



9103 shown here with HV option

9103 Picoammeter User Guide



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About This Guide

The **9103 Picoammeter** communicates via USB using an ASCII command interface, and is compatible with any programming language and platform that supports USB serial communication.

RBD provides a Microsoft Windows-compatible application (called **Actuel**) for controlling the unit, but you can also write your own control using the API (Application Programming Interface) documented in this guide in the “Communications and Command Reference.”

The features listed in the guide are described with instructions for operating the unit via RBD’s Actuel application, as well as via the ASCII command interface. There are some features that are only directly supported by the Actuel application; these are described in the section “Additional Actuel Features”. Actuel also provides a console interface so you can experiment and test using the command interface.

The “Getting Started” section immediately following describes the installation procedure for the Picoammeter drivers and Actuel application software.

Additional Resources

More information on the 9103 Picoammeter, as well as software updates, is available at <https://rbdinstruments.com/products/picoammeter.html>

Tutorial videos for the 9103 Picoammeter and other RBD Instruments’ products can be found at <https://www.youtube.com/user/RBDInstruments/videos>

Getting Started

The **9103 Picoammeter** provides all the features of an auto-ranging picoammeter with the advantage of a USB interface for computer display, control, data logging/graphing, and features such as an optional 90V bias of 5 kV DC isolation.

To use the 9103, you'll need to install appropriate drivers for your operating system. You can install and use RBD's **Actuel** application for operating the Picoammeter on Microsoft Windows, or a custom application for Windows and other operating systems. Depending on how you purchased the 9103, these may have been provided on physical media. They are always available at:

<https://rbdinstruments.com/products/picoammeter/tech.html>

The 9103 communicates to the computer via ASCII text typically using a VCP (Virtual COM Port), so for custom applications, you can control the device on any supported operating system using any terminal or control software that is compatible with a VCP driver (for example, National Instruments' LabVIEW). For more advanced applications, other programmable drivers are available.

Driver Only Installation (Windows and Other Operating Systems)

Drivers for various operating systems (Mac OSx, Linux, etc.) are available for the 9103 Picoammeter for use in custom applications. Both Virtual COM port (VCP) and DLL / Direct (D2XXX) drivers are available, depending on your application needs.

Compatible drivers are those listed that for the device **FT232R**.

VCP drivers (for most applications): [VCP Drivers - FTDI \(ftdichip.com\)](https://ftdichip.com)

Direct drivers (for more advanced applications): [D2XX Drivers - FTDI \(ftdichip.com\)](https://ftdichip.com)

The procedure for device driver installation for various operating systems depends on the operating system and configuration. Please consult the operating system manufacturer and FTDI for additional information.

9103 Picoammeter Features

The following list the features of the **9103 Picoammeter** that are built into the device and may be accessed by any application communicating with the device. For example, data logging and graphing is not provided by the device but is provided by the **Actuel** application, however setting an offset null value (“zeroing the meter”) is provided by the device and can be accessed via any application.

Current Measurement

Measure current ranging from 2nA to 2mA

Auto or Manual Range

Select automatic ranging or measurement ranges from 2nA to 2mA

Interval and Single Sampling

Measure samples of current at timed intervals ranging from 25 ms (2 ms with high-speed option) to 9999 ms, or measure a single sample of current

Auto or Manual Range

Select automatic ranging or measurement ranges from 2nA to 2mA

Offset Null

Null (zero) the offset at a particular range (not available for when auto-range is set)

Input Grounding

Enable the input to be shorted to ground when not sampling (and automatically opened when sampling)

Output via External Chart Recorder

(optional on non-HV 9103 models)

Convert the sample current measurement to a voltage and output to a chart recorder or similar device

Sample Filter

Select the speed and accuracy of the built in sample filter

Query Status

Query status, calibration, and diagnostic information from the device

Device Identifier

Each 9103 can be programmed with a 10 character unique device identifier.

90V Bias

(optional on non-HV 9103 models)

Apply a +90V bias to the input.

High-Voltage Reference

(optional)

Float the 9103 up to 5000 V.

9103 Picoammeter Hardware Interface Front Panel



Pictured with HV option

- Off / On Switch:** Turns the unit off and on (when connected to a USB port)
- Power LED:** Stays lit (green) when there is power to the unit
- Data LED:** Briefly lights (blue) when data is being transmitted by or received by the unit
- USB Port:** Connector for USB serial bus cable (type B)
- Input Connector:** Current measurement in (SHV as shown HV option, isolated BNC standard)
- HV Connector:** MHV for high voltage supply (HV models only)
- Input Connector:** Isolated BNC for current measurement input

Back Panel



- Chart Recorder Output:** Banana jacks - black negative, red positive (*non HV models only*)
- Ground:** Green banana jack grounding the unit
* For best results, it is strongly suggested that you use the ground cable (included) to connect the unit to PC ground or vacuum chamber
- External Bias** Isolated BNC for customer supplied isolated DC power supply (*non-HV models only*)

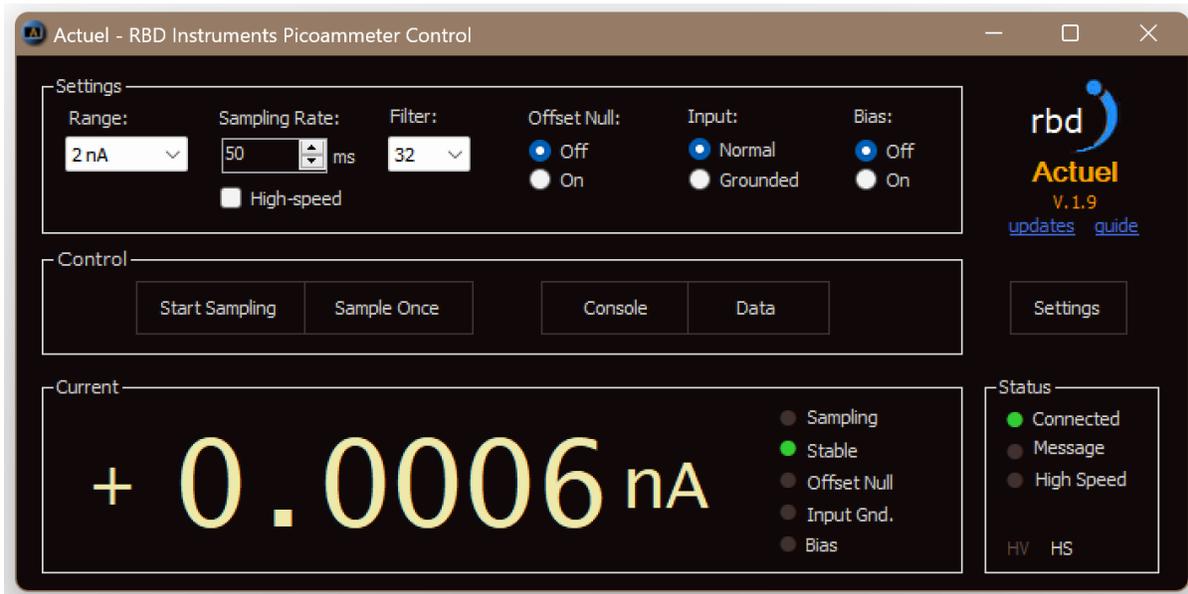
9103 Picoammeter Software Interface

The **9103 Picoammeter** device uses a USB interface and is controlled with an ASCII command protocol. Any application that can communicate with a virtual COM (communications) port can control the device and read current. The command interface is the same regardless of the method used to communicate with the device.

Using the Actuel Application

The **Actuel** application provides a Windows-compatible user-interface for controlling the 9103 Picoammeter, as well as additional features for data logging and graphing. I

The Actuel application also provides a “terminal” style window (the **Console**) that allows you to directly input commands to the device using the ASCII interface. Use caution when using the Console to control the 9103 - most of the commands run independently of the application interface and can cause the **Actuel** application to run out of sync with the device. For example, if the Actuel interface has initiated interval sampling, and you use the Console window to set the interval to zero, this may not be reflected in the Actuel interface. Should this happen, simply re-launch the Actuel software.



Using Third-Party Software

Many third party software applications can be programmed to communicate with a virtual COM port, and most programming environments provide library support for programming COM ports. While the specifics for programming a COM port are out of the scope of this manual, a guide to the communication settings and command reference is included at the end of this manual. Additionally, drivers are available from FTDI for direct USB communication (see “Getting Started”).

Connecting the 9103 Picoammeter

All Models

USB Interface / Power

Connect the 9103 Picoammeter to the PC before turning the unit on. The unit receives power from the USB connection. The green LED labeled “Power” should be lit when the unit is on.

Ground (IMPORTANT)

The 9103 Picoammeter comes supplied with a connector for grounding the unit. For best results, it is strongly suggested that you use the ground cable (included) to connect the unit to PC ground, or vacuum chamber (where applicable).

Standard Models (non-HV)

Current Input

Input to the 9103 Picoammeter is connected on the front panel (BNC connector).

External Bias Option (BNC)

The External Bias option allows for a voltage supply of up to +/- 500V isolated DC to be applied between the 9103 signal input (BNC connector) and the device under test (DUT).

Note that the voltage source used with the External Bias needs to be isolated from ground (floating). To check your voltage source to see if it is isolated, measure the resistance from the supply NEG output to ground. If the NEG is connected to ground (indicated by a low resistance measurement) then your supply is not isolated and will not work with the 9103 External Bias option.

Another way to test your supply is to turn it on and set it to a low output voltage (10V DC, for example). If you measure between the POS and NEG outputs you should see 10V DC. If you measure from POS to ground (the green output or the chassis of the supply) you should not read any voltage. If not, then your supply is isolated and can be used with the 9103 External Bias option.

Chart Recorder Option (Double Banana)

The Chart Recorder output option provides a 0 to 2 V DC output voltage per current range. For example, 0 to +200.00 nA of current in the 200nA range produces a recorder output voltage of +2 V DC. In another example, 0 to -2.000uA produces a recorder output voltage of 0 to -2 V DC.

The recorder output option is typically used in a fixed gain mode (0 to 200nA for example), but can be used in the auto range as long as you keep track of which current range the 9103 is using.

The recorder output can be calibrated by the user using the Console in Actual or a third-party application (see command ‘C’ in “Communicating with the 9103 Picoammeter”).

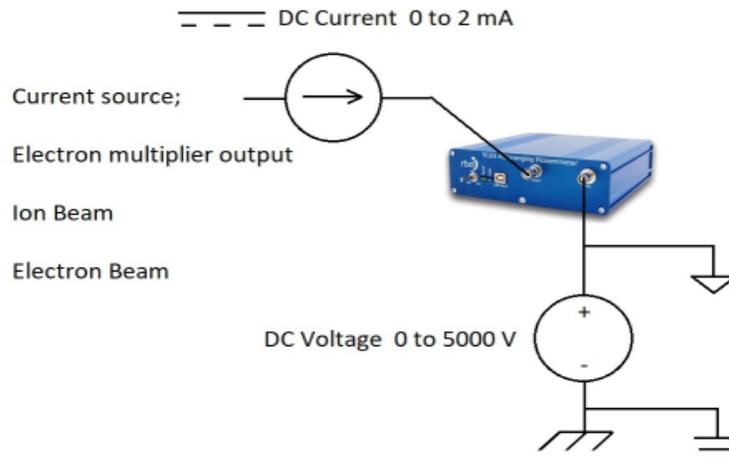
HV Models

Current Input

Input to the **9103 Picoammeter** is connected on the front panel (SHV connector)

High-Voltage Reference

The high-voltage reference supply (floating ground) is connected on the front panel (MHV connector.)



There is a 1M ohm current limit resistor inside the 9103 in series with the right hand MHV HV supply connector and the board signal reference. The 1M ohm current resistor helps to reduce current transients when the HV supply is being ramped up. For best results, ramp up the high voltage slowly.

The signal input connector is SHV and the HV supply reference is MHV in order to prevent the HV supply from being connected to the 9103 input by mistake. If you prefer to have both connectors as SHV, MHV to SHV adapters are available.

The HV version of the 9103 can be “floated” up to 5kV DC. The purpose floating is to bias the 9103 signal input relative to an electron beam, ion beam, or electron multiplier.

The HV version of the 9103 is not designed as an insulation tester where voltage is applied until breakdown occurs. Any arcing at high voltage will result in erroneous readings, lock up or damage to the 9103.

Auto-Range with High Voltage

Note that the Auto-Range feature of the 9103 does not work in High-Voltage mode - see “Selecting the Range” for special instructions on range selection.

Communicating With the 9103 Picoammeter

Overview

The **9103 Picoammeter** communicates over a USB interface using an ASCII command interface. If you are writing custom applications for programming the 9103, you have a choice of driver types (see “Getting Started / Driver Only Installation” for more details).

Except in rare cases, communicating with the 9103 as a **virtual COM port (VCP)** is simplest and provides access to all the 9103 functionalities.

Using Actuel (with the Virtual COM Port Driver)

When using the 9103 with Actuel, you will be communicating with the standard VCP driver, and the 9103 will appear as a generic USB Serial Port. In Windows device manager, it will be assigned a COM port and appear in the Ports dropdown:



Most of the time, you can simply run the Actuel software, and it will automatically detect the first 9103 device. If you have multiple devices, each instance of Actuel run will detect the next device available.

Resolving Multiple Device Conflicts by Manually Selecting the COM Port

In rare instances, another USB may be utilizing the same FTDI chip as the 9103 and a conflict will arise. This can often be easily resolved by simply changing the order of plugging in / turning on the devices.

If this does not solve the issue, you can manually select the COM port that each instance of Actuel uses to communicate with the 9103. Click the Settings button from the main Actuel window and check Select COM Port, and select the number that matches the 9103 unit as shown in the Device Manager. (Note that you are not changing the COM port, but instructing the Actuel software to match the 9103 port assigned by Windows).

You can assign multiple instances of Actuel to multiple devices, however note that the software will only recall the last instance assigned, so you will have to set this up for each software session.

Using a Custom Application with the Virtual COM Port (VCP) Driver

Most application / programming environments can communicate easily with the 9103 serial interface as a virtual COM port (see the “Communications and Command Reference” for details). As with Actuel (above), the 9103 will appear as a generic USB Serial Port. In Windows device manager, it will be assigned a COM port and appear in the Ports dropdown (see “Using Actuel” above). You can choose to parse the Ports for the 9103 or assign it directly in your program, depending on your needs.

Using a Custom Application with Direct Drivers

If your application needs to communicate with the 9103 programmatically through an API (this may be the case, for example, if your programming environment does not provide a serial communications library), you can do so using the direct drivers and documentation provided by the USB chip manufacturer FTDI found here: [D2XX Drivers - FTDI \(ftdichip.com\)](http://ftdichip.com)

Using the 9103 Picoammeter

Selecting the Range

The **9103 Picoammeter** can be operated in auto or manual range mode. When Auto Range is selected, the device dynamically sets the range based on the last few current samples. When first reading current (or after the input current moves outside of the previous range), it may take a few readings before the values read are stable and accurate (see “Interpreting Sample Results” under the section “Reading (Sampling) Current” below).

Using Actual

To select the range, click the Range combo box and select either Auto or one of the manual ranges..

Using the Command Interface

To select the range, use the range commands “&R0” – “&R7”

0-7 corresponds to the selected range.

“&R0” corresponds to Auto range.

“&R1” – “&R7” correspond to manual ranges.

See the ‘Communications and Command Reference’ at the end of this manual for more details.

High-Voltage Mode

When operating the 9103 in the HV mode, the input range must be selected before increasing the HV supply voltage. Do not use the Auto Range feature when floating the 9103 as transient errors will occur during the range change period. Start with a lower gain (higher current range) and then once you know the approximate range of expected values you can select the closet gain range that provides the best resolution. For example, if you were expecting to measure 0 to 150 nA you would select the 200 nA range, not the 2 uA range.

High-Speed Mode

When operating the 9103 at the highest speed (2 mS sampling rate), it is suggested you chose a specific range, since using Auto-Range at this speed may degrade the sample rate.

Reading (Sampling) Current

Of course, the main function of the **9103 Picoammeter** is reading current, and this can be accomplished in a variety of ways.

Current Reading Modes

The device itself supports both an interval and a single sample mode of operation. Interval sampling allows you to take and record current samples at a specified interval. Single-sample mode allows you to take a single sample data. Using third-party software, you can automate the acquisition of single samples in order to acquire data at longer intervals than supported by the device (over 10 seconds), as well as mixed intervals (for example, 5 samples per second for 2 seconds each minute).

Reading Current at a Specific Rate

The **9103 Picoammeter** supports sampling at rates of between 15 mS (2 mS with the High-Speed option) and 9,999 mS (approx. 10 seconds).

Input and Bias While Sampling

If you set the option to ground the input, the input will be opened automatically prior to sampling and re-grounded afterwards. Likewise, if you turned on the bias option, the 90 V bias will be applied when the input is opened after sampling begins.

Using Actuel

To setup interval sampling using Actuel, first select a sampling rate from the Sampling Rate field. Click the Start Sampling button or hit the 's' key to begin sampling. Click the button again (it will not read Stop Sampling) to stop.

High-speed option: select the High-Speed checkbox to sample at rates faster than 25 mS.

Using the Command Interface

To setup interval sampling using the command interface, send the Picoammeter the "&l" command with the next 4 digits specifying the sampling rate in milliseconds. For example "&l0100" begins sampling at an interval of 100 mS.

To stop sampling, send the "&l" command with a value of 0 ("&l0000")

High-speed option: The High-Speed interval sampling command works the same as the standard speed but uses the "&i" command. You can use this command for all speeds if you wish. The high-speed message received is different than the standard message and contains 10 samples.

Note that you must first also change the USB protocol to high-speed mode. See the 'Communication and Command Reference' for more details.

Reading a Single Current Sample

The **9103 Picoammeter** supports the reading of a single sample of current. Acquiring a single sample during interval sampling stops interval sampling.

Note that if you set the option to short the input when current is not being read, the input will be opened automatically for 5 seconds, during which you may wish to acquire subsequent samples (since the first few may not be stable due to the shorted input). If the bias option is turned on it will be applied at this time.

Using Actual

To acquire one current sample, simply click the Sample Once button.

Using the Command Interface

To acquire a single sample send the command “&S”.

High-speed option: The High-Speed option allows you to perform a single acquisition of up to 10 samples at a specified interval using the “&s” command. See ‘Communication & Command Reference’ for more details.

Interpreting Current Sample Results

The **9103 Picoammeter** is capable of reporting current value, units, and polarity, along with stability and over/under range status.

While the device is capable of reporting current using up to 8 digits in standard notation with units, please note that the accuracy of the lowest-order digits is dependent on the selected range (see Specifications)

Stability is reported by the device for each current sample taken. When the unit first begins sampling, or a new range is selected (either manually by the user, or automatically by the device when auto-ranging is selected and the input current moves outside the current range), the device may take a few seconds to stabilize. Stability time is also affected by the filter setting (see “Selecting the Filter Type” below). If the current is unstable, a warning appears over a dimmed display.

Current values that are greater than selected range (or the range of the device when auto-ranging is selected) are reported as being over-range; values that are less than the selected range are reported as under-range.

Using Actual

Current is displayed in a fixed 5 digit (plus decimal) format. Stability and Over/Under range warnings are displayed in the Current display section of the application.

Using the Command Interface

Sample current data (including stability, range, polarity, value, and units) is reported by the unit using the “&S” command. As an example, the result “&S=,Range=002nA,-0.0692,nA” represents a stable reading in the 2 nA range, with a value of negative 0.0692 nA. Unstable values are reported with an

asterisk character (for example, "&S*,Range=002uA,-0.0724,uA"), and range is reported with a ">" (over) or "<" (under) character (for example, "&S<,Range=002uA,-0.0727,uA" represents an under-range reading).

High-speed option: High-speed sample are similarly formatted but may contain up to 10 samples. See the 'Communication & Command Reference' for more detail.

Selecting the Input Current Filter

The **9103 Picoammeter** contains a built-in filter that averages the input current and helps produce more accurate readings, at the expense of a slightly long time to stabilize. The value of the filter determines the number of samples acquired to average the final reported current result. Higher values result in more accuracy but a longer stability time (however, at higher values the filter may mask some high-frequency data). You can set the filter values using both the **Actuel** application and the command interface.

Using Actuel

Click the Setup button to open the Setup window. Select the filter value from the Filter drop-down (0, 2, 4, 8, 16, 32, 64).

Using the Command Interface

Use the command "&F" to set the filter values to either 2, 4, 8, 16, 32, or 64. Three digits are used for the numerical setting (ex. "&F008" sets the filter to 8). Lower values may result in slightly less accurate readings, but faster time to stability.

High-speed Mode

Note that at higher speeds the 9103 filter may mask some high-frequency data when set to higher values. Experiment with using different values for you application.

9103 models with the high-speed option includes a separate filter for buffering high-speed data, settable from 0 to 6. The default value for high-speed data collection is 2. There is normally no need to change this value and it can only be set using the Command Interface – see the Communication and Command Reference for more information.

Grounding the Input

The 9103 Picoammeter has the ability to short the input to ground. Note that the optional 90 V bias is automatically turned off when the input is grounded – this is a function of the 9103 Picoammeter and occurs automatically regardless of the method used to control the device.

The input grounding feature enables grounding only when the device is not sampling current. When interval sampling is started and the input is grounded, the input will be opened during sampling, but re-grounded when sampling is stopped.

The input ground is designed to ground vacuum chambers when not measuring current in order to prevent specimen stages and manipulators from floating, which can produce charging and shifted peaks. And, when grounded the input of the 9103 is protected from any electron or ion beam arcing that may occur.

Since the bias and input ground are mutually exclusive, you can select the 90 V bias and grounded input at the same time – whenever current is sampled, the bias will be turned on and the input opened. After sampling, the bias will be turned off and the input grounded.

If input grounding is enabled and a single sample is requested, the device will open the input for a period of 5 seconds after the sample is requested. This feature is implemented because requesting a single sample while the input is grounded will result in an unstable value, and it will take a few seconds before an accurate reading can be made. If this is a problem (especially when automating the device using a third-party programming environment), it is suggested you either disable input grounding then delay a few seconds before the sample is acquired, or take multiple samples over a 5 second period to ensure a stable, accurate value.

Using Actual

To enable grounding the input, select the Input option “Grounded”. To open the input for normal operation, select the “Normal” option.

Using the Command Interface

Use the command “&G1” to enable input grounding; the command “&G0” disables the feature.

High-Voltage Mode

In the case of the HV version of the 9103, the input would be shorted not to chassis ground, but to the HV reference supply which would protect the 9103 from arcs when not measuring current. Note that the Ground Input should only be selected with a fixed gain range when using a HV version 9103.

Setting the Current Offset

The **9103 Picoammeter** can be instructed to apply a null offset correction, automatically subtracting the current sampled at the time the option is selected from any subsequent current readings (effectively “zeroing” the meter) This offset cannot be used during auto-ranging. Changing the range or cycling power to the device automatically discards the offset.

Using Actuel

Select the Offset Null radio option to turn the offset null feature on or off (not available when the auto-ranging is selected). Selecting a new range when the offset is on will automatically turn it off.

Using the Command Interface

To turn the offset null feature on, send the “&N” command. To turn the offset null off, simply send a range command (“&R0” – “&R7”). Note that you can select the same range as you are currently using to turn of the offset adjustment – for example, if you previously selected “&R3”, sending “&R3” after “&N” will turn the feature off.

Using the Chart Recorder

The **9103 Picoammeter** provides a chart recorder output that produces a 0 – 2 V voltage in response to the sample current, allowing you to interface a chart recorder for logging sample data over time. You can set the logging interval, as well as calibrate the chart recorder output to match your device. The chart recorder updates every 200 ms by default, however this is user-selectable.

Using Actuel

Actuel does not currently provide a dedicated interface for setting up the chart recorder, however the command interface may be utilized by opening the Console window. See “Using the Command Interface” immediately below for more information.

Using the Command Interface

Setting the Chart Recorder Options

Using the Command Interface

To set the chart recorder (logging) interval, use the “&L” command with a value between 0050 and 9999 milliseconds. For example, “&L0100” sets the interval to 100 milliseconds.

To calibrate the chart recorder, use the “&C” command as follows:

“&C5”: Reset chart constants to default (adjust while input disconnected)

“&C6”: Adjust chart zero to be more positive (adjust while input disconnected)

“&C7”: Adjust chart zero to be more negative (adjust while input disconnected)

“&C8”: Increase chart gain (adjust while input 1 nA, chart output should be 1.00 V DC)

“&C9”: Decrease chart gain (adjust while input 1 nA, chart output should be 1.00 V DC)

For more information, see the ‘Communications & Command Reference’ at the end of this manual.

Calibrating the Chart Recorder Output

If the chart recorder output is not in spec, adjust as follows:

- 1) Send &R1 to select 1 nA manual range, disconnect the input current, wait for readings to stabilize
- 2) Send &N command to NULL any minor errors, send &C5 command to reset the chart contents
- 3) While observing the voltmeter, send &C6 to increase the reading toward zero, or &C7 to decrease the reading toward zero
- 4) Reconnect the input current, set to +1 nA, wait for readings to stabilize
- 5) While observing the voltmeter, send &C8 to increase the reading toward 1.00 Vdc, or &C9 to decrease the reading toward 1.00 VDC.

Setting the Device Identifier

The **9103 Picoammeter** has the ability to store a 10-character device identifier string in non-volatile memory. This identifier can be still be recalled after the device is cycled on/off, and is especially handy when multiple devices are being used on the same PC.

The identifier can be made up of any characters and is case-sensitive. By default, the device identifier is factory set to NEW_DEVICE.

Using Actuel

Double-click the device ID string in the Status section of the main window. Type a new 10 character identifier and hit the enter key. The ID is displayed in both the main and data windows. Note that when data is exported from multiple synchronized devices, the device ID appears in the header for the data for each device.

Using the Command Interface

Use the command “&Pxxxxxxxx” to set the device ID, where 'xxxxxxxx' is the identifier string. Note that spaces are allowed.

The “&Q” (Query command) can be used to retrieve the device ID, and is displayed as “P, ID=xxxxxxxx” (where 'xxxxxxxx' is the identifier string).

**Picoammeters purchased prior to September 2013 require a factory firmware update for this feature, available at a nominal charge from RBD Instruments.*

Model Identifier

The model options of your **9103** are displayed in the Status section of **Actuel**. HS is displayed for high-speed models, and HV is displayed for high-voltage models. If both options are disabled or there is no option displayed (older models), the 9103 is standard-voltage, standard-speed.

Using the 90 V Bias (optional)

The **9103 Picoammeter** has an optional 90 V bias that can be applied to the input. Note that the bias is automatically turned off when the input is grounded – this is a function of the **9103 Picoammeter** and occurs automatically regardless of the method used to control the device.

Since the bias and input ground are mutually exclusive, you can select the 90 V bias and grounded input at the same time – whenever current is sampled, the bias will be turned on and the input opened. After sampling, the bias will be turned off and the input grounded.

Using Actuel

Select the Bias On radio button to turn the 90 V bias on, and the Bias Off radio button to turn the 90V bias off.

Using the Command Interface

Use the command “&B1” to turn the 90 V bias on, “&B0” to turn the 90V bias off.

Resetting the 9103 Picoammeter to Factory Defaults

You can reset the 9103 Picoammeter to factory defaults – this does not erase or change the calibration settings.

Using Actuel

Actuel does not currently provide a dedicated interface for resetting the factory defaults, however you can do so by opening the Console window and sending the “D” command.

Using the Command Interface

Use the command “&D” to reset the device to factory defaults.

Calibration

It is recommended that the **9103 Picoammeter** be calibrated each year as part of your normal instrumentation maintenance program.

The 9103 Picoammeter does not need to be sent to RBD Instruments to be calibrated. It is recommended calibration be performed by a certified calibration facility. Calibration procedure information is available from RBD Instruments upon request or at

<http://rbdinstruments.com/products/picoammeter>

Additional Actuel Features

Actuel provides features for synchronizing devices as well as recording, graphing, and exporting data. To access data recording features, click the Data button in the main Actuel window. To access additional recording, formatting, graphing, and exporting options, click the Show Options button in the Data window. You can also use this button to hide the options.

Recording and Exporting Data

Actuel provides features for recording data samples over time. These samples can be copied or exported as text for use in graphing, spreadsheet, etc. applications. To access data recording features, click the Data button in the main Actuel window.

Data recorded by Actuel is time-stamped. Although the time-stamp is not displayed, it can be exported with the data in a variety of formats.

Starting / Stopping Data Recording

To start recording data, simply click the Record button, or hit the “r” key (If the unit is not already sampling, pressing the record button will begin sampling automatically). Data is displayed in the selected format in the field below. If the Data field is not empty, any new data recorded is appended to the previously recorded data.

To stop recording data, click the Stop Recording button.

Saving, Copying, and Clearing Recorded Data

To save (export) data to a text file, simply click the Save button. You will be prompted for a file name, and the data will be saved as an ASCII text file.

To copy data to the clipboard, click the Copy button.

To set the options for exporting data, click the Show Options button. The export options affect data that is copied to the clipboard as well as data saved to a file.

To delete all data / clear the Data field, click the Clear button.

Note that closing the Data window deletes all previously recorded data.

Saving data automatically while recording

To instruct **Actuel** to automatically save data while recording, click the Show Options button and check the Auto-save option. Click the File... button to select the data file. By default this is the last file used to save data (whether automatically or clicking the Save button).

The Auto-save feature will save data every .5 minutes to 30 minutes depending on your selection, and save any remaining data at the end of a recording. When more than one 9103 Picoammeter is synchronized using multiple copies of **Actuel**, the Auto-save feature will save data from all synchronized 9103s for which the Auto-save option is selected providing the Data window is opened, data is being recorded.

IMPORTANT: When Auto-save is selected, the last file saved to - whether by using the Auto-save option or clicking the Save button - is over-written as soon as a new recording is started. If you wish to save to a new or different file, click the File... button to select one.

Data Information Displayed on the Graph

The minimum and maximum of the data is displayed at the top left of the graph.

Setting the Data Recording Options

There are various options available that determine what data is recorded.

Selecting the “Record out of range values” option will record all sample values regardless of whether they fall within the selected range of the Picoammeter. If this option is not selected, only values that fall within the selected range are recorded.

Selecting the “Record unstable values” option will record all samples regardless of whether the data was sampled in a stable or unstable state. If not selected, only stable data values are recorded.

The “Record every” option allows you to specify recording or averaging over a number the number of samples entered. For example, if you set this value to 4, every 4th sample will be recorded. This allows you to specify a data logging sample rate higher than the 9103’s maximum sample rate of 10 seconds, which is especially handy for recording over a long period of time when you do not want to produce large data sets. Note that the unused samples are discarded. Set this value to “1” to record every sample.

By clicking the “Average” option, **Actuel** will record the average of the number of selected samples, and use this as the recorded value.

Setting the Data Formatting Options

There are various options available that determine how recorded data is formatted. Note that Actual always records and displays data in decimal format (in keeping with the fixed format of the 9103 device), regardless of your region/locale operating system settings.

Selecting the “Display stability / range” determines whether the stability and range status of a sampled value is displayed along with the value. This only applies if you chose to record those values that are unstable and/or out-of-range. If this value is not checked the stability and range are not displayed. You can select the notation used to display sample data values by selecting a choice in the “Sample Value Notation”. The following notations are available:

- Engineering (units): Decimal notation with units suffix, example: 0.0777534 nA
- Engineering (no units): Decimal notation with no units, example: 0.0777534
- Scientific (E) Notation: Scientific notation using the “E” suffix (often used by spreadsheet applications, etc.), example: -7.690850E-011

Setting the Data Export Options

There are various options available that determine how recorded data is exported. Note that these options affect not only how data is saved to files, but also how data is copied to the clipboard.

Selecting the Export Absolute Time option will export the data with an additional column containing the time-stamp. You can format the time-stamp for either UTC (universal) or local time.

Selecting the Export Relative Time option will export the data with an additional column containing the relative time. The time scale begins at zero, with each data point reflecting the accumulated sampling time. Though not as accurate as the absolute time, this will create a uniformly spaced time axis more suitable for graphing and analyzing most data.

Selecting the Comma, Tab, or Space delimiter option selects the character used between data columns.

Graphing Data

Actuel automatically graphs data while you record, and displays it in the Data window (for more information, see the previous section, “Data Recording”). Various options are available for determining how graph data is display. There is also a feature to copy the graph as a bitmap.

How the Graph Time Scale is Calculated

Actuel displays sample data as current vs. time, with time being calculated by the sample rate. Keeping this in mind, please note how the following affect the time displayed on the graph vs. real-time:

- If “Record unstable values” is not checked in the data recording options, graphing stops until sampling is stabilized.
- If “Record out-of-range values” is not checked in the data recording options, graphing stops when data is out of range.
- If recording is paused then restarted, the graph begins displaying data from where it left off.
- The sample rate used for all data in the graph is the current rate, regardless of the rate when data was collected.

If you need a more accurate display of current vs. real-time, set the recorder to record all values and do not pause recording or change the sample rate while graphing.

Data Information Displayed on the Graph

The minimum and maximum of the data is displayed at the top left of the graph. Additionally, hovering over data with the mouse will display the current and the time under the mouse cursor.

Displaying Graph Data

You can deselect the Show option to stop displaying data if you are only interested in recording and need better performance on slower systems.

Copying the Graph

To copy the graph to the Clipboard, click the Copy button below the graph. You can copy the graph while sampling.

Setting the X-axis (Time) Options

There are three options for determining how the graph is displayed with respect to time:

Expand: Selecting this option will cause the x-axis to grow with respect to the total acquisition time. As the data gets closer to the end of the graph, the graph will redisplay with extended time proportional to the total.

Last: Selecting this option displays the last minutes of the graph as determined by the field to the right of the option. The left side of the time axis is always referenced to 0. For example, if you select “Last 5 mins.”, the x-axis of the graph will display 0 – 5 minutes. Once there is more than 5 minutes of data, the graph will continue to add data points to the end and remove them from the beginning, so that the data flows from right to left through the time axis.

From (to): Selecting this option displays the data from the time specified in the first field to the time in the last field to the right of the option. Note that if you collect data past the point in the “to” field, that data is not displayed unless you increase the time, or select the Last or Expand option.

Setting the Y-axis (Current) Options

You can choose to set a fixed range for the Y-axis (current), or have Actual automatically adjust the range of the graph.

Auto- Range:

There are three options for determining how the polarity of current displayed on the y-axis, as well as an option for selecting the baseline of the y-axis, when the range is not fixed

+/- (Pos./Neg.): Selecting this option will display all current regardless of polarity , with the y-axis adjusting automatically depending on the full range of data. The top of the graph is the positive maximum.

+ (Pos.): Selecting this option displays only positive polarity current values. Negative values are truncated and displayed as 0. The top of the graph is the positive maximum.

- (Neg.): Selecting this option displays only negative polarity current values. Positive values are truncated and displayed as 0. Note that when this option is selecting, the direction of the graph is reversed and the top is the maximum absolute negative-polarity value.

Zero (0) Baseline: Selecting Zero (0) Baseline references the bottom of the y-axis to zero (0), regardless of the absolute minimum current value. This option is not available if “+/- (Pos./Neg.)” polarity is selected.

Fixed Range:

When the **Fixed Range** option is set you can choose the **Min** and **Max** current to display, as well as the **Units**.

Additional Graph Options

Click the **More...** button for options to show/hide the grid, as well as for setting the axes, data, grid, and text colors..

Using Multiple 9103 Picoammeters with Actuel

Multiple instances of Actuel can be run when more than one 9103 Picoammeter is connected to a PC. Additionally, Actuel provides features for synchronizing sampling, recording, and exporting of data from multiple devices, simulating a multi-channel system.

Synchronization Multiple Devices

To synchronize multiple devices, first run one instance of Actuel for each device. Click the “Sync All” option on any one of the copies of Actuel. Now, when you sample, record/graph, or export data, all devices will respond to these commands synchronously.*

Sampling: When “Sync All” is selected, clicking the “Sampling” button will result in sampling being started /stopped for all copies of Actuel and all devices attached.

Recording: When “Sync All” is selected, clicking the “Record” button will result in data recording being started/stopped for all copies of Actuel and all devices attached.

Saving (Exporting): When “Sync All” is selected, clicking the “Save” button will save data (sequentially) for all copies of Actuel and all devices attached. It will also auto-save for all recording devices.

Using the Device ID With Multiple Devices

Each 9103 Picoammeter is capable of storing a 10-digit device identifier string in memory (recalled when the device is cycled on/off). This can be useful when sampling, recording, and exporting data with multiple devices. In addition, the device ID is displayed for each data set when data is exported. See the section “Setting the Device Identifier”.

**Device synchronization is not designed to be sample-accurate at start; there may be a small one or two sample delay between devices. However, this error is not cumulative – once devices are synchronized their sampling rate is controlled by hardware. For example, a 50 mSec delay between devices will result in data that is offset by exactly 50 mSec throughout.*

Displaying Current While Minimized

Actuel features an option to display current, sampling and stability status, device ID, and to control sampling in a smaller window, which is always displayed on top of any other window.

To use this feature, check the option “Minimized Display” on the main window. When you minimize the main window, the smaller window will now be displayed, and can be positioned anywhere on the screen.

To display the full-size window, Simply click “Close” from the minimized window.

Specifications

General

Feature	Specification
USB Interface	160 mW power consumption
Min. DAC Resolution	2 nA: 0.1 pA / 2 mA: 100 nA
Sampling Rate	Standard: 40 reads/sec. High-Speed option: 500 reads/sec
Range	2 nA to 2 mA with 100 fA resolution
Input Protection	50 mA (fused)
Recorder Output Voltage	+/- 2.000 V per range (<i>standard-voltage only</i>)
Warm-up	1 hour to rated accuracy
Environment	Operating 0° C to 50° C
Dimensions	55 H x 170 W x 165 L (mm) / 2.11H x 6.68W x 6.30L (inches)
Net. Weight	0.816 kg / 1.5 lbs.
Connections (<i>standard-voltage</i>)	Input: Isolated BNC; Recorder Option Analog Output: Banana jacks
Connections (<i>high-voltage</i>)	HV Input: SHV; HV Reference: MHV
Bias Options	No Bias; Internal (fixed +90 V DC); External (BNC) (<i>standard-voltage only</i>)
Safety	Conforms to USB Power Specification – for user by qualified personnel who are trained in the use of test and measurement instrumentation
High-voltage Option	5 kV DC isolation
Accessories Included	Instructions manual, low noise BNC cable, USB power cable, USB driver, installation instructions, Actuel software

Resolution and Accuracy per Range

Range	Resolution	Accuracy / Offset (18° – 28°C, 0 - 70% RH)*
2 nA	100 fA	0.5+/- % + 500 fA
20 nA	1 pA	0.5 +/- % +3 pA
200 nA	10 pA	0.4 +/- % +20 pA
2 uA	100 pA	0.4 +/- % +200 pA
20 uA	1 nA	0.4 +/- % +2 nA
200 uA	10 nA	0.4 +/- % +20 nA
2 mA	100 nA	0.4 +/- % +200 nA

*Temperature Coefficient: 0°–18°C & 28°–50°C. For each °C, add 0.1 × (% rdg + offset) to accuracy spec.

Theory of Operation

A low noise BNC cable provides the input current to the 9103. A low leakage double diode protects the 9103 amplifier from over voltage with respect to ground.

(For the **HV version** of the 9103 - which can float up to +/-5kV DC - the input connector is an SHV and the HV reference connector is an MHV.)

The current is then input to a low femtoampere input current precision amplifier where the DC current is converted to a voltage. The converted voltage is fed into a precision high input impedance buffering amplifier before finally being converted to a digital value by the 24 bit digitally filtered ADC. The A/D converter is fed with a 2.50V reference. This produces a conversion of -8388608 to +8388607 for the maximum differential input of [-2.50V, +2.50V] ($2^{23} = 8388608$). With no error, an input of 0.000000000000A will produce an output conversion of 0. The margin between maximum differential input Voltage $\pm 2.50V$ and nominal range $\pm 2.00V$ allows offset calibration to accurately place the 0 conversion for 0 input current. Thus the nominal range is -6710886 for -2.0V to +6710886 for +2.00V. The filtering is user selectable with the effect of increased noise performance of the current measurement with a corresponding increase in the acquisition time.

The ADC continually measures the current but the output can be averaged depending on the acquisition time selected by the user. The fastest acquisition time is 15mS with a typical acquisition time of 500mS or longer.

The USB interface circuitry utilizes an industry standard flash microcomputer for ease of installation. Typical current draw for the 9103 is 160mA.

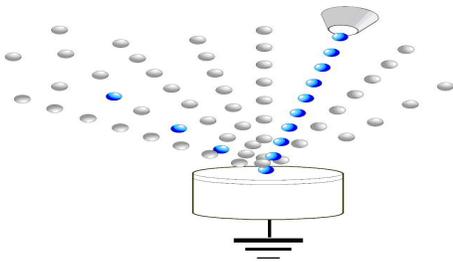
Magnetic isolators are used to provide signal isolation between the micro controller and USB interface, and the current measurement circuitry and power supplies. Ten signals transition the isolation barrier, eight of which act as controlling inputs to the current measurement circuitry, and two of which provide feedback to the micro controller.

Bias option – The bias option incorporates a low-noise 90 VDC supply, with a 100k ohm resistor to limit the current to the 9103 in the event that the input becomes shorted while the 90V bias is applied.

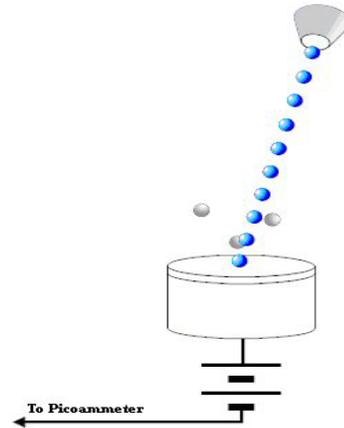
How the +90 Volt DC Bias Improves the Accuracy of Electron and Ion Current Measurements:

When the electron or ion beam impacts the target, secondary electrons are ejected. When measuring the target current the secondary electrons will subtract from the total current, resulting in an inaccurate current measurement.

Adding an ultra-low noise +90 V DC supply in series with the picoammeter will bias the target and substantially reduce the number of secondary electrons that leave the target; greatly increasing the accuracy of the target current measurement.



No Bias Voltage on Sample



With 90 VDC Bias Voltage on Sample

High Voltage Option

The High Voltage Option isolates the signal input and reference connections from ground and allows the 9103 to “float” up to +/- 5kV DC. Increasing the DC voltage isolation from chassis ground to 5000 volts (5kV) opens up new possibilities for researchers such as direct DC current measurement of very small electron and photo multiplier signals. Electron and ion beam measurements can be biased to reduce secondary electrons or to retard the beam as needed for experiments.

Communications & Command Reference

Introduction

The **9103 Picoammeter** utilizes an ASCII communications protocol for all message content. By properly setting the VCP (Virtual COM Port), you can use applications that communicate with the VCP – from terminal emulation apps to National Instruments’ LabVIEW for more sophisticated control.

If you are using the **Actuel** application supplied with your Picoammeter, there is a built in console window that allows you to communicate directly with the Picoammeter using the commands outlined in this the following section – simply click the Console button to open the window at any time. Note that when using Actuel, you don’t need to manually setup communications. Also, note that the ampersand character “&” that precedes all commands is automatically prefixed for you.

Setting up Communications

Microsoft Windows

The **9103 Picoammeter** uses a USB-serial converter chip manufactured by FTDI for communications. After installing the device drivers, the **9103 Picoammeter** will, when plugged into the PC and turned on, appear listed in the Windows Device Manager under the Ports heading as USB Serial Port (COMx), where x is the COM port number assigned by Windows.

To setup the COM port, double-click this entry (or right-click and select Properties) to bring up the Properties dialog. Note that the Manufacturer listed will be FTDI (not RBD). Click the Port Settings tab and set the fields as follows:

Setting	Value
Bits per Second (Baud Rate - standard speed)	57.6 K
Bits per Second (Baud Rate – high-speed)	230.4 K
Data Bits	8
Parity	None
Stop Bits	1
Flow Control	None

See command ‘U’ in “Communicating with the 9103 Picoammeter’ / ‘Command Reference” below for more information on switching speeds for 9103’s with the high-speed option.

Some serial communications applications supply their own interface for setting up COM ports and storing settings. In that case, the settings shown above still apply.

Other Operating Systems

Refer to your operating system for specific instructions on setting up virtual COM ports.

Communicating with the 9103 Picoammeter

Sending and Receiving Commands

For most commands, messages are sent from the computer to the **Picoammeter**, which asynchronously sends an acknowledgment back after the command execution completes. If a command message is incomplete, and error message is sent at the end of the timeout period.

Message Structure

The following table illustrates the structure of messages sent to and from the **Picoammeter**:

Attribute	Values	Length (bytes)	Description	Comments
PREFIX	'&'	1	Start of message	
MESSAGE ID	ASCII alpha character	1	Indicates content of message, whether command or data, etc. (See Message ID table below)	Supports 52 characters (upper & lower case)
DATA	ASCII alpha-numeric characters	0-80	For sample data messages: Formatted as comma separated string: "range, value, value, units" Over-range status indicated by '>' or '=' in front of the range. Value is 8 digits plus a moving decimal point, dependent on the range. Units are nA, uA, or mA. For command messages: Parameter strings depend on the individual commands	Variable length messages are allowed
CR/LF	End of line	2	End of message, standard carriage return / line feed (CR = ASCII character 13, LF = ASCII character 10)	1

Command Reference

The following table illustrates the message identifiers used when communicating with the Picoammeter. Note that all messages are preceded by the character '&'.

Message ID	Description
'A'	From device or PC, sent after receiving and processing a valid command message that does not have its own reply. May be used from the PC to acknowledge sample data messages, keeping the USB LED lit.
'B'	From PC, controls the (optional) Bias supply. Parameter is either 1 (turn bias on) or 0 (turn bias off). This setting will be stored in the Picoammeter eeprom if the store ('&Z') command is sent. (Note that the bias is automatically turned off when the input is grounded – see command 'G')
'C'	From PC, command message for calibration. Parameter string: single character as follows: 1 = start offset calibration, device reports when complete 5 = reset Chart constants to default (adjust while input disconnected) 6 = adjust Chart zero to be more positive (adjust while input disconnected) 7 = adjust Chart Zero to be more negative (adjust while input disconnected) 8 = increase Chart Gain (adjust while input 1 nA, Chart output should be 1.00 Vdc) 9 = decrease Chart Gain (adjust while input 1 nA, Chart output should be 1.00 Vdc) A = Enable ('&CA1') or Disable ('&CA2') Autocal of offset at power-up F = apply a factory offset adjustment to the active range R = report runtime calibration values (updated at range change, but not stored in eeprom) Q = report stored calibration constants (eeprom)
'D'	From PC, reset device. Default stored parameters reloaded, device initialized as for power up.
'E'	From device, sent if there was an error. Includes string description of error.
'F'	From PC, controls the filter settings for the sample data. Allowed values are 000, 002, 004, 008, 016, 032, and 064.
'f'	<i>(High-speed enabled 9103 only – this command is only available if operating at 230.4K baud – see 'U')</i> From PC, controls the first level filter setting for the sample data during hi-speed communications. Allowed values are 000 - 006, default is 002. Value of 000 disables the first level firmware filter. Note that a value of 006 is always used for standard-speed data messages.
'G'	From PC, enables shorting the input to ground. When enabled the input is grounded when the device is not interval sampling. (Note that the bias is automatically turned off when the input is grounded – see command 'B') 1 = Input grounded 0 = input normal If interval sampling is begun, the inputs are opened until sampling is stopped. For single samples, the input is opened for 5 seconds after a sample is requested
'I'	From PC, command message to set the data sample interval, parameter is in milliseconds, 0020 to 9999. Use 0000 to turn off auto-sampling
'i'	<i>(High-speed enabled 9103 only – this command is only available if operating at 230.4K baud – see 'U')</i> From PC, command message to set the hi-speed data sample interval, parameter is milliseconds, Allowed range of 0002 to 9999. Value of 0000 turns off the auto sampling. Note: Setting this parameter to a value > 0 forces the legacy auto sampling interval to 0. Note 2: When using the 500 sample / sec rate (&i0002) a specific range should be selected, as the auto-range feature uses additional time that may degrade the sample rate.
'K'	From PC, returns the product Key string (9103-000, 9103-F00, 9103-SHV, 9103-FHV – normal-speed, high-speed, normal-speed / high voltage, fast-speed / high voltage respectively)
'L'	From PC, command message to set the Logging Chart (chart recorder) update interval, parameter is milliseconds, 0050 to 9999
'M'	From PC, requests a command menu, from the device, sends a formatted command menu.

'N'	From PC, trigger the External Offset Null, function (not allowed if Auto Range is selected, correction is lost with new range or power cycle)
'P'	From PC, set the 10 character device identifier
'Q'	From PC, query device for current configuration. From device, report configuration Use Q1 or Q2 for extended status reports
'R'	From PC, sets the device range, parameter options are 0=Auto Range, 1=2nA, 2=20nA, 3=200nA, 4=2uA, 5=20uA, 6=200uA, 7=2mA
'S'	Contains one sample of measured data (sent from device) or requests an immediate sample (sent from PC)
's'	<i>(High-speed enabled 9103 only – this command is only available if operating at 230.4K baud – see 'U')</i> Contains ten samples of measured data (sent from device), or requests a specified number of samples at a specified interval (&s#####,%%%% sent from PC, ##### = num samples, %%%% = interval in mSec)
'U'	<i>(High-speed enabled 9103 only)</i> The default USB baud rate of 57.6K can be changed to 230.4 K to operate in high-speed mode: &UF switches baud rate to 230.4K &US switches baud rate to 57.6.K <i>Note: the 9103 recalls the last baud rate used. Once a command is set to switch baud rates, the port rate must be switched (or the port closed/opened with the new rate) in order for subsequent commands to take effect.</i>
'V'	Sets the number of digits, displayed values are 5, 6, 7, 8. Default is 5.
'Z'	Stores current configuration in eeprom

Sample Data Message Format

Note: The high-speed sample message may be preceded by a null character on certain systems. Parsing algorithms should be designed to strip any characters before the ampersand ('&')

Incoming Message ID	Description
'S'	&S,#% % % % %,\$*.*****,@@<CR><LF> # {= Stable, > over-range, < under range, * unstable} % % % % {range string} \$ {+ or -} *.***** {8 characters plus decimal point for value} @@ {units, nA, uA, or mA}
's' <i>(high-speed enabled 9103 only)</i>	&s,#% % % % %,\$*.****,* ****,* ****,* ****,* ****,* ****,* ****,* ****,* ****,* ****,* ****,@@<CR><LF> # {= Stable, > over-range, < under range, * unstable} % % % % {range string} \$ {+ or -} *.**** {5 characters plus decimal point for value} @@ {units, nA, uA, or mA}

Working with High-speed Data Commands (HV Option Only)

The 9103's high-speed option enables you to sample at intervals as small as 2 ms (500 samples/sec).

To switch to high-speed mode:

Sending the command 'U' to the 9103 switches modes: '&UF' enables high-speed and sets the port baud rate to 230.4k; '&US' returns the 9103 back to standard speed of 57.6k.

IMPORTANT: Once you switch modes on the 9103, the port needs to be closed and re-opened at the appropriate speed before you can communicate with the unit. If you switch to 230.4k, but your application is still programmed to run at 57.6k, you will not be able to communicate with it. And since the 9103 recalls the last speed it was programmed to run, this change is basically permanent until you can send another command. If you get into trouble programming, you can always run the **Actual** application and switch speeds from there.

Using the high-speed sampling commands

There are two new sampling commands available: 's' for one-shot sampling, and 'i' for interval. Sampling. High speed mode must be enabled and the COM port set for 230.4 K. Note that the existing commands ('S' and 'I') still work for high-speed 9103s, but cannot operate speeds than 25 ms.

Both the 's' and 'i' commands will cause the 9103 to respond with a set of 10 data points instead of 1. If you're programming the 9103, you'll of course need to parse the commands.

Additionally, the 'i' command can be used at any speed – so if you write an interval parser for higher speeds, you can still use that command for high-speed data collection if you choose.

Since the 's' command returns only one message but with 10 samples, there is an additional parameter to specify the interval, as well as a parameter to specify the number of sample messages to be returned – which means this command can now be used for controlled interval sampling (as opposed to the 'I' and 'i' commands, which are free running).

For example, '&s00002,00100' will return two sample messages with 10 samples each spaced at 100ms intervals, for a total of 20 samples.

Parsing the high-speed sample message:

The format for high-speed messages is similar to standard speed, however it includes 10 samples instead of one. Since there can be no range change in the middle of a 10-sample high-speed message, the units for all 10 samples is the same and included at the end of the string. Here's an example:

```
&s=,Range=002nA,-0.0009,-0.0007,-0.0006,-0.0009,-0.0007,-0.0007,-0.0007,-0.0010,-0.0004,-0.0006,nA
```