Model 200
0.01 Hz - 15 MHz
Analog Network Analyzer

MANUAL REVISION 1B
ANALYZER SOFTWARE VERSION 1.0
Copyright 2002

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Federal Communications Requirements
Warning- This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a class A computing device pursuant to Subpart J of Part 15 of FCC rules, which are designed to provide reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in residential areas is likely to cause interference in which case the user at his own expense will be required to take whatever measures may be required to correct the interference.
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The Model 200 Analog Network Analyzer

The Model 200 Analog Network Analyzer system is composed of an analog source/receiver unit, a parallel port interface adapter, probes, interface cables and software for a user provided Windows based computer.

The Model 200 Analog Network Analyzer offers the following high performance features

• 11.6 millihertz to 15 Megahertz coverage
• 110 dB’s of dynamic range with 0.025 dB mag. and 0.2 degree phase accuracy
• Up to 10,001 measurement points with linear or logarithmic frequency sweeps
• Automatic magnitude and phase correction compensates for test leads or fixtures

Graphical interface features

• Windows® based graphical user interface with real time plotting
• Virtual instrument front panel for complete access to all system parameters
• Automatic or manual scaling and shifting of screen plots for optimum viewing
• Advanced marker functions and master graphs give data and delta readouts.
• Advanced functions including complex impedance

Source features

• Direct digital synthesis for fast sweeps
• 11.6 millihertz to 15 MHz range, 11.6 millihertz resolution
• Output level adjustable in 1 dB steps from 1.25 millivolts to 1.77 volts rms
• 50 ohm output with current limiting
• Output can be DC offset up to +/- 10 V eliminating large coupling capacitors at low measurement frequencies

Receiver features

• Two channels for B/A ratioed, transfer function measurements
• High selectivity two stage receiver architecture for high noise immunity
• Digital signal processing provides a user selectable IF bandwidth, optimizing noise immunity and measurement speed
• Selectable AC (>=10Hz) or DC coupling with one megohm input impedance
• Inputs can be DC offset up to +/- 10 V facilitating DC coupled measurements.
Host PC requirements for using the Windows software version 1.0

Operating System: Windows versions 98 through XP. PC Hardware: 1 Ghz processor or higher recommended and a bidirectional parallel port. Note that add-on parallel port PCI type cards will not work as a parallel port for the analyzer interface.

Hardware Installation

• Identify the Host PC’s parallel port, the parallel port interface adapter’s connectors and the Source/Receiver connector.

• Connect the Source/Receiver unit to the parallel port interface adapter using the provided 10 foot 36 pin cable. Secure at both ends using the cable’s retaining clamps.

• Connect the parallel port interface adapter to the host PC’s parallel port using the provided 6 foot 25 pin Dsub cable. Taking care not to overtighten, secure both ends of the cable using the thumbscrews.

• Connect the provided +12V power supply adapter to the parallel port interface adapter. With the provided AC cord, plug the +12V power supply adapter into the AC mains, preferably switched on with the Host PC.

• Turn on the power to the Host PC. Turn on the parallel port interface adapter’s power switch. The interface adapter’s green power light should be on.

• Connect the source probe, a 1:1 cable with clips, to the source output BNC. Connect the two input probes, labeled "A" and "B" to their respective BNC’s.

• Proceed to the next step for installing the software and drivers.
Chapter 1: System Installation

Parallel Port Adapter Rear Panel

AP Instruments Inc.

OFF  ON  +12 VDC

TO HOST PC PARALLEL PORT

POWER

Parallel Port Adapter Front Panel

POWER
TO SOURCE/RECEIVER

MODEL 200 PARALLEL PORT INTERFACE ADAPTER

Made in USA

Source / Receiver Rear Panel

HOST PC INTERFACE

ANALYZER (BNC) GROUND MUST BE WITHIN 42V PEAK OF HOST PC GROUND

ACCESSORY

EARTH GROUND

SERIAL NUMBER:
WWW.APINSTRUMENTS.COM
MADE IN USA

Source / Receiver Front Panel

POWER  SOURCE OUT

ANALYZER (BNC) GROUND MUST BE WITHIN 42V PEAK OF HOST PC GROUND

CHANNEL A — RECEPTOR INPUTS — CHANNEL B

1MΩ, 25pF Input Impedance
Applied External Voltage Limits are +15V Peak to +15V

© AP Instruments Inc.

Model 200 Source Receiver Unit

15 MHz Analog Network Analyzer

50Ω Output Impedance
Applied Voltage/Current Limits to Source are ±15V/50mA Peak to ±15V/50mA

© AP Instruments Inc.

Model 200 Source Receiver Unit

15 MHz Analog Network Analyzer

50Ω Output Impedance
Applied Voltage/Current Limits to Source are ±15V/50mA Peak to ±15V/50mA

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Model 200 Source Receiver Unit

15 MHz Analog Network Analyzer

50Ω Output Impedance
Applied Voltage/Current Limits to Source are ±15V/50mA Peak to ±15V/50mA

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Model 200 Source Receiver Unit
Chapter 1: System Installation

Software Installation

Configuring the PC’s Parallel Port using the PC’s BIOS Setup

The analyzer software requires that the parallel port be set to “bidirectional mode”. This configuration is enabled in the PC’s BIOS setup program. The PC’s BIOS setup program is accessible only at PC power up at which point a message similar to “press key XXX to enter setup” is shown briefly on the screen. If no bidirectional mode is available then use EPP mode.

Installing the Windows Software

Insert the software installation media labeled "AP Instruments Windows Software for the Model 200 Parallel Port Network Analyzer" into the host computers drive.

While in Windows, use the program manager’s RUN command to execute the setup program "x:\setup" where x is the drive letter of the PC’s drive where the installation media is located. The setup program will create a directory (default location of C:\AP Instruments ) and transfer the required program files to this directory. The setup program will also create a program group called "AP Instruments".

Installing the Parallel Port Driver

NOTE: Installation of the driver requires that the installer be logged on with Administrator privileges.

IMPORTANT: The analyzer will not function without the correct driver installed. Please follow these steps to install the parallel port driver. Depending on the Windows version being used there may be variations in the steps listed below.

· From the Start menu select Settings then Control Panel
· Open the System item within the Control Panel
· Select the Hardware tab from the System Properties dialog
· Click the Device Manager button
· Open the Ports (COM&LPT) tree item,
a Printer Port sub-item will then be displayed
· Open this Printer Port (LPT1) sub-item
· Select the Driver tab from the Printer Port (LPT1) Properties dialog
Chapter 1: System Installation

- Click the Update Driver button
- When the Hardware Update Wizard appears select Install from a list or specific location (Advanced) and click the Next button
- Select Don’t search I will choose the driver to install and click the Next button.
- Click the Have Disk button
- Click the Browse... button from this Install From Disk dialog
- From this Locate File dialog navigate to the AP Instruments\Install\Drivers directory (this will be under C:\ from a default installation)
- Select the subdirectory that corresponds to the PC’s Windows version
- Select the lptapiWDM.inf file and click the Open button
- Click OK from the Install From Disk dialog

Note: If the driver fails to be recognized at this stage then restart the device manager’s Update Driver procedure. This time allow Windows to search for the best driver while specifying the driver subdirectory for your version of Windows.

- Click Next from the Hardware Update Wizard
- When the Wizard completes click Finish
- Click Close from the Printer Port Properties dialog
- The Device Manager should now contain an AP_Analyzer_Port_Resources item with a Printer Port (LPT1) sub-item
- Close the Device Manager, Close the System Properties, Close the Control Panel
- Restart the computer and reopen the Device Manager, examine the Printer Port Resources under AP_Analyzer_Port_Resources. Verify that the port I/O address begins at 0378 Hex. If it does not then record the starting address and proceed to Configuring the port I/O address below.

Configuring the port I/O address

This procedure does not need to be performed if the port I/O address begins at 0378 Hex as verified above. If the port starting address is different from this then the system registry will have to be updated. This is done by running the analyzer configuration utility found on the start menu under the AP Instruments program group. Enter the recorded start address in the configurations Port edit box, enter 2 in the Mode edit box and click on the Apply button to update the registry with the correct settings. Exit the utility when done.
Chapter 1: System Installation

Starting the Software

The Windows analyzer software icon, named APfra, is located within the AP Instruments program group. Before starting the software make sure the analyzer hardware is properly installed in the host PC, all cables are connected and the adapter’s power is on. Double clicking on the APfra icon will start the software.

The program will allow power to the source/receiver unit (as will be evident by the green power indicator LED). At this point the virtual control panel will be available and the installation is complete. The power to the source/receiver unit will automatically switch off at program termination.

**WARNING!**

DO NOT ATTEMPT TO MAKE MEASUREMENTS ON HOT OR UNGROUNDED SYSTEMS !!!! DO NOT ATTEMPT TO SHIFT THE SOURCE/RECEIVER GROUND BEYOND 42V PEAK FROM HOST PC (EARTH) GROUND OR OPERATOR SAFETY WILL BE COMPROMISED AND EQUIPMENT DAMAGE MAY OCCUR!!!. If it is necessary to make measurements on such systems then use an isolation transformer on the system and ground the system under test to an earth ground. See application notes for high common mode voltage measurement procedures. Working on or around line voltages has electrical shock hazards for both the operator and the instrument that must be understood before measurements are attempted!

**IMPORTANT NOTICE!**

It is recommended that the source/receiver unit be positioned, by at least several feet, away from the PC and the PC’s monitor (CRT). These units generate strong magnetic fields that can cause erroneous measurement results. Also, do not set heavy objects on the source/receiver unit.
Software Overview

The Frequency Response Analyzer Software (APfra.exe) program uses a PC based Windows platform to provide a virtual control panel and graphing windows user interface to the frequency response analyzer hardware. The software’s user interface offers the following key components:

- A virtual front panel for Instrument control.
- A graphics display which plots the acquired data in a variety of formats, called display modes and provides real-time data analysis through markers and master or reference traces.
- Control over system parameters such as graph colors and data format.
- Data exportation. Measured data is made available to other applications through the clipboard (as static data).
- Environment persistence. Save and restore all the display attributes and analyzer parameters (including special calibrations) for a particular measurement.

Virtual Instrument Front Panel

Nearly all functions relating to the operation of the Frequency Response Analyzer are available on the toolbar(s). The toolbars include Main, Sweep Control, Sweep Frequency, Source Parameters, Receiver Parameters, Graph Tools and Marker Functions. Functions not assigned to a toolbar icon are available through one of the pull down menus. Note that not all functions are available unless the Extended Functions Interface is checked in the View menu.

All parameters take effect immediately as they are selected. The exception to this are the edit boxes which include start & stop frequency, sweep points, averaging factor, user dwell value, source output level & DC offset. These edit boxes have their values updated by hitting the Carriage Return (Enter) or Tab key.
Chapter 2: Virtual Front Panel Operation

Menu Selections

There are six pull down menus that, along with the toolbars, comprise the analyzer’s virtual front panel.

Toolbars

There are seven toolbars that, along with the pull down menus, comprise the analyzer’s virtual front panel. The toolbars visibility is controlled by checking the appropriate box in the View menus [Toolbars...] dialog box. The toolbars can be docked or floating. The docked toolbars can be frozen in place by checking the freeze toolbars box in the View menus [Toolbars...] dialog box. The toolbars include the following:

- Main Toolbar
- Sweep Control Toolbar
- Sweep Frequency Toolbar
- Source Parameters Toolbar
- Receiver Parameters Toolbar
- Marker Functions Toolbar
- Graph Tools Toolbar
Chapter 2: Virtual Front Panel Operation

Graphics Display Window

The graph display has three basic modes of display. A particular mode is selected using the graph menu. The three modes are as follows: Magnitude and Phase, Absolute Magnitude and Complex Impedance. At the top of the graphing window is a title bar for entering a graph title. Directly under the graphing window is the Data Window which displays marker data. At the bottom of the screen a status bar is available which shows current system status.
Chapter 2: Virtual Front Panel Operation

Graph Traces
The graph display window can display two separate data traces simultaneously, distinguishable by their color, and plotted in real time. These datum can be displayed together or singularly by using the left and right trace display selectors available through the toolbar. The trace colors can be selected by using the [Tools][Options | Color...] dialog box. The minimum and maximum range of the graphed data can be chosen manually or automatically using the Manual Scale / Auto Scale toolbar buttons. The axis scaling for each trace is indicated separately on the left and right ordinates. The format of all numeric data displayed for either the axis scaling or the marker readout can be changed using the [Tools][Options | Data Format...] dialog box.

Master Trace
The master trace is a stored data trace available within the graph display. Master traces allow comparisons between a stored trace and the active trace. To add master traces to the display use the master trace toolbar button. When master traces are selected the current active trace data is copied as the master trace. The master trace marker data readout is displayed below the active trace marker data in the Data Window. The delta data readout, displayed to the right of the absolute marker data, gives the difference between the master and the active data trace separately for both left and right traces.

Reference Trace
The reference trace is a floating horizontal baseline from which relative measurements are made. Use the Reference Trace toolbar button to activate the reference traces. When active, two reference traces appear, a left and right reference trace. The reference value and delta data corresponding to the vertical marker intersection are displayed in the Data Window. Setting the reference value is accomplished by moving the trace with the mouse or typing a value in the 'Set Value' dialog box (right mouse button activated).

Markers
The graph display markers consist of a vertical line for each marker. The markers are first enabled by using the Markers toolbar button. The markers are moved by depressing the left mouse button with the mouse pointer in the vicinity of the desired markers and moving the mouse left or right as desired. The marker data is displayed in the Data Window. The Data Window is located directly below the graph trace.
Graph Display Modes

Magnitude and Phase
The first display mode, magnitude and phase, graphs the ratioed measurement of channel B divided by channel A. The magnitude represented is expressed in dB while the phase is expressed in degrees. A positive value of magnitude indicates gain through the network under test (i.e. B>A) while a negative value of magnitude indicates attenuation. The phase display range can be chosen through the [Options | Format Phase...] dialog box to be either a range of +/- 180 or 0 to 360 degrees. The phase shift indicates the relative phase shift from channels A to B. Note that the source level does not enter the equation. The source level does, however, become important for optimizing the signal to noise ratio and preserving the linearity of the network under test.

Absolute Magnitude
The second display mode, measures the absolute magnitude of channels A and B displaying it in RMS volts. This mode is useful for diagnosing a noisy B/A measurement by showing the actual (absolute) signal strength of each channel.

Complex Impedance
The third display mode graphs the complex impedance of a network under test when using an external reference resistor connected to the network in a specific manner (see application note on measuring complex impedance). The reference resistor value is entered as a parameter. The complex impedance, Z, can be displayed as one of the following:
Real Z and Imaginary Z
Magnitude and Phase of Z
Equivalent Capacitance and Resistance
Equivalent Inductance and Resistance.
A choice of series or parallel circuit models are available.
Menu Selections

File Menu

Open Setup...
Opens a dialog box which allows a previously saved configuration to be loaded. All parameters will be set to the new values.

Save Setup
The current configuration file is updated. This updated setup can then be recalled using the Open Setup... command. Only the configuration of the selected display mode is saved. See File Types, Use and Format for more information.

Save Setup As...
Opens a dialog box which allows the current configuration to be saved as a file. This setup can then be recalled using the Open Setup... command. Only the configuration of the selected display mode is saved. See File Types, Use and Format for more information.

Open Data...
Opens a dialog box which allows previously saved sweep data to be loaded into memory and displayed in the graph window. Once in memory, sweep data is available for Clipboard Copy.

Save Data As...
Opens a dialog box which allows the current displayed sweep data to be saved as a text file. The data is written in the following format:
One line per data point, On each line are three (3) tab separated values ordered as Frequency, Left Graph display units and Right Graph display units.
Data is saved with the extension .dat.

Save Master Data As...
Opens a dialog box which allows the current displayed master sweep data to be saved as a text file. The data is written in the following format:
One line per data point, On each line are three (3) tab separated values ordered as Frequency, Left Graph display units and Right Graph display units.
Data is saved with the extension .dat.
Chapter 2: Virtual Front Panel Operation

Print Graph...
Opens the standard print dialog box. The graph display window is printed using the selected print options. This command behaves differently than the toolbar print button which does not invoke the dialog box.

Print Display Mode Setup...
Prints to the system printer a list of the current analyzer setup parameters.

Print Preview
Displays a preview of the printed page.

Printer Setup...
Opens the standard print setup dialog box.

Exit
Exits the application. Sweep data in memory will be lost unless saved. The present configuration will be lost unless saved.
Edit Menu

Copy Data
Copies sweep data to the clipboard. After executing this command the clipboard will contain the last full sweep, except during the first sweep which will copy only the current collected data. The sweep data will be copied with the same format as in Save Data As... and using the selected phase format. This function is unavailable (grayed) when sweep data memory is empty. This function is also available on the Toolbar.

Copy Master Data
Copies the Master sweep data to the clipboard. After executing this command the clipboard will contain the contents of the master data. The sweep data will be copied with the same format as in Save Data As... and using the selected phase format. This function is unavailable (grayed) when the master trace is not active.

Copy Bitmap
Copies the (graphical) contents of the Graph Window and Data Window to the clipboard. The resulting bitmap can be pasted into a program (i.e. MS Paint) that accepts bitmaps.

Paste Data to Master
Pastes the clipboard data, as previously copied using the Copy Data command, to the Master Trace.
Chapter 2: Virtual Front Panel Operation

View Menu

Toolbars…
This dialog box gives the option, through a checkbox, to display the individual toolbars. An option to freeze any nonfloating toolbars is also available.

Status Bar
In checking this option a status bar at the bottom of the display will be visible. The status bar indicates the display mode, the sweep status, the sweep count and a sweep bargraph.

Extended Functions Interface
In checking this option all of the analyzer software functions are available for use on the virtual control panel. If unchecked a reduced set of functions are available for use.

Graph Menu

Magnitude & Phase
Selects the Magnitude and Phase display mode. When this mode is selected the left trace will display magnitude B/A data in decibels and the right trace displays phase B/A data in degrees.

Absolute Magnitude
Selects the Absolute Magnitude display mode. When this mode is selected the left trace will display the absolute magnitude of channel A in volts and the right trace displays the absolute magnitude of channel B in volts.

Complex Impedance…
Selects the Complex Impedance display mode. When this mode is selected the Complex Impedance option in the Tools menu appears allowing complex impedance parameters to be selected. These parameters include:
Chapter 2: Virtual Front Panel Operation

Topology - The measurement configuration used.
Reference Resistor - The series resistor to the network under test.
Equivalent Circuit - Model the equivalent circuit as Series or Parallel.

From the dialog box a display view selection is made from the following:

Complex Impedance (Rect) - Display complex impedance in rectangular coordinates, \( Z(f) = X(f) + iY(f) \), the real part (X) on the left and the imaginary part (Y) on the right.
Complex Impedance (Polar) - Display complex impedance in polar coordinates, \( Z(f) = R(f)A(f) \), the magnitude (\( R = |Z| \)) on the left and the angle (A) on the right.
Equivalent Circuit (C&R) - Display the capacitive (left trace) and resistive (right trace) components of an equivalent (series / parallel) circuit.
Equivalent Circuit (C&Damping) - Display the capacitive (left trace) and damping factor (right trace) components of an equivalent (series / parallel) circuit.
Equivalent Circuit (L&R) - Display the inductive (left trace) and resistive (right trace) components of an equivalent (series / parallel) circuit.
Equivalent Circuit (L&Quality) - Display the inductive (left trace) and quality factor (right trace) components of an equivalent (series / parallel) circuit.
Chapter 2: Virtual Front Panel Operation

Tools Menu

Calibration...
Allows a user defined probe correction array to be generated and subsequently assigned to the probe cal toolbar buttons. This feature is used to compensate for the frequency response of probes and cables.

Complex Impedance...
Allows complex impedance parameters to be selected. These parameters include:

- Topology - The measurement configuration used.
- Reference Resistor - The series resistor to the network under test.
- Equivalent Circuit - Model the equivalent circuit as Series or Parallel.

From the dialog box a display view selection is made from the following:

- Complex Impedance (Rect) - Display complex impedance in rectangular coordinates, $Z(f) = X(f) + iY(f)$, the real part $(X)$ on the left and the imaginary part $(Y)$ on the right.
- Complex Impedance (Polar) - Display complex impedance in polar coordinates, $Z(f) = R(f)A(f)$, the magnitude $(R = |Z|)$ on the left and the angle $(A)$ on the right.
- Equivalent Circuit (C&R) - Display the capacitive (left trace) and resistive (right trace) components of an equivalent (series / parallel) circuit.
- Equivalent Circuit (C&Damping) - Display the capacitive (left trace) and damping factor (right trace) components of an equivalent (series / parallel) circuit.
- Equivalent Circuit (L&R) - Display the inductive (left trace) and resistive (right trace) components of an equivalent (series / parallel) circuit.
- Equivalent Circuit (L&Quality) - Display the inductive (left trace) and quality factor (right trace) components of an equivalent (series / parallel) circuit.

See the application notes in the manual for more information on making complex impedance measurements.

Variable Source...
Allows for the definition of the AC source level as a function of frequency. The variable source toolbar button must be activated to enable this dialog box.
Chapter 2: Virtual Front Panel Operation

Trace Summing...
Enables the master trace to be replaced by any one of the following: Master+Data, Master-Data, Data-Master. This feature is useful for summing gains around a feedback loop and for graphically comparing the difference between two traces. The master trace toolbar button must be activated to enable this dialog box.

Options...

Colors...
Allows color selections to be made for the various graph display window elements. Printer line style options are assigned here.

Display...
Additional graph and control panel functions selected here.

Format Data...
Allows formatting of the data displayed beside and below the graph. Data formatting is independently available for Frequency data, Left trace data, Right trace data, and Delta (Master trace minus the realtime trace) data. The three formatting options are as follows:

Standard - Numbers are formatted with the standard notation of commas separating every three digits (i.e. 12,456,100.96).
Exponential - Numbers are formatted in exponential notation (i.e. 1.24 e07)
Engineering - Numbers are formatted in a scientific notation with the value always between 1 and 1000, a unit modifier is added to represent the decimal position (i.e. 12.45 M).

The number of displayed significant digits is entered in the sigfig edit box. The values above were formatted with sigfig = 2.

The phase option allows the phase data to be presented in either the +/- 180° or 0-360° format.

Data Columns...
Defines the left to right order of marker data columns as displayed in the Data Window.
Chapter 2: Virtual Front Panel Operation

Trace Math...
Allows a user defined mathematical multiplier and offset to be applied to the data traces.

Advanced...
Sweep dwell can be adjusted from 0 to 999ms. Normally sweep dwell is left at 0. The receiver Preamp selection allows the automatic preamp gain selection to be overridden. Normally Auto is selected.
Chapter 2: Virtual Front Panel Operation

The Toolbars

Main Toolbar

- **New Setup** - Loads default parameters into the analyzer virtual control panel replacing those in the previous configuration.

- **Open Setup** - Loads the selected setup file into the analyzer virtual control panel replacing those in the previous configuration.

- **Save Setup** - The current configuration file is updated. This updated setup can then be recalled using the Open Setup... command. Only the configuration of the selected display mode is saved. See File Types, Use and Format for more information.

- **Copy Data** - Copies sweep data to the Windows clipboard. After executing this command the clipboard will contain the last full sweep, except during the first sweep which will copy only the current collected data. This function is unavailable (grayed) when sweep data memory is empty. This function is also available from the edit menu.

- **Print** - Prints the graph display window on the default printer in landscape orientation. In order to print using alternate options use the print command from the file menu.

- **Help** - Executes the help. This function is also available from the help menu.
Chapter 2: Virtual Front Panel Operation

Sweep Control Toolbar

- **Start Sweep**
  Begins a sweep using the set parameters.

- **Stop Sweep**
  Terminates the sweep in progress. Sweep data is not accessible until a complete sweep is finished.

- **Pause Sweep**
  Pauses the sweep in progress. A second actuation of the pause sweep button restarts the sweep. Actuating the stop sweep button while paused will reset the sweep.

- **Sweep Mode**
  If Single sweeps are enabled then the sweep activity is suspended upon collection of the last data point. A new single sweep is started by clicking the start sweep toolbar button or sweep menu option. If Continuous is selected then the sweeps are repeated continuously.

- **Sweep Type**
  If Lin x is enabled then the frequency increment between data points remains constant. The Log x sweep mode gives a frequency increment between points that is logarithmically increasing with frequency thus compressing the frequency axis. Use the Log x selection for Bode type plots. This parameter is not used when sweeping with a frequency points list file. The increment between each point is solely determined by each frequency point value.

- **Y Axis Graphing Type**
  If Lin y is enabled then the units are displayed formatted for linear units. If Log y is enabled then the units (except phase) are displayed formatted for logarithmic units. Use the Log y selection for Bode type plots.
Points
Enter the number of data points to collect. The maximum number of points is 10,001. Available RAM may limit the number of points you can use. Roughly, 25K per 100 points are required. This parameter is not used when sweeping with a frequency points list file. The number of data points will be equal to the number of frequency values in the file.

Avg
Sweep averaging is toggled on and off by clicking the Avg checkbox. The Averaging Factor specifies the weighting of each sweep into the displayed trace, is a value from 1 to 999, entered into the Avg edit box. The weighting of a sweep (weighting factor) is 1 / Averaging factor. When enabled, the averaging function averages each sweep into the trace with a weighting factor equal to the sweep count, until the Averaging Factor is reached. When the specified averaging factor is reached, the trace is updated with each sweep weighted by the Averaging Factor.
Sweep Frequency Toolbar

Sweep frequency limits may be entered as Start/Stop, Center/Span, or File list values.

Start/Stop
Two edit boxes allow for sweep start and stop frequencies to be entered. Frequency values may be entered as standard values, with or without separating commas (ie. 100.2 or 1,200), exponential values (ie. 1.2e5), or with one of three standard SI prefixes: m-milli, k-kilo, M-mega (ie. 1k, 2.6M). After typing a new frequency value you must enter it by hitting the Carriage Return (Enter) or Tab key. Regardless of how the value was entered it will be converted to the comma separated format.
In the event the frequency value entered causes an error (value out of range or start frequency greater than stop frequency) a message box will be displayed and either value may be edited to remove the error.

Center/Span
Two edit boxes allow for the sweep range to be entered as a center frequency and a total span. Frequency values are entered exactly as described in Start/Stop above.

File List
When File list is selected, a frequency point list (.fpl) file is used as the sweep frequency points. The filename is entered into the corresponding edit box either manually or selected through the Browse dialog box.
Chapter 2: Virtual Front Panel Operation

Source Parameters Toolbar

<table>
<thead>
<tr>
<th>On</th>
<th>Off</th>
<th>Level</th>
<th>1.25 mV</th>
<th>6.00 dB</th>
<th>Offset</th>
<th>0.0 V</th>
</tr>
</thead>
</table>

**Output**

If On then the AC output is set by the level established in the Level edit box. If Off then the AC output from the source is set to zero regardless of source Level setting. The DC source offset is not affected. The output must be off when measuring signals generated from an external source.

**Constant Source Level**

Selecting the constant source level will keep the AC source level constant with frequency.

**Variable Source Level**

Selecting the variable or swept source will allow the AC source level source to vary as a function of the sweep frequency. Upon activation the variable source dialog and the variable source trace appears for editing.

**Level**

The source output level entry ranges from 1.25 mV to 1.77 V RMS. There are 64 discrete levels available in 1 dB increments. The level may be typed in directly or increased / decreased in user definable dB steps. Note: When the level is typed in directly use the Carriage Return (Enter) or Tab key to enter the new value. When using the inc / dec buttons the source level will be updated automatically.

**DC Offset**

The Source entry has a range of +/- 10 Volts DC with a resolution of 0.1 Volts DC. The Fine entry has a range of +/- 0.128 Volts DC with a resolution of 0.002 Volts (two millivolts) DC. It is advised to first set the source followed by the fine adjust. The new DC offset will be entered after hitting the Carriage Return (Enter) or Tab key.
Chapter 2: Virtual Front Panel Operation

Receiver Parameters Toolbar

Probe Cal 1,2
When selected a user defined probe correction array is used to compensate for the frequency response of probes and cables. Note that this button is greyed out until a probe calibration file is assigned using the probe cal 1 toolbar button assignment as found in the Probe Calibration Dialog Box.

Coupling
If AC is selected the analyzer uses its internal coupling capacitors. AC coupling can only be used for sweep frequencies $\geq 10$ Hz. If DC coupling is selected then automatic DC offset tracking is employed for inputs up to +/- 10 VDC.

BandWidth
The higher, or wider, the IF bandwidth the faster the sweep will take place. The lower, or narrower the IF bandwidth the better the noise immunity. The noise floor will change approximately 10 dB with each setting. Choose the highest bandwidth that gives a trace with acceptable noise levels.
Chapter 2: Virtual Front Panel Operation

Graph Tools Toolbar

Markers
Toggles graph markers. When enabled, the makers and data window are visible. Markers are positioned by dragging them using the left mouse button. The marker data is displayed below the graph within the Data Window.

Reference Trace
Toggles reference traces. Reference traces are horizontal lines which can be set to any value and are used to obtain relative data. When enabled, additional rows appear in the data window which display the reference trace data and the difference (Delta) between the data and reference trace, that is, the Data Trace - Reference Trace. Note: Reference and Master traces cannot be displayed simultaneously.

Master Trace
Toggles master traces. At the moment this is enabled, the data traces are copied and displayed as master traces. When markers are enabled additional rows appear in the data window which display the master trace data and the difference (Delta) between the data and master trace, that is, the Data Trace - Master Trace. Note: Master and Reference traces cannot be displayed simultaneously.

AutoScale
Executes an automatic scaling procedure on both the left and right trace, then redispays the graph. Only the realtime trace data is used for autoscaling. Thus it is possible that master trace data may lie outside the graph after autoscale.

Manual Scale...
Opens the manual scale dialog box in which graph scaling for the left and right trace is accomplished. When this dialog box opens, the current minimum and maximum values are displayed.
Chapter 2: Virtual Front Panel Operation

Zoom
Toggles zoom mode. When enabled (and the mouse is within the graph area) the cursor changes to a magnifying glass which defines the new start, stop frequencies and the new upper, lower graph limits.

UnZoom
Restores the display to view the graph as the limits existed before the Zoom command was activated.

Display Left Trace
This button controls the visibility of the left trace. By default the trace is visible (button pressed). While hidden, all left trace data, including reference or master trace data are hidden, and all rows within the data window corresponding to this data are removed. Hiding data does not in any way inhibit processing (ie. averaging, trace math, etc.), it only removes the data from view.

Display Right Trace
This button controls the visibility of the right trace. By default the trace is visible (button pressed). While hidden, all right trace data, including reference or master trace data are hidden, and all rows within the data window corresponding to this data are removed. Hiding data does not in any way inhibit processing (ie. averaging, trace math, etc.), it only removes the data from view.
**Chapter 2: Virtual Front Panel Operation**

**Marker Functions Toolbar**

| Markers | 2 | Active | 1 | Search Value | 0.00 deg |

Note: This Toolbar is active in the Extended Functions Interface only

**Markers Scroll Box**

The up/down arrows allow from 1 to 5 markers to be displayed.

**Marker Active Selection Box**

Chooses which marker (marker 1 to marker 5) is to be used as the active marker for the advanced marker functions.

**Search Left Data, Right Data**

Depending on the button selected specifies the left or right data trace to be used as the data trace source for the marker search functions.

**Search Absolute**

The value in the search value edit box is to be used as the search value by the search left/right commands. The active marker will attempt to find the absolute value listed in the search value edit box in the specified data trace.

**Search Relative**

The value in the search value edit box is to be used as the search value by the search left/right commands. The active marker will attempt to find the relative value listed in the search value edit box in the specified data trace. The relative value is based on the reference trace value which must be active for this function to be ungreyed.

**Marker Tracking**

With the search left or search right button selected the active marker will attempt to track the value in the search value edit box. The marker frequency becomes the variable so that the value in the search value edit box can be tracked.
Search Value Edit Box
A user defined quantity is entered and used for the marker search functions.

Search Left of Marker, Right of Marker
Will search, and located the active marker, at the marker’s left or right. The absolute or relative value as listed in the search value edit box is the search value. The left data trace or right data trace to be searched is selected with the Search Left Data, Right Data toolbar buttons.

Find Max, Min
Searching the specified data trace the active marker will locate the maximum or minimum value.

Ref to Marker
The reference trace is relocated to the current value of the active marker in the specified data trace. The reference trace must be active for this function to be ungreyed.
Introduction to Analog Network Measurements

Network analysis and network measurements determine the most fundamental properties of a given network. These properties include the frequency response transfer function, input/output impedance and group delay, all over a given frequency range. In many electronic applications, including filters, amplifiers and systems with feedback, the most important characteristic is the frequency response of that network, circuit, or system. The frequency response gives the magnitude (gain or attenuation) and phase, as a function of frequency, between two desired points in the system under test. The frequency response is measured directly by a network analyzer for voltage-voltage transfer functions. High-frequency power transfer functions are measured by the addition of a power splitter and through-line terminations. Impedance can be calculated using a known reference resistor in series with the unknown network. Group delay can be derived from the phase data since it is the negative derivative of phase with respect to frequency.

In the case of filters, the two quantities of interest are typically the stopband attenuation and the passband insertion loss along with possibly the group delay characteristic in the passband. With amplifiers, the main quantity of interest is gain “flatness” over frequency in which case the 3 dB gain rolloff point defines the amplifier’s bandwidth. With feedback systems, either electrical or electromechanical, the open and closed loop frequency response characterize the system. Feedback systems can exhibit unwanted oscillations, i.e. instabilities, unless the open loop response is evaluated and appropriately compensated for, to ensure stability.

The frequency response function of an electrical network is defined as the sinusoidal output response divided by the sinusoidal input stimulus. The input and output can be voltage or current depending on the desired transfer function. Note that the frequency response is a ratioed quantity of output to input, and that the input and output are described by complex numbers or phasors. The frequency response, at each frequency point of interest, is then given by a complex number, or phasor. The phasor can be fully described by its magnitude and
phase components. It is these quantities, the magnitude and phase of the input and output that are measured and ratioed by the network analyzer to obtain the frequency response.

The B/A ratioed measurement described above is equivalent to subtracting the input signal from the output signal when each quantity is in logarithmic form. In the model 200 network analyzer the network’s input signal is, by convention, measured by channel A and the output signal is measured by channel B. The expression B/A then describes the resulting frequency response transfer function.
Basic Measurement Procedures

The optimum network analyzer measurement setup is, as expected, highly dependent on the circuit under test. The frequency range of interest, circuit gain, circuit impedance at the probe points and DC voltage levels are among the factors affecting the measurement setup. Passive circuits are generally easier to measure than active circuits because they have low noise levels, don’t usually have special bias voltage requirements and are typically insensitive to source drive levels. Active circuits, on the other hand, may have the properties mentioned above that make measuring them in a linear mode of operation more challenging. It is important to have a good idea of what the measurement results should be before they are taken. The real value of network measurements is in finding the incalculable and the miscalculated frequency response.

Users that are new to network measurements should become familiar with the analyzer’s operation by first measuring a simple passive network before advancing to measuring, for example, the loop gain of a high gain feedback circuit.

General Measurement Procedure

Using the control panel set the network analyzer parameters to the following:

[1] In the FILE menu select Default Setup or load a specific configuration previously defined and saved using the Open Setup menu selection. This will establish a set of system parameters for general use. Specific requirements are met by using the appropriate control panel button or menu selection.

[2] Set the desired frequency coverage by using the START and STOP or CENTER and SPAN control panel buttons located in the SWEEP subpanel. If the start frequency is less than 10 Hz then DC coupling will have to be selected in the RECEIVER subpanel.

[3] If desired set the graph title using the OPTIONS|Title menu selection.

[4] Decide on what stage(s) in the circuit the transfer function is to be measured. Locate the input node and output node of this network.
As depicted below, connect up the source probe and the channel A probe to the network’s input node. Connect up the channel B probe to the network’s output node. If the output impedance of the stage preceding the network under test is less than approximately 50 ohms then an isolation resistor may be needed to provide a high enough source drive level. Make sure that the x1, x10 switch on both channel A and B probes are in the same position, typically x1, and this setting corresponds to the attenuation entered in the RECEIVER subpanel. See the application note on high frequency measurements.

If not in a continuous sweep mode then select this mode in the SWEEP subpanel. Increase the source drive level from its minimum level until the graphics display shows a noise free plot. If the plot is not visible or only partly visible actuate the Autoscale function from the toolbar. Bandwidth can also be adjusted so as to optimize trace noise or sweep time. Take care not to increase the source drive level to a point such that the network under test is no longer operating in a linear mode of operation as this can give erroneous results.
High Frequency Measurements

At frequencies higher than a few hundred kilohertz two important issues arise in network measurements. The first is that of isolation between a network’s input and output nodes. The analyzer has a minimum dynamic range of 100 dB which can be compromised by coupling paths within the network under test or in the probe connections themselves. The source of this isolation problem can be either 1) conducted through “common mode impedances” and/or 2) radiated, with radiated coupling typically increasing with frequency. Basic RF layout and design practices reduce or eliminate this problem. It is recommended that coaxial cables with BNC interconnects be used above one megahertz.

The second issue is that of probe loading effects. For higher frequency measurements on high impedance circuits determine (very approximately) if the 80 pf capacitance of the probe tip in the x1 position on the output node will influence the measurement. The output node should have an impedance commensurate with the desired measurement accuracy. For example at 1 MHz a capacitance of 80 pf has an impedance of 2 K ohms and the node under test should then have an impedance of 200 ohms or less, at 1 MHz. This will give errors of less than 0.05 dB magnitude and 6 degrees phase. Although inconvenient, the effect of the probe shunt capacitance can be factored out knowing the actual output impedance of the circuit. The x10 position will reduce the probe capacitance to under 15 pf although the dynamic range of the instrument will typically be lowered by 20 dB in this setting. Note that BOTH channel A AND channel B probes must have the SAME setting or else the measurement will have an erroneous result of 20 dB. It is also important that the probe attenuation be entered into the RECEIVER window Atten selection for the automatic frequency correction to be valid.
Circuits with Nonzero DC Voltage Levels at the Input / Output Node

If the circuit’s selected input node, also the network analyzer’s source connection and channel A connection, has a nonzero DC voltage it will be necessary use one of the following techniques:  1) DC offset the source (+/- 10 VDC max) to match the circuit’s offset using the DC OFFSET entry in the SOURCE window or 2) AC couple the source to the circuit using a capacitor or transformer.  If method 2 is used consideration will have to be given to the difficulty in obtaining a sufficiently low driving impedance at low frequencies with a reasonably sized coupling capacitor.  In the case of a transformer low and high frequency response needs to be considered.  The coupling method does not need to have a flat response since ratioed measurements cancel source flatness deviations.  In both techniques the input channels must also be either:  1) AC coupled using the network analyzer’s internal coupling capacitor (>=10Hz only), or 2) DC coupled which will enable the automatic DC offset tracking up to a maximum of +/- 10 VDC.  To allow sufficient voltage “headroom” for large amplitude signals the maximum DC offset should be +/- 7.5 VDC.

Measuring Circuits with High Common Mode Voltages

For frequency response measurements on circuits that have large voltage offsets (>10 VDC) from ground it is necessary to couple the source to the circuit under test using a signal injection transformer covering the frequency range of interest.  Using 10-to-1 probes for the receiver’s input channels will increase the maximum input voltage to 200 Volts.  For high voltages the receiver channels can also be either transformer coupled, connected using active differential probes, or connected using an isolation amplifier.  Running a frequency calibration with any of the aforementioned connection schemes, with the probes in place, will remove (i.e. normalize) the frequency response of the probes.
Measuring Feedback Loop Frequency Response

In feedback circuits it is necessary to measure the gain and phase for the complete path around some chosen loop, i.e. the open loop gain and phase. If the network analyzer is connected such that the source and channel A are connected to the desired “beginning” point in the loop and channel B is connected to the desired “end” point in the loop the gain measured is the desired loop gain and the phase measured is the phase change around the loop. In the case of negative feedback, the phase change includes a 180 degree phase shift when the feedback signal is inverted in the loop.

The network analyzer display shows a ±180 degree phase range so the inversion in the feedback loop will cause any additional phase shifts beyond -180 degrees to “wrap around” and appear as a phase of +180 - (additional phase shifts). In a typical negative feedback circuit with one pole (i.e. 20 dB/decade rolloff) the phase would start off at +180 degrees and, at the pole frequency, show +135 degrees. The phase reading can then be directly interpreted as “phase margin” at the frequency where the loop gain magnitude is equal to one (0 dB).
In most cases to make a loop gain measurement the feedback loop must be left closed due to high DC gain or bias conditions. These conditions would force the circuit into a nonlinear area of operation if the loop was opened making a valid measurement impossible. If the node at the source connection has a nonzero voltage then the source will have to be DC offset to match the node voltage or AC coupled using a capacitor or transformer. The resistor \( R_{opt} \) can be used to prevent circuit loading due to small differences in source and circuit voltages. For high frequency loop gain measurements the source probe capacitance as well as the input channel probe capacitance can have a destabilizing effect on the circuit - see the high frequency measurement note above. The source probe capacitance effect can be reduced by using a series resistor between the source and the circuit’s selected node. Use a resistor as large as needed to maintain stability. The source drive level can be increased to the level required to obtain a noise free trace.

Two measurement methods are detailed below. The first is a DC coupled technique which has the advantages of a DC to 15 MHz frequency coverage. The disadvantage of this technique is that its implementation may require the use of a buffer amplifier. The second, AC coupled, technique is simpler in that it only requires a resistor and a transformer to implement. The disadvantage of this technique is that it is frequency limited by the bandwidth of the transformer used.

**DC Coupled, Buffer Amplifier Method**

Unless the feedback loop under test has a buffer stage with high input impedance and low output impedance it may be necessary to temporarily add such a stage to maintain the existing feedback loop characteristics and make a valid measurement. The diagram below shows the placement of such a temporary buffer and the network analyzer connections for a feedback loop frequency response measurement. The buffer circuit below, with the 35 MHz bandwidth op-amps, adds approximately 3 degrees of phase shift at 1 MHz to the measurement. Lower speed op-amps can be used for lower frequencies, if desired. The circuit shown assumes \( Z_{out} @ V_{out} \) is much lower than \( R_{FEEDBACK} \) over the frequencies of interest. If this is not the case then to obtain the actual loop gain response it may be necessary to terminate the \( V_{out} \) node with an impedance equivalent to \( R_{FEEDBACK} \) and to add a series impedance to \( R_{FEEDBACK} \) equal to \( Z_{out} \).
AC Coupled, Transformer Method

The secondary of a transformer is used in this technique to develop a drive voltage across a small resistor, typically 10 to 50 Ohms. This resistor is typically placed in series with the loop’s feedback resistor as shown in the diagram below. The transformer’s frequency response does not have to be flat over the measurement range but does need to provide an adequate drive level over the measurement range to ensure a good signal to noise ratio.
Configuration For
Transformer
Coupled Feedback
Loop Measurements:
Measuring Complex Impedance

To measure the input or output impedance of a network the analyzer is connected to a known reference resistor, **R**, that is in series with the network. The source output and channel A are connected to one side of **R** and the other side of **R** is connected to channel B and the network under test as depicted below. For best accuracy the resistor **R** is chosen such that its impedance is within a factor of 5 or so of the expected impedance of the network under test, at the frequency of interest. The impedance calculations derived below are done automatically by the software when the Complex Impedance option is chosen within the Graph menu.

Let the transfer function measured by the analyzer be **H(f)**, the unknown complex impedance, **Z(f)** = x + jy, is then given by: 

\[ Z(f) = R \cdot H(f)/(1-H(f)) \]

This result is derived using the generalized voltage divider formula with the substitution of **VB** = **H**·**VA**. First the magnitude of **H(f)** is converted from dB’s to linear form by dividing by 20 and taking the antilog (base 10). The phase is used directly as read
from the analyzer taking care to include the sign. The converted magnitude along with the phase now represents $H(f)$ in polar form, and is then converted to rectangular form and substituted into the formula above. The resulting complex number is the impedance in ohms and will typically have a real part, $x$, representing the equivalent series resistance, and an imaginary part, $y$, representing the equivalent reactance of the network under test. A capacitive reactance will have a negative imaginary part, while an inductive reactance will have a positive imaginary part. The equivalent capacitance is given by $C = -1/(2\pi f y)$ and the equivalent inductance given by $L = y/(2\pi f)$ where $f$ is the measurement frequency in Hz.
Line Current Harmonic Measurements

A measurement mode for line current harmonic precompliance testing can be accomplished by using the Absolute Magnitude Display as chosen within the Graph menu. By setting up a fpl file list of the first forty line harmonic frequencies this mode can graph a plot of the harmonics of the power line current. Choose a receiver bandwidth of 10 Hz. It is highly recommended that the IEC standard be obtained and understood by the user before this test is undertaken. A copy of this standard is available through ANSI, Phone (212) 642-4900. The current is measured using an external current transducer, connected to channel A or B. The current transducer frequency response bandwidth is required to be flat from 50 Hz to 2.5 KHz. Note that the current transducer must have an output that is safety isolated and meets the SELV (Safety Exposed Low Voltage) requirements when connected to measure line current. One such current transducer that meets the above requirements is the PR-30 available from LEM USA.
Power Transmission/Reflection Measurements

In applications such as passive filters and circuits for communications the parameters of interest involve not voltage transfer functions but rather power transfer functions. Because power can be reflected as well as transmitted through a network due to impedance mismatches the voltage and power transfer functions are not necessarily the same. The model 200 network analyzer, in its most basic configuration, measures voltage/voltage transfer functions since it has high impedance inputs. To measure power transfer functions the network analyzer inputs need to be terminated, using feedthrough terminations, to the desired impedance (typically 50 or 75 ohms). This will convert the power into a voltage which is measured by the analyzer. Also the measurement configuration must be able to determine the actual power transmitted through or reflected from the network under test. This is accomplished by using a power splitter and, in the case of reflection measurements, a directional coupler. The model 200 network analyzer has the capability to measure transmission (S21 or S12) as well as the return loss of a reflection measurement directly. The derived quantities including the reflection coefficient, VSWR and impedance can be calculated from the return loss measurement’s magnitude and phase information using the relationships given below.

- **Reflection coefficient magnitude** = $10^{-\text{return loss}/20}$ where the return loss is expressed as a positive quantity in dB. The reflection coefficient magnitude is between 0 and 1.

- **Reflection coefficient phase** = the phase measured at the return loss measurement.

- **VSWR** = $(1 + \text{reflection coefficient magnitude})/(1 - \text{reflection coefficient magnitude})$.

- **Impedance** = Characteristic impedance (i.e. 50 Ohms) * $(1 + \text{reflection coefficient})/(1 - \text{reflection coefficient})$

Transmission Measurements

In the case of transmission measurements the power incident to the network under test can be determined by sampling the incident source power using a power splitter and making a ratioed measurement of the output power to input power. As shown in the drawing (below) the sampled incident power is mea-
Chapter 3: Application Notes

sured by channel A while the transmitted power is measured by channel B. Note that the input channels A and B must be terminated to the characteristic impedance of the network under test using feedthrough terminations. A frequency calibration can be performed with the power splitter in place and a through line substituted for the network under test for enhanced accuracy. The power splitter can be a simple resistive splitter shown below which will result in a 6 dB power loss from the source to the network under test. A low loss transformer coupled splitter such as a Mini-Circuits model ZSC-2-2 can also be used.

![Transmission Measuring Setup Diagram](image)

**Reflection or Return Loss Measurements**

With reflection measurements the power reflected from the network under test back toward the source is the quantity of interest. The reflected power is measured by a directional coupler such as a Mini-Circuits model ZDC-15-6. The directional coupler has a tap which represents a portion (i.e. -15 dB) of the reflected power. A return loss measurement can be made by taking a ratioed measurement of the incident power to the reflected power. The incident source power is sampled using a power splitter. As shown in the drawing (below) the sampled incident power is measured by channel B while the reflected power, as sampled from the coupler tap, is measured by channel A. This ratio is taken to
keep return loss a positive quantity. Note that the directional coupler’s output port is connected to the power splitter while the coupler’s input port is connected to the network under test. This is because it is the reflected power from the test network that enters the coupler’s input port. Note that the input channels A and B must be terminated to the characteristic impedance of the network under test using feedthrough terminations. A frequency response calibration **must** be performed with the power splitter and directional coupler in place using a short substituted for the network under test. The short will give a theoretical return loss of 0 dB with a phase shift of 180 degrees and gives the reference point by which the return loss is measured. The -15 dB reflected power coupling tap of the directional coupler is calibrated out by the frequency response calibration procedure.

**Reflection Measuring Setup**
The Model 200’s Network Analyzer System is comprised of a host PC, a Parallel Port Adapter and a Source/Receiver unit. The host PC provides the operator I/O, file storage and data post-processing. The parallel port adapter provides the real time data preprocessing and power supply for the Source/Receiver unit. The Source/Receiver unit contains the frequency source output and the two input, or receiver channels.

The host PC interfaces with the parallel port adapter’s DSP microprocessor (uP) using the PC’s parallel port. The DSP uP in turn interfaces with the Source/Receiver unit, via a cable, using a high speed bidirectional serial interface isolated from the host PC. The parallel port adapter’s isolated DC-DC converter uses an external +12v supply as its power source. The converter up and down converts the +12v input to supply the Source/Receiver unit with the needed voltages.

The network analyzer uses a “swept sine” approach to measure the transfer function of the network under test. This approach requires a sinusoidal, variable frequency, source output and two input channels capable of sampling the sinusoidal input over a broad frequency range. The source is of the DDS or direct digital synthesis type which meets the requirements of fast frequency changes, logarithmic or linear sweeps, wide frequency range and low parts count. The receiver is of the heterodyning type which enables a broad frequency range with a fixed low frequency I.F. for high accuracy and low noise analog to digital conversion.

Both the source and L.O. use a DDS source which functions by accumulating a selectable phase increment at the system clock rate. This accumulated phase value is then directly mapped to the sine value using a ROM lookup table. The sine value is then converted to a voltage using a high speed DAC, the output of which is low pass filtered to remove aliases. The L.O. output is used directly to drive the L.O. side of the receiver mixers. The source output, however, is passed through a stepped attenuator giving 0 to 63 dB’s of attenuation. The attenuator’s output is then DC offset by a user selected amount and buffered enabling the source output to drive 50 ohm loads.
Appendix A: Theory of Operation

The receiver channels A and B are identical thus the following description applies to both. The input signal drives a high impedance input buffer which in turn drives a stage capable of being DC offset for automatic DC offset tracking. The offset stage then drives an amplifier stage switched by the DSP uP for maximum signal to noise ratio. The amplifiers output drives the signal side of the mixer resulting in a mixer output that is a fixed I.F.. The I.F. signal is then low pass filtered to remove aliases and sampled by the analog to digital converter.

The receiver’s analog to digital converter output is sent to the DSP uP over the serial interface. The DSP uP converts the data from both input channels, in real time, to complex numbers representing the phase and magnitude of the sinusoids at the channel A and B inputs. The DSP uP then passes these complex numbers to the PC for error correction and scaling for presentation on the PC’s graphics display.
Appendix B: Measurement Accuracy

APPENDIX B

Measurement Accuracy

The basic accuracy of the analyzer is specified to be 0.025 dB magnitude and 0.2 degrees phase. These specifications assume that a system calibration has been performed after a 30 minute warm-up period at the operating ambient temperature. The analyzer's accuracy can be undermined by changing or swapping the input probes after calibration has been performed.

There are a number of factors that determine the accuracy, or lack thereof (uncertainty or error) of a given frequency response measurement made by the network analyzer. They are listed below in an order which does not necessarily reflect their significance.

Possible error contributing factors external to the analyzer include:
- Probe Loading
- Probe Compensation
- Transmission Line Effects

Possible error contributing factors internal to the analyzer include:
- Signal to Noise Ratio
- Source Frequency Accuracy
- Temperature Drift
- Receiver Linearity

To obtain the worst case measurement error the errors from all of these factors need to be summed together as they relate to a given measurement situation. The term 'res', as used in the charts below, indicates the values are below 0.01 dB magnitude or 0.1 degrees phase.

Probe Loading Error

Probe impedance, chiefly capacitance, can cause loading of the circuit under test and can be a significant error source as described in the discussion on high frequency measurements.
Probe Compensation Error

Ten-to-one (x10) probes, needed for reducing the probe loading effect introduce a frequency response error. The frequency response error can be canceled by performing a frequency response calibration. The adjustment procedure is performed once at the factory on the included probes and should be performed periodically as follows: Set the analyzer for a 0.994 V rms signal level output and sweep from 100 Hz to 100 kHz (log sweep). Connect the source and input channels together. Place one probe in the x1 position, if available, or use a 1:1 cable. Place the other probe in the x10 position. Using a small screwdriver or adjustment tool set the x10 probe compensation adjustment for maximum flatness. Likewise, adjust the second x10 probe in a similar manner keeping the probe on its assigned channel (do not swap probes back and forth between channels).

Transmission Line Effects

When using coaxial cables at higher frequencies and long cable lengths the transmission line effects give rise to "standing wave patterns" on cables unless the cables are properly terminated at their endpoints with the cable’s characteristic impedance. The analyzer’s inputs have a one megohm impedance which may need to be terminated to the cables impedance. To avoid this type of error use through-line terminators at the analyzer’s input channel BNC’s.

Signal to Noise Ratio Error

This error term is labeled “signal to noise ratio” or SNR and is the difference, in dB’s, between the analyzer’s receiver noise floor and the smallest of the two input channel’s signal magnitude. The analyzer’s noise floor is specified to be at least 100 dB’s below the largest allowable signal which is 1.7 volts rms. An input signal at the worst case noise floor level would then have a magnitude of approximately 18 microvolts rms and the SNR would be 0 dB. The analyzer’s typical noise floor is approximately 5uV rms using a IF bandwidth of 10 Hz. This type of error is a random quantity that manifests itself as trace noise. The chart below lists the measurement error as a function of SNR.

Source Frequency Error

The source frequency is accurate to 100 ppm (0.01%) or 20 ppm (special) which
Appendix B: Measurement Accuracy

**Temperature Drift Error**

The temperature drift error is due to magnitude and phase changes with the analyzer’s internal temperature changing. This results from the operating temperature being different from the temperature at the time the frequency calibration was performed. This error source can be minimized by performing a frequency calibration at the ambient operating temperature after a 30 minute warm-up period. The expected worst case temperature coefficients are 0.0025 dB magnitude and 0.01 degree phase, per degree Celsius.

**Receiver Linearity Error**

Since the frequency calibration is performed at a single, high, input level any variations in the analyzer’s linearity will cause a magnitude error at other, significantly different, input levels. The chart below gives this error as a function of input level.

<table>
<thead>
<tr>
<th>Signal Strength</th>
<th>SNR in dB’s</th>
<th>Mag. Error (dB)</th>
<th>Phase Error (deg.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18 uV</td>
<td>0</td>
<td>3</td>
<td>45</td>
</tr>
<tr>
<td>56 uV</td>
<td>10</td>
<td>0.414</td>
<td>13.6</td>
</tr>
<tr>
<td>180 uV</td>
<td>20</td>
<td>0.043</td>
<td>5.7</td>
</tr>
<tr>
<td>560 uV</td>
<td>30</td>
<td>0.0043 (&lt; res)</td>
<td>1.81</td>
</tr>
<tr>
<td>1.8 mV</td>
<td>40</td>
<td>&lt; res</td>
<td>0.573</td>
</tr>
<tr>
<td>5.6 mV</td>
<td>50</td>
<td>&lt; res</td>
<td>0.181</td>
</tr>
<tr>
<td>18 mV</td>
<td>60</td>
<td>&lt; res</td>
<td>0.0573 (&lt; res)</td>
</tr>
<tr>
<td>56 mV or more</td>
<td>70 or more</td>
<td>&lt; res</td>
<td>&lt; res</td>
</tr>
</tbody>
</table>

makes its consideration important only on circuits with extremely high Q such as crystal filters.
### Receiver Linearity Error Chart

<table>
<thead>
<tr>
<th>Input Signal Level</th>
<th>Magnitude Error in dB’s</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1 mV</td>
<td>0.30</td>
</tr>
<tr>
<td>1 mV</td>
<td>0.15</td>
</tr>
<tr>
<td>10 mV</td>
<td>0.01</td>
</tr>
<tr>
<td>&gt;10 mV</td>
<td>&lt; res</td>
</tr>
</tbody>
</table>
### APPENDIX C

**Specifications**

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TYPICAL SPEC.</th>
<th>MIN. / MAX. SPEC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sweep Speed, Per Point</td>
<td>3 msec. (600 Mhz PC)</td>
<td>PC Dependent</td>
</tr>
<tr>
<td>Source/Receiver Isolation</td>
<td>120 dB</td>
<td>100 dB min.</td>
</tr>
<tr>
<td>Temperature, Operating</td>
<td>5 °C / 35 °C</td>
<td>-40 °C / 70 °C</td>
</tr>
<tr>
<td>Temperature, Storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Source/Receiver:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>5 lbs.</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>3.5&quot;H x 10&quot;W x 15.&quot;L</td>
<td></td>
</tr>
<tr>
<td>Interface Adapter:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>1 lbs</td>
<td></td>
</tr>
<tr>
<td>Dimensions</td>
<td>1&quot;H x 6&quot;W x 9&quot;L</td>
<td></td>
</tr>
<tr>
<td>Analyzer (BNC) ground to</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PC ground common mode</td>
<td></td>
<td>42V Peak</td>
</tr>
<tr>
<td>voltage</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SYSTEM

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>TYPICAL SPEC.</th>
<th>MIN. / MAX. SPEC.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Accuracy</td>
<td>50 ppm</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Flatness, DC to 1 Mhz</td>
<td>+/- 0.2 dB</td>
<td></td>
</tr>
<tr>
<td>1 to 15 Mhz</td>
<td>+/- 1.5 dB</td>
<td></td>
</tr>
<tr>
<td>Harmonics</td>
<td>- 40dBc</td>
<td></td>
</tr>
<tr>
<td>Spurious, Exc. Harmonics</td>
<td>- 55dBc</td>
<td></td>
</tr>
<tr>
<td>AC Output Level Range</td>
<td></td>
<td>1.25mV / 1.77V rms</td>
</tr>
<tr>
<td>AC Output Level Error</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>DC Offset Range</td>
<td></td>
<td>-10/+10 V Peak</td>
</tr>
<tr>
<td>DC Offset Error</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Residual DC Offset</td>
<td>10mV</td>
<td></td>
</tr>
<tr>
<td>Current Limit</td>
<td>80mA</td>
<td></td>
</tr>
<tr>
<td>Output Impedance</td>
<td>50 Ohms</td>
<td></td>
</tr>
<tr>
<td>Absolute Maximum Safe</td>
<td></td>
<td>+/- 15 Volts Peak</td>
</tr>
<tr>
<td>Voltage at Source Output</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### SOURCE
Appendix C: Specifications

For measurement frequencies > 11KHz. A minimum of 1.2 cycles at the source frequency are used giving a minimum time per point of 
(1.2/frequency) + 2 ms.

Ratioed measurements cancel source flatness deviations and absolute source level errors.

Using (IF) bandwidth of 10 Hz or less and 50 sweep Averages.

With an Absolute Magnitude Full Spectrum calibration as described in Chapter 3.

Specifications subject to change without notice.
APPENDIX D

File Types; Use and Format

Below is a description of the various files which are used by the Network Analyzer Windows software.

 Filename.nac
Files of extension .nac are user defined setup files. These files are created using the menu command [File|Save Setup As...].

 Filename.dat
Data files. Created with the command [File|Save Data As...] are text files of sweep data. The data is written in the following format: One line per data point, On each line are three (3) tab separated values ordered as Frequency, Left Graph units, Right Graph units. Data in this format can be easily imported into applications.

 Filename.fpl
A Frequency Points List (.fpl) file is used to define specific frequency values for a sweep. The format of this text file is described in detail below (Frequency Point List (FPL) Files).

 Filename.cal
This file is generated by a probe calibration. They are binary files and should not be edited. Creating and loading probe calibration files is accomplished through the [Tools][Calibration...] dialog box.
Frequency Point List (FPL) Files

As an alternate method of frequency sweeping, the software allows a series of frequency values, stored in a file, to be used as the data collection points. These files have the extension .fpl (Frequency Points List) and the format is as follows:

An ASCII text file with one frequency value per line. The value may be either decimal or exponential format. It is important that there are no blank lines (even at the top of the file) or extra carriage returns, also, the frequencies must increase from the top of the file on down.

The following is a valid 5 point FPL file:

100.38
103.45
1E+4
5.23E+4
800000.9654

The [File | Save Data As...] menu option can be helpful in creating FPL files. Suppose a 400 point logarithmic sweep from 1K to 100K is desired, but the sweep must include the exact value of 10500.00. This can be accomplished by performing a standard log sweep with the limits specified, then save the data to a file (creating a .dat file). By deleting all but the first column in the .dat file and changing the extension to .fpl a 400 point FPL file of the frequency values used in the logarithmic sweep is created. Now find the frequency value closest to 10500.00, +1.05826072562617E+004, and change it to 10500.00. This file can now be used to perform the required sweep.
Appendix E: Default Setup Values

APPENDIX E

Default Setup Values

Sweep

Sweep Points 100
Sweep Frequency Input Start / Stop
Sweep Start Frequency 10 Hz
Sweep Stop Frequency 15,000,000 Hz
Sweep Center Frequency 7,500,005 Hz
Sweep Span 14,999,990 Hz
Sweep Averaging Off
Sweep Averaging Factor 20
Sweep Mode Continuous
Sweep Type Linear
Sweep Dwell Auto
Sweep Dwell User Value 0 ms

Source

Source Output On
Source DC Offset (Source) 0.0 V
Source DC Offset (Fine) 0.0 V
Source Level 1.25 mV

Receiver

Receiver Coupling AC
Receiver Attenuation x1 (unaffected by default setup)
Receiver Preamp Auto
Receiver BandWidth 1 Khz
Appendix E: Default Setup Values

**Colors**

- Grid: Light Gray
- Markers: Dark Green
- Left Trace: Light Blue
- Left Master Trace: Dark Blue
- Right Trace: Light Red
- Right Master Trace: Dark Red

**Data Format**

- Mag & Phase: Frequency Eng / 2
  - Left Trace: Std / 2
  - Right Trace: Std / 2
  - Delta: Exp / 1
- Abs Mag: Frequency Eng / 2
  - Left Trace: Std / 3
  - Right Trace: Std / 3
  - Delta: Exp / 1
- Cmplx Imp: Frequency Eng / 2
  - Left Trace: Exp / 3
  - Right Trace: Exp / 3
  - Delta: Exp / 1

- Trace Display: Left & Right Trace
- Phase Format: +/- 180°
- Title: Clear

**Complex Impedance Setup**

- Reference Resistor: 1000 ohms
- Equivalent Circuit Mode: Series
- Display Mode: Impedance (Rect)
APPENDIX G

Repair and Warranty Information

Repair

If, after reviewing and implementing the diagnostic procedures in appendix F the unit is still non-operational then proceed as follows:

[1] Contact AP Instruments for further assistance and, if needed, a return authorization.

[2] Pack the instrument, including all accessories, in the original packing and shipping materials. If the original shipping materials are not available ensure that there is at least four inches of packing material surrounding the instrument and the individual components have been separately wrapped to prevent scratches during shipping.

[3] Ship the package, insured for full value, to the address obtained in the factory return authorization contact above.

Warranty

The Model 200 comes with a one year limited warranty. During the warranty period, AP Instruments will, at its option, either repair or replace the products that prove to be defective. Should AP Instruments be unable to repair or replace the product within a reasonable amount of time, a refund of the purchase price may be given upon return of the product.

Warranty Exclusions

The warranty on your Model 200 shall not apply to defects resulting from:

- Customer supplied software or interfacing.
- Damage by accident or abuse.
- Unauthorized modifications or misuse.
- Operation outside the environmental specifications of the product.
SPECIFICALLY, AP INSTRUMENTS DOES NOT EXTEND TO YOU, THE END USER, ANY EXPRESS WARRANTY OR ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS FOR USE OR FITNESS FOR ANY PARTICULAR PURPOSE IN CONNECTION WITH THE HARDWARE, SOFTWARE, OR Firmware EMBODIED IN OR USED IN CONJUNCTION WITH THIS PRODUCT EVEN IF AP INSTRUMENTS HAS BEEN ADVISED OF THAT PURPOSE.

AP INSTRUMENTS IS NOT RESPONSIBLE FOR ANY DAMAGES OR LOSS, WHETHER DIRECT INCIDENTAL OR CONSEQUENTIAL, WHICH YOU, THE END USER, MAY EXPERIENCE AS RESULT OF YOUR PURCHASE OR USE OF THE HARDWARE, SOFTWARE OR Firmware EMBODIED IN OR USED IN CONJUNCTION WITH THIS PRODUCT.

Some states do not allow limitation of implied warranties, or exclusion or limitation of incidental or consequential damages, so the above limitations may not apply to you. This warranty gives you specific legal rights. You may have other rights which may vary from state to state.
APPENDIX H

Source Fuse Replacement

The Model 200’s source is fused to protect against an excessive external current flowing into the analyzer source output stage. The lack of output from the source can be the result of a blown source protection fuse. The protection fuse is a LITTELFUSE PICO II 0.125 Amp Fast Blow part number 251.125.

The socketed fuse is located immediately behind the source output BNC connector and is accessible without removing the shields. Replacing the fuse first requires removing the source/receiver unit’s top cover. This is accomplished by first removing the front and rear panel bezels. The bezels are removed by slightly twisting the sides outward and then pulling the bezel away from the panel. The front panel’s top screws (two screws) on each side of the analyzer’s case are then removed. The rear panel’s top and bottom screws (four screws) are then removed along with the rear panel. The top cover can then be removed, exposing the socketed spare fuse located to the side of the source BNC connector.

Preventing Blown Fuses

The source protection fuse blows if the circuit under test had voltage potentials which resulted in excessive current into the source output. To prevent this from occurring it is recommended to ensure a source impedance of 20 ohms per volt of exposed voltage. For example a 300 Ohm resistor in series with the source should suffice to keep the source current below 50 mA in case of a misconnection to a +/-15v potential. Make sure the analyzer is powered up before connecting to powered circuits. Likewise, remove the analyzer connections before powering down the circuit under test.
APPENDIX I

System Calibration

Note that the probe calibration procedure, as performed by the user using the software’s Tools menu, is not a system calibration and only compensates for the effects of the probes.

To obtain accurate measurements the system should be calibrated periodically. It is recommended that system calibration be performed annually. To obtain a NIST traceable calibration the analyzer must be sent to AP Instruments. AP Instruments uses custom hardware fixtures and data logging software to verify the results of the calibration with NIST traceable quantities.