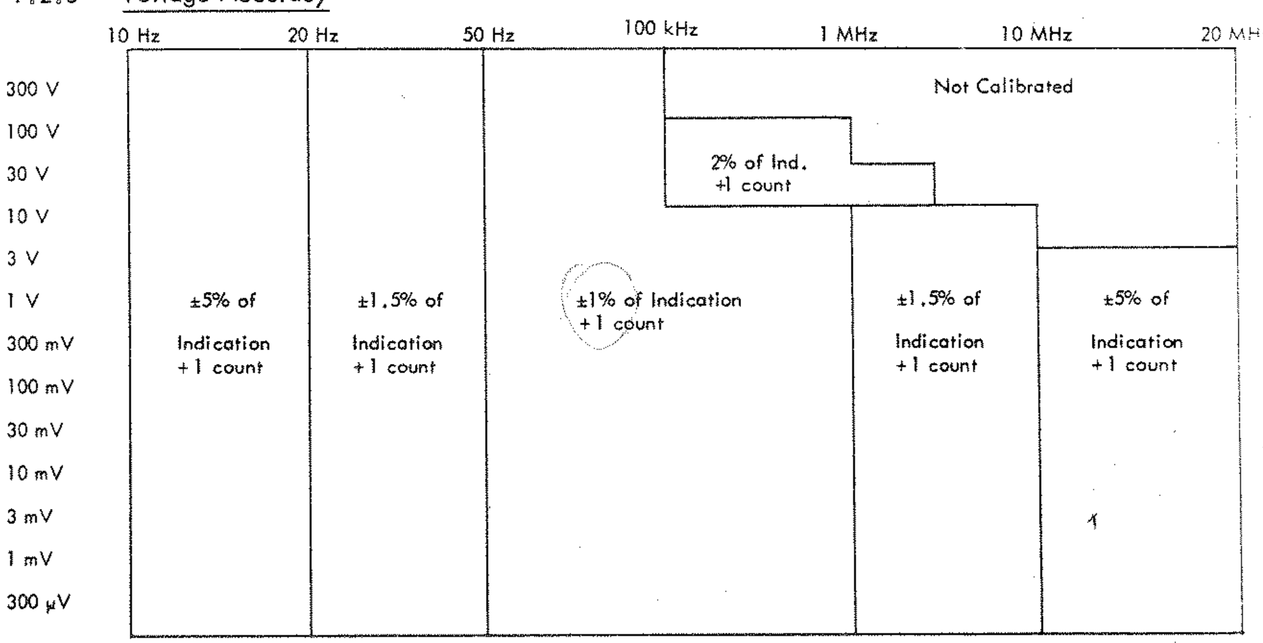
Lowest displayed voltage level ≅ 250 μV

1.2.2 Bandwidths

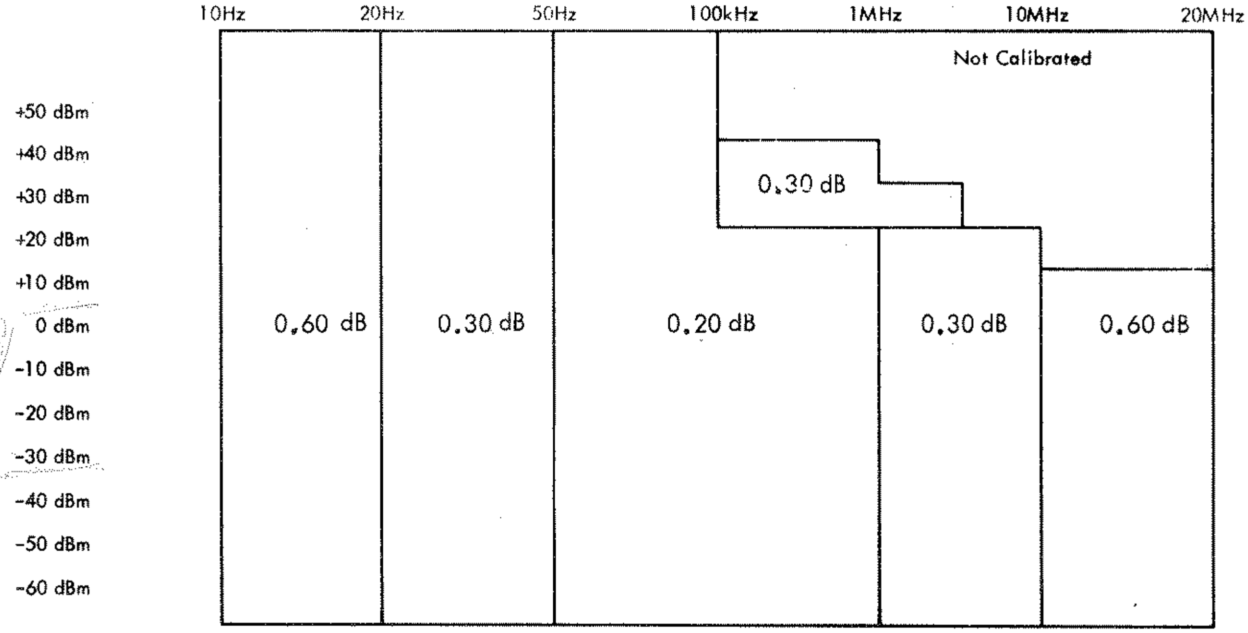
10 Hz to 20 MHz

10 Hz to 100 kHz

1.2.3 Voltage Accuracy



1.2.4 dBm Accuracy (dBm Options Only)



1.2.5 Stability

Reference conditions:

Line Voltage:	115 V, ±2%
Line Frequency:	50 Hz - 400 Hz
Warmup Period:	1 hour
Temperature:	21° C to 25° C

Warmup time: Useable after 2 minutes; 0.3% drift after 1 hour

Effect of ±10% line voltage change: ≤ 0.2% of indication

Effect of ±10% line frequency change: ≤ 0.2% of indication

1.2.6 Indicators

Digital — LED type, 3 digits +1, decimal point, units (V, mV, dB), underrange, over-range, and polarity for dBm.*

Analog — Edge meter, calibrated over 12 dBm range.

*Four digits with dB options

1.2.7 Outputs

A. At 44-pin edge connector, rear mounted

Range:	4 lines, 8, 4, 2, 1
Display:	4 lines, 8, 4, 2, 1
	4 lines, digit indicator (1, 2, 3, 4)

Overrange:	1 line
Underrange:	1 line
Analog out:	1 line
-dBm:	1 line
Encode complete:	1 line
Logic levels:	1 = 2.4 V to 5.25 V
	0 = $\leq$ 0.7 V

B. At rear-panel binding posts

Low terminal:	Case ground
High terminal:	DC Analog output:
Amplitude:	+10 V fs on "1" ranges;
	+9.5 V fs on "3" ranges.
Function:	Linear function of input voltage over 10 dB range from full scale.
Accuracy:	±0.25% rdg ±0.3% fs relative to meter indication.
Source Resistance:	≅ 5 ohms; max. loading 1 mA at fs for specified accuracy.

1.2.8 Remote Control

(At 44-pin edge connector on rear panel)

Manual disable:	1 line
Range enable:	12 lines
dB enable:	1 line
Auto enable:	1 line
Response time:	1 line
Bandwidth:	1 line
Encode hold:	1 line
Encode trigger:*	1 line

Above commanded with logic low (0 to 0.7 V) referred to ground.

*Encode interval triggered by logic low pulse, with pulse width between 0.5 and 2.0 μsec.

1.2.9 Input

Connector:	BNC type, signal low at case ground
Impedance:	2 MΩ, $\leq$ 25 pF
Equivalent noise:	< 35 μV
Swinging:	(60 Hz, 120 Hz, 180 Hz) $\leq$ ±0.5% fs; $\leq$ ±1.0% at 1/3 scale.

1.2.10 Response

Type:	rms, calibrated in rms
Crest factor:	6 at full scale;
	18 at 1/3 scale
Waveform:	Sine, complex, pulse or random

1.2.11 Response Time

Response time	*Up Scale	*Down Scale
Fast > 200 Hz	1 sec.	2 sec.
Slow < 200 Hz	4 sec.	6 sec.

*Time to arrive within specified accuracy after application of step function of signal, measured at analog dc out.

1.2.12 Overload Recovery

Response Time	Overload at fs	Time*
Fast (> 200 Hz)	20 dB	5 sec.
"	40 dB	7 sec.
"	60 dB	9 sec.
"	80 dB	9 sec.
"	100 dB	9 sec.
Slow (< 200 Hz)	20 dB	5 sec.
"	40 dB	8 sec.
"	60 dB	10 sec.
"	80 dB	10 sec.
"	100 dB	10 sec.

*To within ±1% of final indication.

1.2.13 Power Requirements

115 or 230 volts ±10%, 50 to 400 Hz

1.2.14 Temperature Influence

Temperature Range		Influence
Reference	21° C to 25° C	0
Normal	18° C to 30° C	0.01% of Indication/°C
Severe	0° C to 50° C	0.02% of Indication/°C

1.2.15 Dimensions

5.2" high (without rubber feet), 8.3" wide, 12.5" deep (132 x 211 x 318 mm)

1.2.16 Weight

9.75 lbs. net (4.42 kg)

1.2.17 Options and Accessories

Model 93AD-01	Autoranging. Automatically selects correct range for the voltage applied to the input connector (within the voltage and frequency limits).
Model 93AD-08	Rear-signal input option. Input C is ≤ 45 pF. Specified accuracy applies to rear input only.
Model 93AD-09	50Ω dBm display (-50 to +60 dBm).
Model 93AD-10	75Ω dBm display (-50 to +60 dBm).
Model 93AD-15	600Ω dBm display (-60 to +50 dBm).
Model 93-1A	High impedance probe accessory. Input impedance is 10 MΩ, ≤ 11.5 pF; attenuation 10X.
Model 92-1A	Rack-mounting kit, single.
Model 92-1B	Rack-mounting kit, dual.
Model 93-2A	Serial to Parallel Converter.
Model 93-5A	Portable Case.

CHAPTER II

OPERATION

2.1 INSTALLATION

The Model 93AD has been inspected and tested at the factory for compliance with specifications before packing, and is shipped ready for operation. If there is any indication of shipping damage to the instrument, notify the carrier and the factory immediately.

2.1.1 Operating Controls and Indicators

ITEM	FUNCTION
Mode Switch	This three-position rotary switch turns the instrument power on when turned to the MANUAL position. If the 93AD-01 Option instrument is being used, the AUTO position of this switch puts the instrument in the autoranging mode. With the 93AD model, the instrument is inoperative in this switch position.
FULL SCALE Switch	This 12-position rotary switch selects the desired range. Full-scale ranges from 1 mV to 300 V, and dBm ranges are available.
RESPONSE TIME Switch	This adjusts the response time of the instrument to suit the frequency of the signal being measured. For frequencies below 200 Hz the switch must be in the SLOW position; for frequencies higher than 200 Hz, the switch can be in either position.
BANDWIDTH Switch	This restricts the instrument's bandwidth to the range 10 Hz to 20 MHz in one position, and to 10 Hz to 100 kHz in the other position. Unless the high frequency range is required, it is advisable to leave this in the 100 kHz position.
DISPLAY Switch	In Models 93AD-09, 93AD-10, or 93AD-15 instruments, this switch shifts the display from volts to dBm. In the Model 93AD, this switch is inoperative.
INPUT Connector	A BNC connector to accept the probe cable connector or input voltage.

ITEM	FUNCTION
Display	The LED display exhibits 3 digits + 1, decimal point, units (V, mV, dBm), under and over range, and polarity of dBm (4 digits in dB option instruments). The small edgemeter furnishes an analog indication, calibrated in dBm over a range of 12 dBm. Usable for relative dBm indications, this meter will be found particularly useful for peaking or nulling adjustments - operations which are normally difficult using a digital readout alone.
	(The following items are on the rear panel)
RECORDER Terminals	The dc analog voltage output is available at these terminals for connection to external systems. (It is also available at the rear edge-connector.)
Line Voltage Switch	This slide switch changes the power transformer primary from 115 to 230 volts. The voltage selected appears in the center of the switch slide.
Fuse Holder	Contains the line fuse for the instrument; either a 0.10 A or a 0.20 A fuse, depending on the line voltage, is used. The proper fuse value is indicated by the position of the voltage-change switch.
Edge Connector	All external control lines and outputs (BCD and analog) are available at this 44-pin connector. Mating connector recommended is an Amphenol 225-22221-101.
	This safety requirement symbol has been adopted by the International Electrotechnical Commission, document 66 (Central Office) 3, paragraph 5.3, which directs that an instrument be so labeled if, for the correct use of the instrument, it is necessary to refer to the instruction manual.

2.1.2 Instructions for Assembling Instruments into the Model 93-5A Portable Case

A. Remove all four instrument feet and carrying handle.

B. Remove cord-wrap brackets on the rear of the instrument and discard the four attaching screws.

C. Remove rear frame from portable case and retain the eight screws and the two case-latch studs.

D. Attach frame under cord-wrap brackets to the rear of the instrument using the four 6-32 x 9/16" screws provided.

E. Insert instrument from rear of portable case so that panel protrudes through front frame and rear frame seats in its original position.

F. Replace screws and case-latch studs to secure rear frame to case.

G. Insert 10-32 x 5/8" screws provided through holes in front sides of case into threaded holes in instrument previously used for attaching handle.

H. Reverse procedure to remove instrument from case.

2.2 EQUIPMENT OPERATION

2.2.1 See that the voltage selector switch on the rear panel is set to the correct value for the line voltage available, and that the proper fuse is in the fuse holder. Plug the power cable into a receptacle, turn the MODE switch to MANUAL, and allow the instrument to warm up for a few minutes.

2.2.2 Attach the input cable to the INPUT connector. Because of possible unwanted pickup from strong external fields, it is usually best to use coaxial or shielded cable for this, terminated, of course, in a BNC connector. When measurements are going to be made primarily at low frequencies, and it is desired to use wire leads rather than coaxial cable, a BNC-to-binding post adapter may be used here. These are available from several sources; a representative type would be the Pomona Electronics No. 1296.

2.2.3 Set the RESPONSE TIME switch to the position appropriate for the frequency being measured. (FAST for frequencies higher than 200 Hz, SLOW for those lower.) The effect of the SLOW response is to reduce the influence of noise, hum, and other extraneous factors. When measuring high-frequency signals with these unwanted components, it is helpful to use the SLOW position also, unless a fast response is wanted.

2.2.4 Set the BANDWIDTH switch to the desired position - 0.1 MHz or 20 MHz. It should be noted that, although a low-frequency signal can be measured with the switch in the 20 MHz position, using the 0.1 MHz position will help to filter out unwanted high-frequency components that may degrade the measurement.

2.2.5 Set the FULL SCALE range switch to the expected range and apply the signal voltage to the input. The LED display should indicate the voltage value. If the display remains dark, but an upward (or downward) pointing arrow is illuminated, this indicates that the applied voltage is above (or below) the range in use.

NOTE

If, while the display is illuminated, the applied voltage is increased to a value higher than 5% above the maximum limit of the range in use, the display will blank out and the overrange arrow light. As the voltage is raised above this point (about 10% high), the display (and the arrow) will commence to flash alternately at a rate which increases as the voltage is raised. Higher still, the display will abruptly blank out and the overrange arrow will remain illuminated. This behavior is entirely normal, and results from the operation of internal protective circuits.

2.3 OPERATING NOTES

2.3.1 AC Signal with DC Component

The Model 93AD responds only to the ac component of a waveform. If it is necessary to include the dc component present in the signal, this dc should be measured separately with a dc voltmeter. After measuring the ac component with the 93AD, the true rms value may be computed from:

$$E_{rms} = (E_{dc}^{2} + E_{ac}^{2})^{1/2}$$

The dc component is blocked by an input capacitor with a maximum rating of 500 volts. If a dc component of higher value is present, an external blocking capacitor with a suitable rating must be connected externally in series with the high input terminal, with a 20 MΩ resistor connected from the high terminal to ground. This capacitor must be at least 0.1 μF if it is desired to measure to the lowest specified frequency (10 Hz).

2.3.2 Effect of Crest Factor

The 93AD has a crest factor (ratio of peak to rms amplitude) capability of 6 at full scale, increasing proportionally to 18 at 1/3 scale. This may be expressed as:

$$CF = \frac{6}{K}$$

where K = fraction of fs indication

2.3.3 Measurement of Complex Waveforms

The 93AD measures the true rms value of complex waveforms independently of the phase relationship of the harmonics, if the harmonics lie within the instrument's frequency range. Harmonics falling outside this range can cause an error, which is a function of the relative energy of these harmonics and of the relative response of the instrument at these frequencies.

Although the calibrated range of the 93AD is from 10 Hz to 20 MHz, response actually extends beyond these limits. To compute the rms value of a voltage when the rms magnitudes of its components are known (which would include these out-band harmonics) the following equation may be used:

$$E_{rms} = (E_1^{2} + E_2^{2} + E_3^{2} \; . \; . \; . \; . \; E_n^{2})^{1/2}$$

where E_{rms} = rms amplitude of complex waveform;
E_1 = rms amplitude of the fundamental, and
E_n = rms amplitude of n^{th} harmonic.

2.3.4 Measurement of RMS Current

The voltage drop caused by current flowing through a resistor can be measured with the Model 93AD, and the rms value of the current computed. Precision low-inductance resistors must be used in this application; disk or coaxial types are recommended. The crest factor is the same as that for voltage measurements.

2.3.5 Input Characteristics

The input characteristics of the Model 93AD may be represented by a parallel capacitance and conductance. The low frequency value of these components is given in Section 1.2.9. The capacitance value is essentially independent of frequency over the specified frequency range. The input conductance, however, changes with frequency, and a typical curve is shown in Figure 2.1. It should be noted that on the four most sensitive ranges the input conductance becomes negative at the higher frequencies. If a circuit or inductor resonant in this region is connected to the input terminals, oscillation may result dependent on Q and other factors. Should this occur a conductance equal to or greater than the negative conductance connected across the input will eliminate the oscillation.

Table 2.1 shows the maximum loading error that may be expected for three common source impedances for the higher frequencies.

Table 2.1 MAXIMUM LOADING ERROR*

Source Impedance	1 MHz	10 MHz	20 MHz
50 Ω	---	+0.2%	+ 1%
75 Ω	---	±0.2%	± 1%
600 Ω	-0.2%	-15%	-30%

* At Input Terminal of Voltmeter (Without Probe)

2.3.6 Possible Sources of Error

A common cause of error in low-level measurements is ground current - current of signal, power, or other frequency flowing in a common lead impedance. This current flow results in a voltage, in addition to the desired voltage, appearing at the input terminal. Some of the methods for reducing or eliminating the effects of ground currents are:

a. A low-capacitance, high-resistance isolation transformer in the power-line leads. This is most effective in eliminating power and other low-frequency ground current loops.
b. Using coaxial signal leads, and keeping them as short as possible.
c. Making all common ground impedances as low as possible.

Another cause of error, which is apparent at high frequencies with long lengths of coaxial cable for signal connection, is a relatively high standing-wave ratio on the cable. This is best handled by using a matched system to operate the cable as a flat line.

A third possible source of error is the presence of strong magnetic or electrostatic fields, either around the leads or near the instrument. Shielding and/or spacing is usually effective in reducing this type of error.

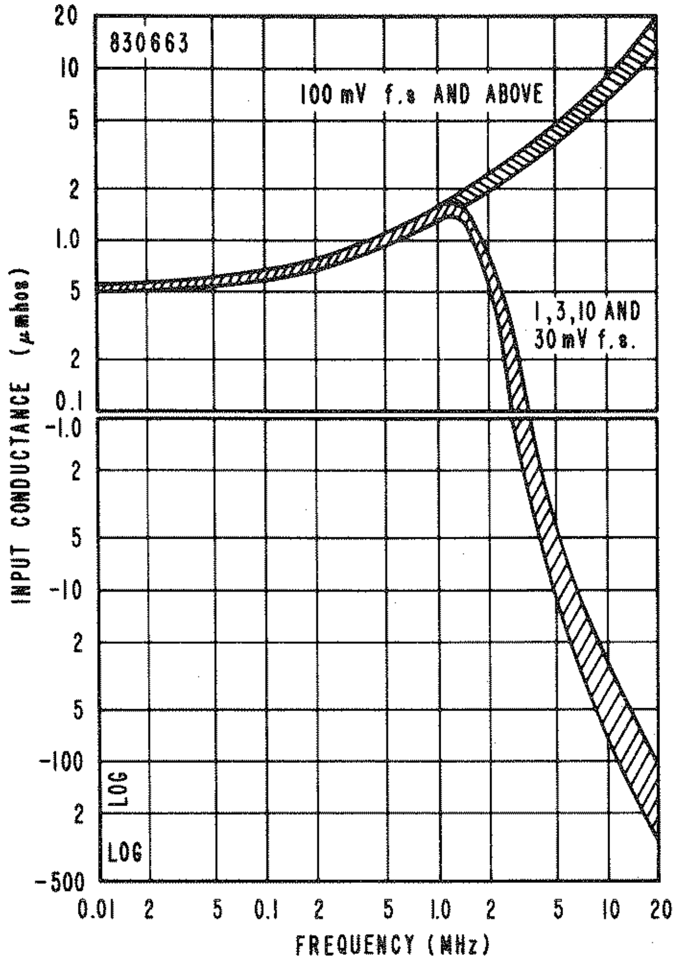


Figure 2.1 Typical Input Conductance vs. Frequency

2.3.7 Autoranging Operation

The Model 93AD-01 option instrument includes automatic range-switching circuitry. The correct range for the voltage applied is automatically selected when the instrument is operated with the MODE switch in the AUTO position. The ranging circuits are triggered by the same section that controls the overrange and underrange indicators in non-automatic operation. When the overrange arrow lights, for instance, at approximately 7% over the nominal top of a given range, the instrument automatically shifts to the next highest range. It should be noted that the 93AD actually has at least 5% overrange capability before range-changing is necessary. Down-ranging is triggered at approximately 16% below the down-scale point of the range in use (about 1/3 scale).

2.3.8 High-Impedance Probe Accessory

The Model 93-1A High-Impedance Probe increases the input impedance to 10 MΩ, $\leq$ 11.5 pF, and introduces a 10X attenuation factor. When used with the instrument with which it was calibrated, the probe introduces an additional 1% uncertainty to specified accuracy. It is important that the frequency/voltage limits below be observed:

Frequency	Peak Voltage (dc + ac)
10 Hz - 6 MHz	500
6 MHz - 7 MHz	400
7 MHz - 10 MHz	300
10 MHz - 20 MHz	150

2.3.9 Serial to Parallel Converter

The BCD outputs of the Model 93AD are in serial form, suitable for use with a computer. Should parallel data outputs be needed, the accessory Model 93-2A Serial to Parallel Converter can be added to make the necessary conversion. The 93-2A plugs in to the rear-panel edge connector of the 93AD; external connections are then made to the edge connector of the 93-2A. Pin identification can be obtained from the chart in Section 5.5 of this manual.