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Model 2182/2182A Nanovoltmeter

Quick Reference Guide

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Model 2182/2182A Nanovoltmeter Quick Reference Guide

Introduction

This guide is designed to familiarize users with fundamental operation (front panel and remote) of the Keithley Model 2182 Nanovoltmeter. For comprehensive information on all aspects of Nanovoltmeter operation, refer to the Model 2182 User's Manual.

Operation information in this guide is divided into three parts: (1) Basic operation, (2) Settings to optimize performance, and (3) Features to enhance DUT testing. This format allows a new user to easily progress from basic simple operation to more complex procedures.

Remote command programming — For the various Model 2182 operating modes covered in this guide, the related SCPI commands for remote operation are summarized in tables. Most commands have a query form. For example, :OUTPut ON turns the analog output on, while :OUTPut? requests the present state of the analog output. Note that the Model 2182 must be addressed to talk after sending a query command.

For operations where command sequence is important, programming examples are provided. The exact programming syntax will depend on the test program language.

NOTE ***The Model 2182A and later versions of the Model 2182 (firmware version A10 or higher) can be used with the Model 622x to perform Delta and Differential Conductance measurements. The Model 2182A can also be used with the Model 6221 to perform Pulse Delta measurements.***

Delta, Pulse Delta, and Differential Conductance are documented in Section 5 of the Model 622x User's Manual, and Section 5 of the Model 622x Reference Manual.

Measurement capabilities

- Two voltage measurement channels.
- Measure voltage from 1nV to 120V (channel 1); 10nV to 12V (channel 2).
- Temperature measurements
- Ratio, delta, mX + b, and percent math operations.

Front and rear panels

The front and rear panels of the Model 2182 are shown in Figures 1 and 2. The use of the various instrument controls and connectors will be explained throughout this guide.

Figure 1
Front panel

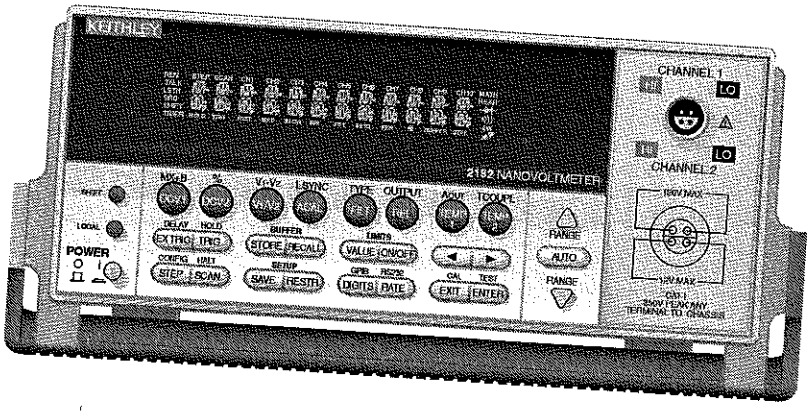
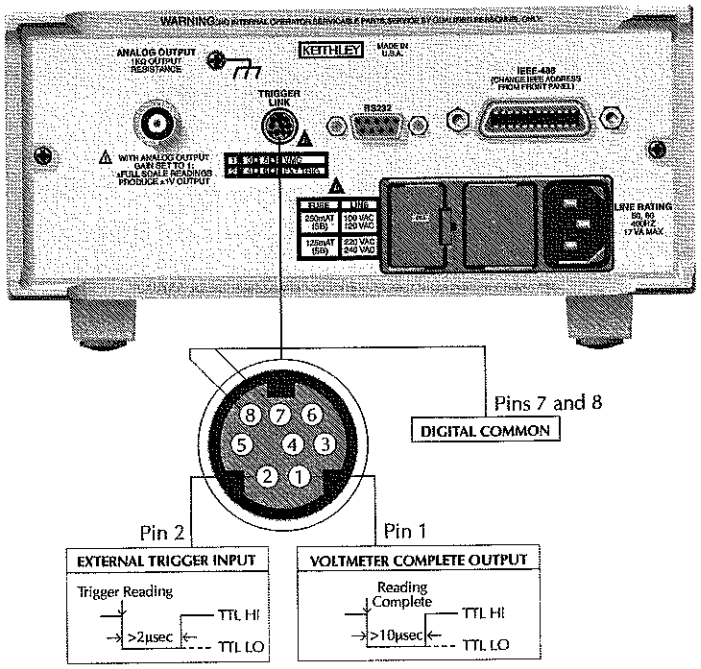


Figure 2
Rear panel



Basic connections

WARNING **A hazardous voltage condition exists at or above 42V peak. To prevent electric shock that could result in personal injury or death, never make or break connections while hazardous voltage is present.**

CAUTION **Maximum Channel 1 voltage measurement is 120V peak. Maximum Channel 2 measurement is 12V peak.**

Optimizing connections

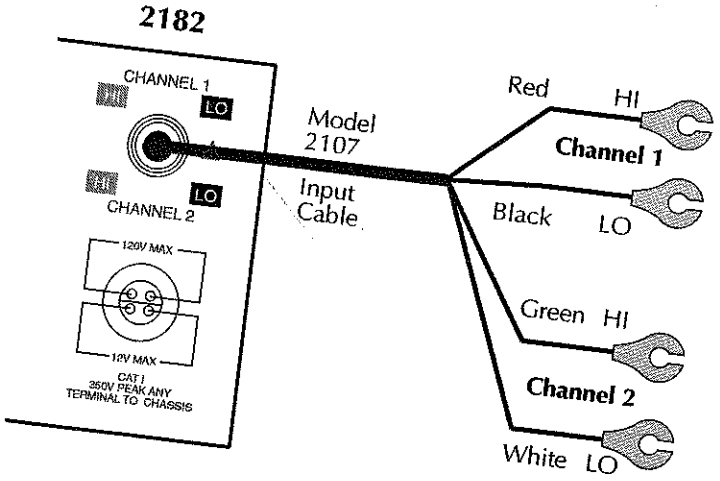
To ensure measurement integrity, observe the following when making connections:

- Use copper-to-copper connections when possible to minimize thermal EMFs.
- Any solder connections should use silver solder to minimize thermal EMFs.
- Clean all connector terminals free of oxidation using a small amount of DeoxIT.

Model 2107 input cable

Figure 3 shows the terminal designations of the supplied Model 2107 input cable. This cable can be used to make voltage measurements and temperature measurements that use an external simulated reference junction. The red and black wires connect HI and LO of Channel 1, and the green and white wires connect HI and LO of Channel 2.

Figure 3
Model 2107 input cable

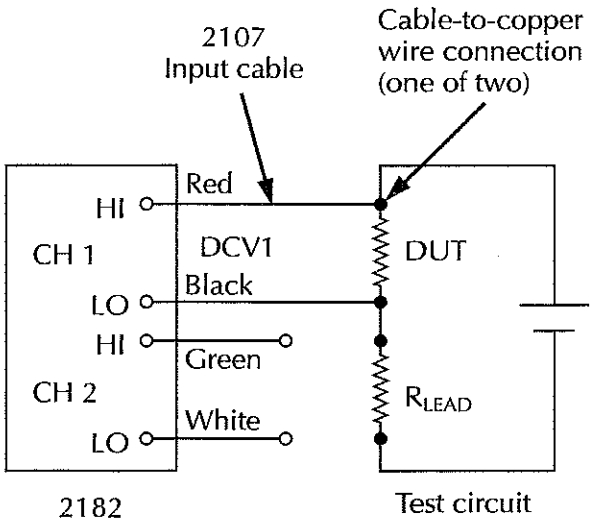


Voltage measurement connections

Single channel measurement connections

Connections for single channel voltage measurements using a Model 2107 cable to connect Channel 1 are shown in Figure 4.

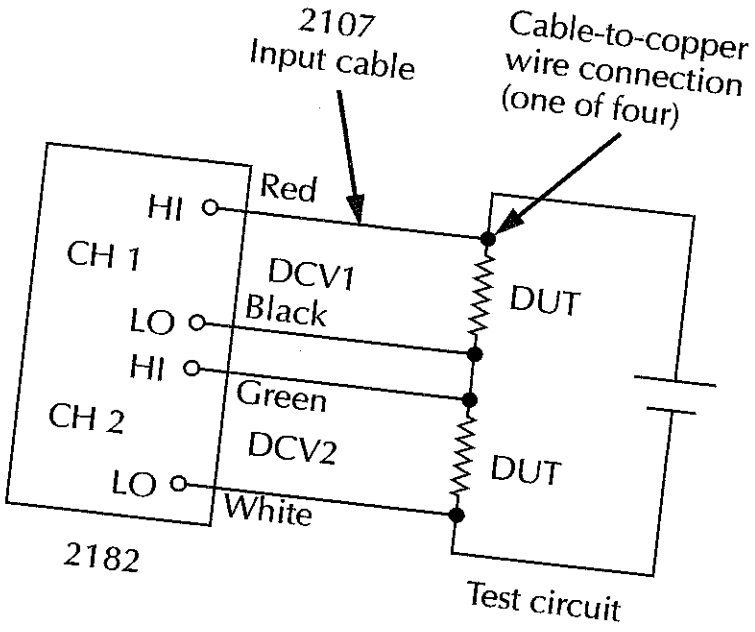
Figure 4
Single-channel measurement connections



Dual channel measurement connections

Connections for dual channel voltage measurements using a Model 2107 cable to connect both Channel 1 and Channel 2 are shown in Figure 5.

Figure 5
Dual-channel measurement connections



Temperature connections

Figure 6 shows connections for temperature measurements using the internal reference junction, while Figure 7 shows connections that use an ice bath as a simulated reference junction. Note that the connection points for the input cable and thermocouple wires are immersed in the ice bath.

Figure 6
Internal reference temperature connections

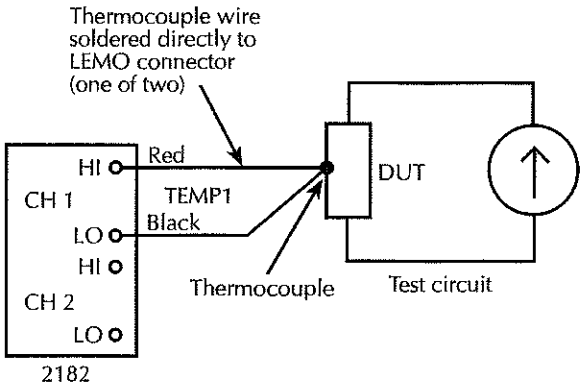
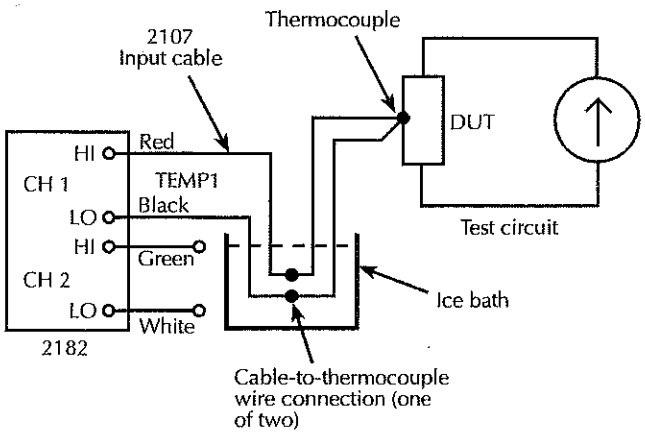


Figure 7
External reference temperature connections



Basic operation

Selecting operating modes

Most front panel keys have a dual operation or function. The nomenclature on a key indicates its primary or unshifted function or operation. The nomenclature in blue above a key indicates its shifted function or operation. To select a primary function press the corresponding key. To select a shifted function, press SHIFT first and then the desired key. For example, press DCV1 to select the Channel 1 voltage measurement function. Press SHIFT then MX+B to choose the mX + b function.

Making voltage measurements

The basic procedure to make voltage measurements is provided in Table 1. It assumes that the DUT is already connected to the Model 2182 as explained in *Basic connections.*

Table 1

Voltage measurement procedure

Procedure	Details
1. Connect DUT.	See Figure 4 or Figure 5 for Channel 1 or 2.
2. Select channel and function.	Press DCV1 to measure voltage on Channel 1. Press DCV2 to measure voltage on Channel 2.
3. Select range.	Use RANGE ▲ and ▼ keys to manually select range. Or press AUTO RANGE (AUTO annunciator on) to enable auto range.
4. Take readings from display.	Observe the voltage reading on the front panel.

Making temperature measurements

The basic procedure to make temperature measurements is provided in Table 2. It assumes that the DUT is already connected to the Model 2182 as explained in *Basic connections.*

Table 2

Temperature measurement procedure

Procedure	Details
1. Connect DUT.	See Figure 6 or Figure 7.
2. Configure temperature.	Press SHIFT then TCOUP, then select: UNITS: °C, °F, or K SENS: TCOUPLE or INTERNL TYPE: J, K, T, E, R, S, B, or N JUNC: INTERNL or SIM
3. Select channel and function.	Press TEMP1 to measure temperature on Channel 1. Press TEMP2 to measure temperature on Channel 2.
4. Take readings from display.	Observe the temperature reading on the front panel.

Measurement considerations

For sensitive measurements, keep these points in mind to maximize measurement accuracy:

- Use only clean, copper-to-copper connections to minimize thermal EMFs.
- Use the REL mode to null out offsets:
  - Connect the circuit, but leave the source disconnected.
  - Select DCV1 or DCV2 as appropriate.
  - Press REL to null offsets.
  - Repeat for other channel if needed.
  - Connect the source, and make the measurement.
- Keep the Model 2182 and test circuit away from electrical noise sources, and shield if necessary.

Remote command programming

Data string

The :READ? command is typically used to trigger a reading and request the data string. The data string is sent to the computer when the Model 2182 is addressed to talk.The data string can be made of up to three elements separated by commas. The first element is the voltage or temperature reading, the second is the channel, and the third is the units. A single element (reading-only) data string is the default condition. See Section 14, *FORMat subsystem,* of the Model 2182 User's Manual for details on all aspects of the data format.

SCPI commands

SCPI commands to measure voltage and temperature are provided in Table 3.

Table 3
SCPI commands for voltage and temperature measurements

Command	Description
:SENSe:FUNCtion <name>	Select function; 'VOLTage' or 'TEMPerature'.
:SENSe:CHANnel <chan>	Select channel: 0 (internal temperature sensor), 1, or 2.
:SENSe:VOLTage:CHANnel1:RANGe <n>	Select channel 1 measure range; <n> = range.
:SENSe:VOLTage:CHANnel1:RANGe:AUTO <b>	Enable/disable channel 1 auto range; (ON or OFF).
:SENSe:VOLTage:CHANnel2:RANGe <n>	Select channel 2 measure range; <n> = range.
:SENSe:VOLTage:CHANnel2:RANGe:AUTO <b>	Enable/disable channel 2 auto range; (ON or OFF).
:SENSe:TEMPerature:TRANsducer <name>	Choose sensor type: TCouple or INTernal.
:SENSe:TEMPerature:RJUNction:RSELect <name>	Select reference: SIMulated or INTernal.
:SENSe:TEMPerature:RJUNction:SIMulated <n>	Set simulated reference temperature in °C: 0 to 60.
:SENSe:TEMPerature:TCouple <type>	Set thermocouple type: J, K, T, E, R, S, B, or N.
:UNIT:TEMPerature <name>	Set temperature units: C, F, or K.
:READ?	Trigger and acquire one data string.

Programming examples

Voltage measurement example — Table 4 shows a typical command sequence to measure voltage on channel 1 using auto range.

Temperature measurement example — Table 5 shows a typical command sequence to measure temperature on channel 1 using a simulated junction with 0°C reference temperature and a type J thermocouple.

Table 4

Command sequence for voltage measurement example

Command[1]	Comments
*RST	Restore GPIB defaults.
:SENS:FUNC 'VOLT'	Select voltage measurement function.
:SENS:CHAN 1	Select channel 1.
:SENS:VOLT:CHAN1:RANG:AUTO ON	Enable channel 1 auto range.
:READ?	Trigger and acquire one voltage reading.

1. Model 2182 must be addressed to talk after sending :READ? to trigger and acquire data.

Table 5

Command sequence for temperature measurement example

Command[1]	Comments
*RST	Restore GPIB defaults.
:SENS:FUNC 'TEMP'	Select temperature measurement function.
:SENS:CHAN 1	Select channel 1 for measurement.
:SENS:TEMP:TRAN TC	Select thermocouple sensor.
:SENS:TEMP:RJUN:RSEL SIM	Choose simulated junction.
:SENS:TEMP:RJUN:SIM 0	Set simulated junction temperature to 0°C.
:SENS:TEMP:TC J	Select type J thermocouple.
:UNIT:TEMP F	Select °F temperature units.
:READ?	Trigger and acquire one temperature reading.

1. Model 2182 must be addressed to talk after sending :READ? to trigger and acquire data.

Settings to optimize performance

Range

To achieve the best accuracy, the Model 2182 should be on the lowest possible measurement range. In most situations, auto range can be used to automatically select the best range. Auto range is controlled (enabled/disabled) by the AUTO range key (AUTO annunciator indicates auto range is enabled).

The DCV1 function has five measurement ranges: 10mV, 100mV, 1V, 10V, and 100V. The DCV2 function has three measurement ranges: 100mV, 1V, and 10V. The range setting (fixed or AUTO) is remembered by each voltage function. There is no range selection for temperature (TEMP1 and TEMP2) measurements. Temperature measurements are performed on a single, fixed range.

The RANGE ▲ and ▼ keys are used for manual range selection. Note that pressing either of these keys disables auto range.

Rate

The RATE key selects the integration time of the A/D converter. This is the period of time the input signal is measured (also known as aperture). The integration time affects the amount of reading noise, as well as the ultimate reading rate of the instrument. The integration time is specified in parameters based on a number of power line cycles (NPLC), where 1 PLC for 60Hz is 16.67msec (1/60) and 1 PLC for 50Hz (and 400Hz) is 20msec (1/50).

Front panel RATE selections are explained as follows:

- 0.1 PLC — Selects the fastest front panel integration time. Select 0.1 PLC (fast) if speed is of primary importance (at the expense of increased reading noise).
- 1 PLC — Selects a medium integration time. Select 1 PLC (medium) when a compromise between noise performance and speed is acceptable.
- 5 PLC — Selects the slowest front panel integration time. Selecting 5 PLC (slow) provides better noise performance at the expense of speed.

Digits

The DIGITS key sets display resolution for the Model 2182. Display resolution for voltage readings can be set from 3½ to 7½ digits. For temperature readings, resolution can be set from 4 to 7 digits.

You can have a separate digits setting for voltage and temperature functions. The digits setting for a voltage function applies to the other voltage function. For example, if you set DCV1 for 5½ digits, DCV2 will also be set for 5½ digits. Similarly, the digits setting for a temperature function applies to the other temperature function. Setting TEMP1 for 6 digits, also sets TEMP2 for 6 digits.

Digits has no effect on the remote reading format. The number of displayed digits does not affect accuracy or speed. Those parameters are controlled by the RATE setting.

Filter

The Model 2182 has an analog filter and a digital filter. When Filter is enabled by pressing the FILT key (FILT annunciator on), it assumes the combination of analog and digital filter configuration for the present measurement function (DCV1, DCV2, TEMP, TEMP2). Filter state (enabled or disabled) and configuration is saved by each function.

Analog filter

With the low-pass Analog Filter ON, the normal-mode noise rejection ratio of the instrument is increased at 60Hz. This filters out noise induced by the power line. The analog filter attenuates frequency at 20dB/decade starting at 18Hz.

A primary use of the analog filter is to keep the high-gain input stage of the Model 2182 from saturating due to the presence of high AC and DC voltage. Note, however, that the filter only attenuates AC voltages for the 10mV range of the Model 2182.

Digital filter

The digital filter is used to stabilize noisy measurements. The displayed, stored, or transmitted reading is a windowed-average of a number of reading conversions (from 1 to 100).

In general, the digital filter places a specified number of A/D conversions (Filter Count) into a memory stack. These A/D conversions must occur consecutively within a selected reading window (Filter Window). The readings in the stack are then averaged to yield a single filtered reading. The stack can be filled in two ways (Filter Type): moving or repeating. The moving filter keeps adding and removing a single A/D conversion from the stack before taking the average, while the repeating filter only averages a stack that is filled with new A/D conversions.

Configuring filters

To configure the filters, press SHIFT TYPE, and then choose your selections as needed. You can turn the analog and digital filters ON or OFF, and set digital filter window, count, and select average or repeat type filters. See Section 3 of the Model 2182 User's Manual for details on filter parameters.

REL key

The REL key sets a rel value for the selected function (DCV1, DCV1, TEMP1, and TEMP2). Note that a unique rel value can be established for each measurement function.

Perform the following steps to set a rel value:

1. Display the reading you want as the rel value. This can be a zero offset reading that you want to null out, or it can be an applied level that you want to use as a baseline.

2. Press REL. The REL annunciator turns on and subsequent readings will be the difference between the actual input and the rel value.
3. To disable REL, press the REL key a second time. The REL annunciator turns off.

Remote command programming

The SCPI commands for speed, digits, filter, and rel are listed in Table 6. The commands for ranging are listed in Table 3.

Table 6
Rate, digits, filter, and rel SCPI commands

Command	Description
Rate commands:	
:SENSe:VOLTage:NPLCycles <n>	Set voltage rate in PLCs: 0.01 to 60.[1]
:SENSe:VOLTage:APERture <n>	Set voltage rate in sec.: 166.7µsec to 1sec.[2]
:SENSe:TEMPerature:NPLCycles <n>	Set temp. rate in PLCs: 0.01 to 60.[1]
:SENSe:TEMPerature:APERture <n>	Set temp. rate in sec.: 166.7µsec to 1sec.[2]
Digits commands:	
:SENSe:VOLTage:DIGits <n>	Set DCV1/DCV2 resolution: 4 to 8.
:SENSe:TEMPerature:DIGits <n>	Set TEMP1/TEMP2 resolution: 4 to 7.
Filter commands:[3]	
:SENSe:VOLTage[:CHANnel1]:LPASs <b>	Enable/disable DCV1 analog filter.
:SENSe:VOLTage[:CHANnel1]:DFILter[:STATe] <b>	Enable/disable DCV1 digital filter.
:SENSe:VOLTage:CHANnel2:LPASs <b>	Enable/disable DCV2 analog filter.
:SENSe:VOLTage:CHANnel2:DFILter[:STATe] <b>	Enable/disable DCV2 digital filter.
:SENSe:TEMPerature[:CHANnel1]:LPASs <b>	Enable/disable TEMP1 analog filter.
:SENSe:TEMPerature[:CHANnel1]:DFILter[:STATe] <b>	Enable/disable TEMP1 digital filter.
:SENSe:TEMPerature:CHANnel2:LPASs <b>	Enable/disable TEMP2 analog filter.
:SENSe:TEMPerature:CHANnel2:DFILter[:STATe] <b>	Enable/disable TEMP2 digital filter.
Rel commands:[4]	
:SENSe:VOLTage[:CHANnel1]:REFerence:STATe <b>	Enable/disable DCV1 rel.
:SENSe:VOLTage:CHANnel2:REFerence:STATe <b>	Enable/disable DCV2 rel.
:SENSe:TEMPerature[:CHANnel1]:REFerence:STATe <b>	Enable/disable TEMP1 rel.
:SENSe:TEMPerature:CHANnel2:REFerence:STATe <b>	Enable/disable TEMP2 rel.

1. 0.01 to 50 for 50Hz.
2. 200µsec to 1 sec for 50Hz.
3. Does not include commands to set digital filter parameters. See Section 3 of Model 2182 User's Manual.
4. Does not include commands to set and acquire rel values. See Section 4 of Model 2182 User's Manual.

Features to enhance DUT testing

Buffer

The Model 2182 has a buffer to store from two to 1024 readings and units. It also stores the channel number for step/scan readings and overflow readings. In addition, recalled data includes statistical information (minimum, maximum, peak-to-peak, average, and standard deviation). The buffer fills with the specified number of readings and stops. Readings are placed in the buffer after any math operations are performed. Math operations include Relative, Ratio or Delta, and mX+b or Percent.

Storing readings

To store readings, press STORE, key in the number of readings to store, and press ENTER. The star (*) annunciator indicates that the buffer is enabled. If in the immediate trigger mode, the storage process will start immediately. If in the external trigger mode, each input trigger (or press of TRIG key) will store a reading.

Recalling readings

To recall readings, press the RECALL key. The BUFFER annunciator turns on to indicate that stored readings are being displayed. The arrow annunciator (↔) also turns on to indicate that additional data is available for viewing. Use the RANGE and cursor keys to navigate through the reading numbers, reading values, and buffer statistics. For any of the buffer statistics (maximum, minimum, peak-to-peak, average, standard deviation), the STAT annunciator is on. To return to the normal display, press EXIT.

Buffer statistics

- **MIN** and **MAX** provide the minimum and maximum readings stored in the buffer. It also indicates the buffer location of these readings.
- The **Peak-to-Peak** reading is the absolute value of the difference between the MAX and MIN readings. It is calculated as follows:

  Peak-to-Peak = |MAX - MIN|

- **Average** is the mean of the buffer readings. Mean is calculated as follows:

$$y = \frac{\sum_{i=1}^{n} X_i}{n}$$

where: X_i is a stored reading.
n is the number of stored readings.