HA7701A

PHASE NOISE ANALYZER

User Manual 1.04

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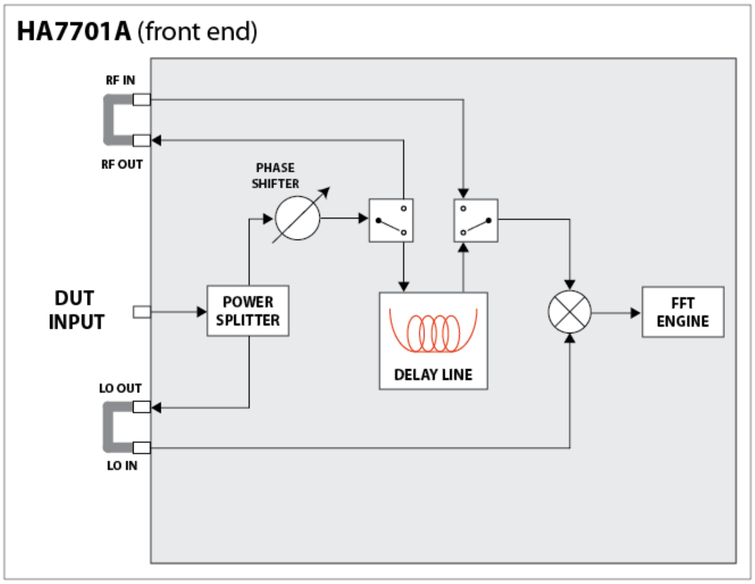
1.0 HA7701A CONFIGURATION SUMMARY

A simplified block diagram of the HA7701A internal configuration is shown below. The HA7701A was designed to accommodate two measurement modes, Absolute and Additive. The signal path is internally switched to route the signal path for the selected measurement mode.



Absolute measurements utilize a delay line discriminator to allow for measurement of less stable sources, such as free running VCO's. Additionally, the configuration allows for use of an external delay line so that users can optimize the measurement for different DUT's.

Additive measurements bypass the internal delay line and route signal to the RF output on the front panel where the DUT will be placed in the system. Care must be taken to optimize the power levels presented at the internal mixer and also to account for phase shift caused by the DUT or lengths of RF cable that are used in the measurement setup.

2.0 PERFORMANCE SUMMARY

The HA7701A is designed for high speed and precise phase noise measurements. The specifications outlined here capture the baseline performance and features that are currently available from the HA7701A phase noise analyzer.

2.1 DUT INPUT (RF SIGNAL INPUT FOR ADDITIVE MODE)

DESCRIPTION	SPECIFICATION
DUT Input Connector	SMA (female), 50 ohm
DUT Input Frequency Range	2GHz to 20GHz
DUT Input Power Level	+17 dBm to +24 dBm (frequency dependent , refer to section **2.4**)

2.2 SUPPLY & TUNE VOLTAGE

DESCRIPTION	SPECIFICATION
DUT Tune Voltage **Voltage Tune Range** **Max Current**	For Vcc control of some DUTs 0V to +20V 5mA
DUT Power Supply **Voltage Supply Range** **Maximum Current**	Integrated power supply 0V to +12V 500mA

2.3 PHASE NOISE MEASUREMENTS

DESCRIPTION	SPECIFICATION
Carrier Frequency Range	2GHz to 20GHz
Measurement Parameters	SSB Phase Noise
Offset Frequency Range	1 Hz – 40 MHz (Settable to 0.1Hz Offset)
Absolute Measurement	VCO/RF Source measurement. Use internal or external delay line
Additive Measurement	Multi-port device measurement (amplifier, downconverter, etc.)
Spurious Analysis	Provides spurious performance data based on a user settable Spur Threshold

2.4 INPUT DAMAGE THRESHOLD

The HA7701A internal mixer (phase detector) will be the point of failure due to excessive RF power.

DESCRIPTION	SPECIFICATION
Phase Detector Damage Level	+23dBm @ 25C (derated linearly to +20dBm @ 100C)

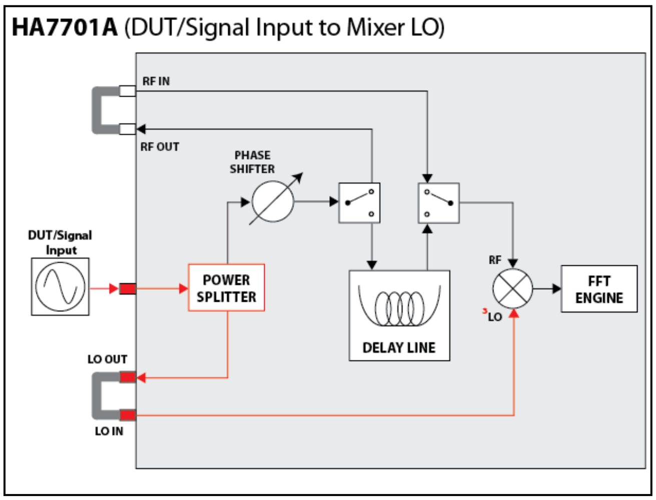
The following section's insertion loss data should be used to set power levels for measurements and ensure that the internal phase detector is not damaged due to excessive RF power.

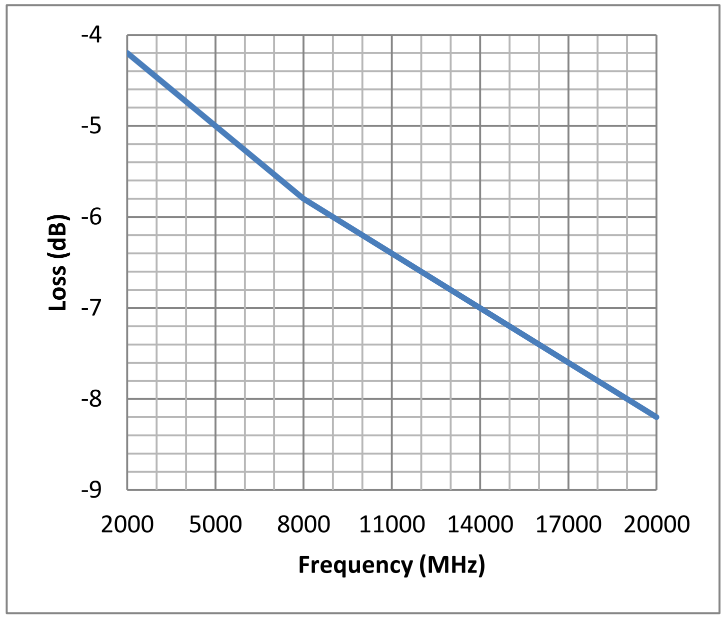
2.5 INSERTION LOSS DATA

Data in this section outlines the insertion loss through the signal pathways internal to the instrument. Driving the internal mixer (phase detector) with appropriate power levels is essential to both Absolute and Additive phase noise measurement modes.

2.5.1 LO Insertion Loss *(DUT/Signal Input to Internal Mixer LO port)*

- Internal Mixer LO Drive Level: +10 to +16 dBm

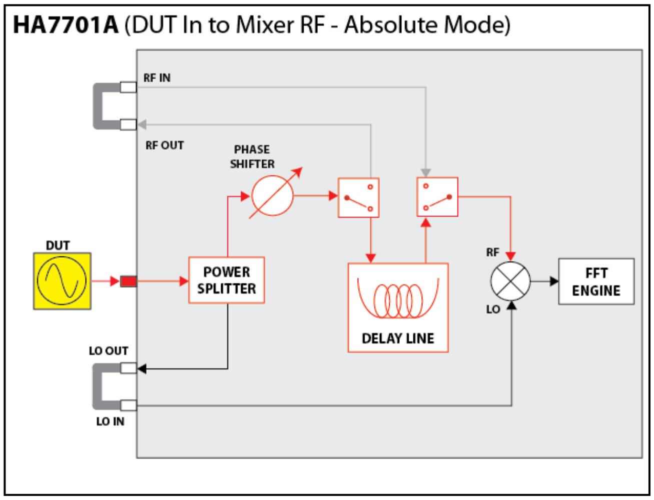


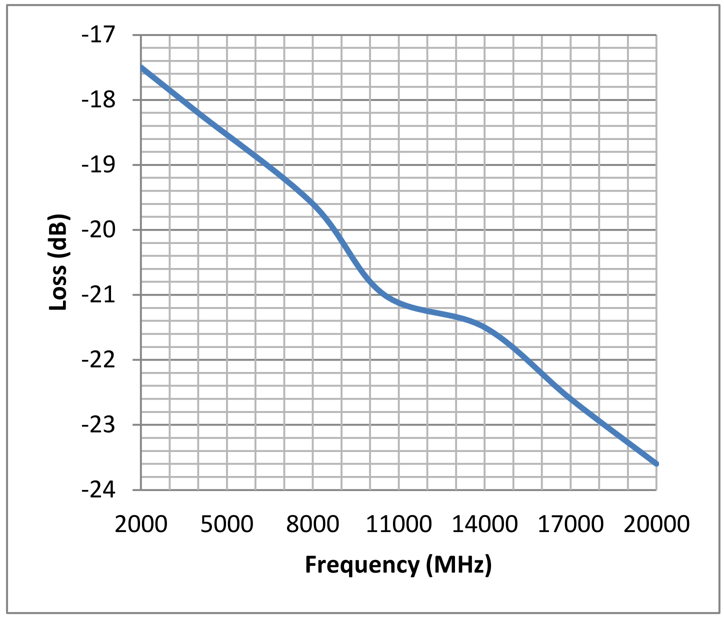


NOTE: The loss through this path is shown as measured with the supplied copper jumper cable installed connecting LO OUT to LO IN.

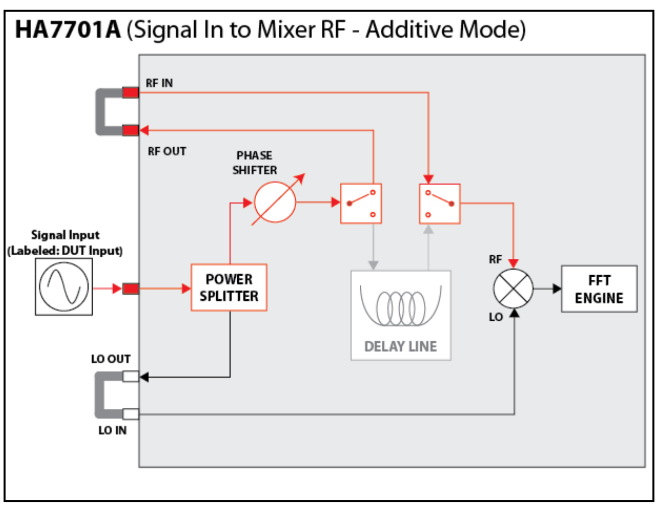
2.5.2 RF Insertion Loss - Absolute Mode *(DUT Input to Internal Mixer RF port)*

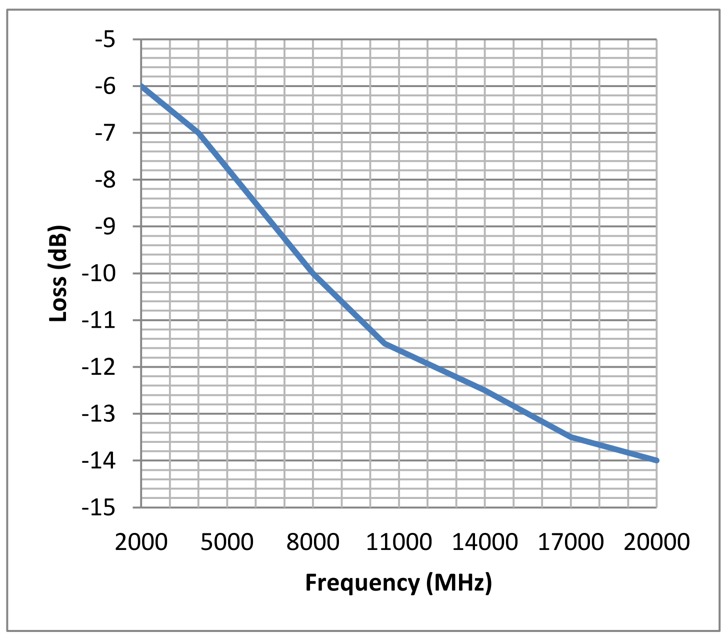
The data below represents the insertion loss in Absolute (Delay Line) measurement mode with the HA7701A internal delay line.





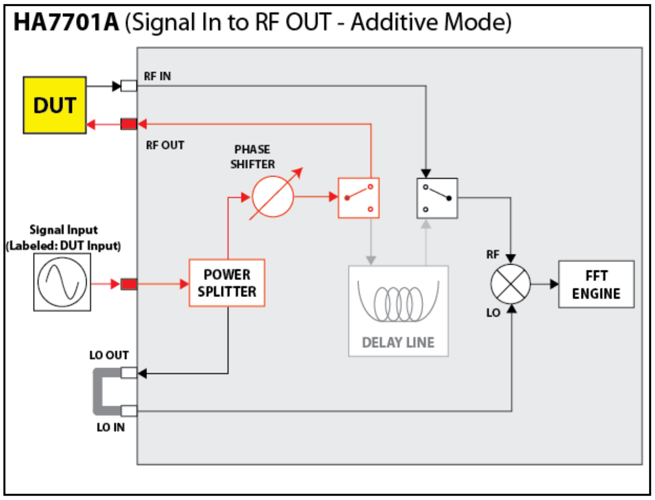
2.5.3 RF Insertion Loss - Additive Mode *(Signal Input to RF Mixer)*

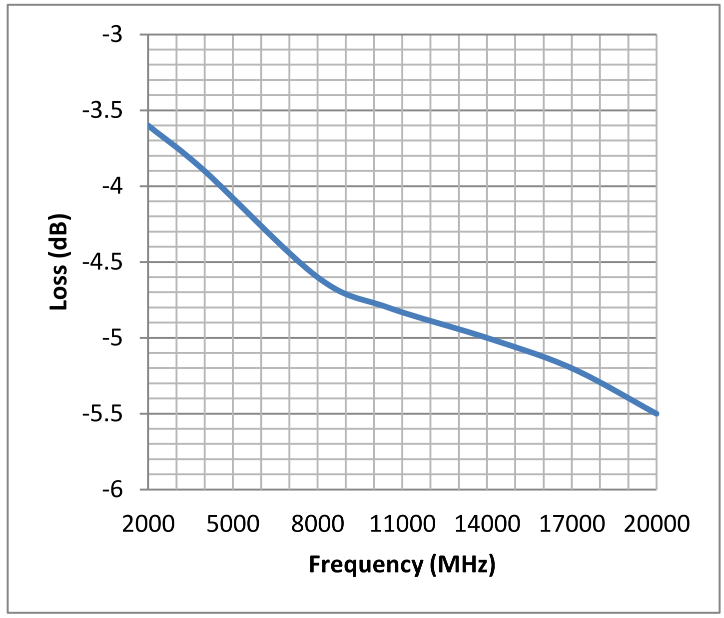




NOTE: The loss through this path is shown as measured with the supplied copper jumper cable connecting RF OUT to RF IN.

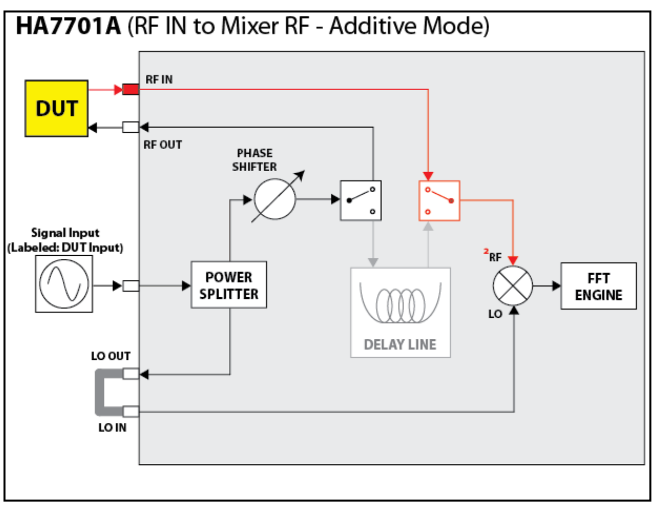
2.5.4 RF Insertion Loss - Additive Mode *(Signal Input to RF Output)*

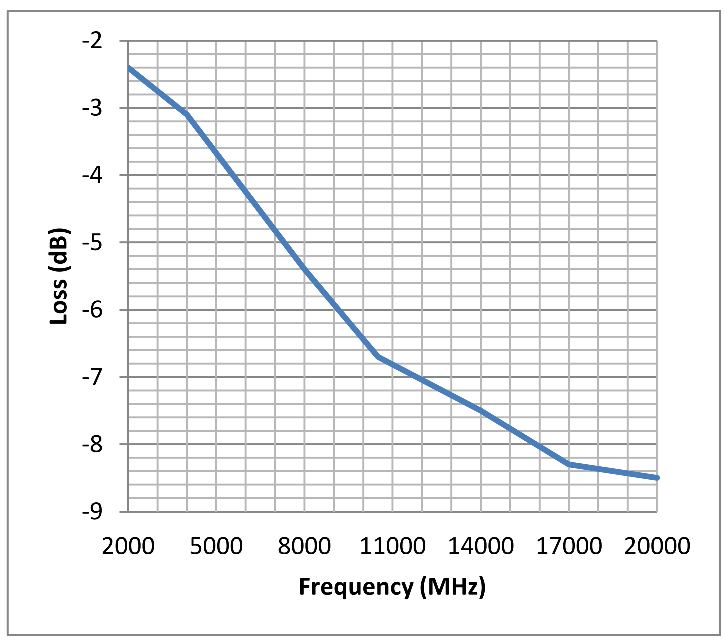




NOTE: Account for the loss in this path to ensure an appropriate input power level is set for the DUT.

2.5.5 RF Insertion Loss - Additive Mode *(RF IN to Mixer RF)*



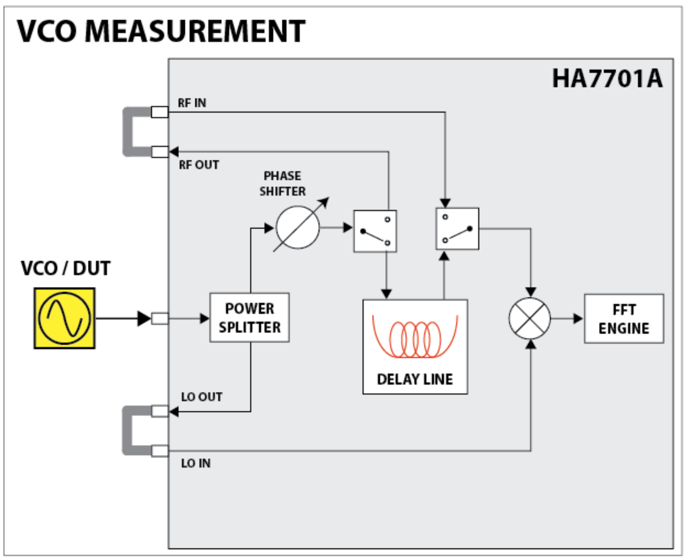


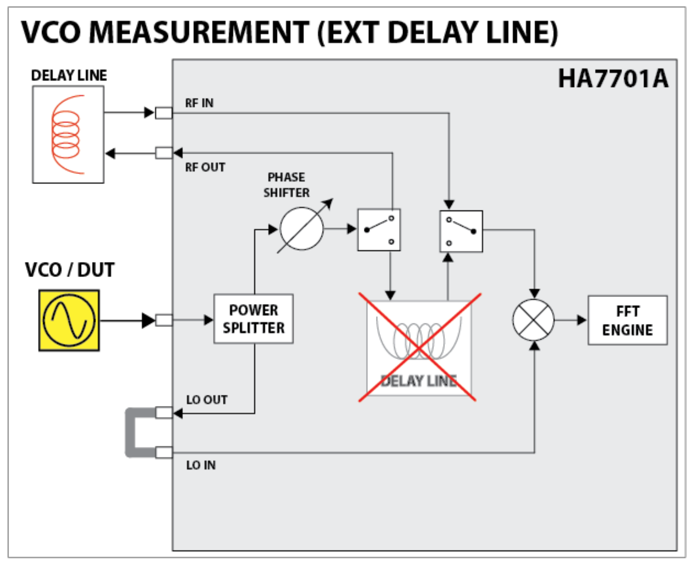
2.6 ABSOLUTE MEASUREMENT SENSITIVITY

Absolute measurement sensitivity is inherently affected by delay line length. Sensitivity can be optimized for different DUT's by using an external delay line. This section will demonstrate the effect of the delay line on the measurement sensitivity and useful offset frequency.

Consider the measurement offset frequency range of concern for the DUT when determining whether an external delay line is necessary. As delay line length increases, performance is increased at lower offset frequencies, however the maximum useful offset frequency is reduced. The opposite is also true: as delay line length decreases the performance is decreased at lower offsets, however performance at higher offset frequencies is increased. The following measurement illustrates the affect of different delay line lengths on Absolute phase noise measurements.

The example measurements uses an ultra low phase noise Holzworth HSM synthesizer as the DUT. The hardware configurations are shown in the block diagrams below.



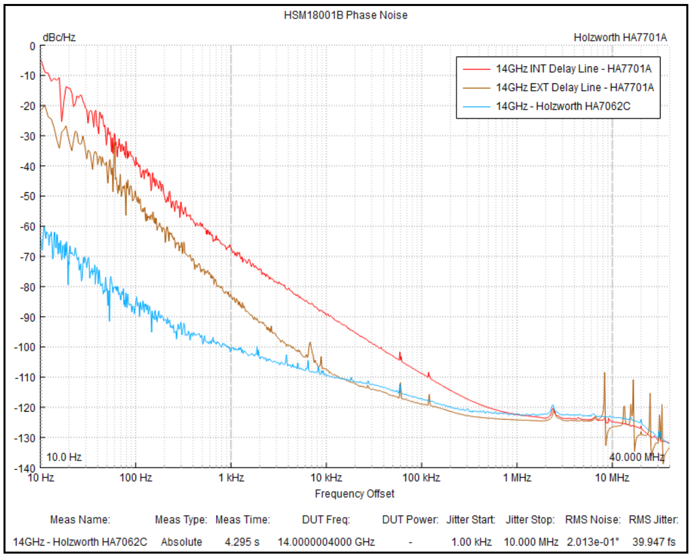


Measurement details and results begin on next page...

Measurement Details:

DUT Information	
DUT	Holzworth HSM18001B Synthesizer
Frequency	14GHz
Power	+20dBm

Measurement Results**:**



14GHz INT Delay Line - HA7701A	DUT Info	Marker Freq	Value [dBc/Hz]
S/N: HA7701A-002	Freq: 14.000 GHz	100.0 Hz	-38.01
Type: Absolute	Power: ---	1.00 kHz	-67.17
Date: 2018-02-23	Gain: 42 dB	10.00 kHz	-89.46
Time: 11:24:54	Acq: 3.221 s	100.00 kHz	-108.82
Temp: 0°C	Offset: 10.0 Hz	1.000 MHz	-122.44
Limit Test: None	# Correlations: 3	10.000 MHz	-124.80

14GHz EXT Delay Line - HA7701A	DUT Info	Marker Freq	Value [dBc/Hz]
S/N: HA7701A-002	Freq: 14.000 GHz	100.0 Hz	-49.15
Type: Absolute	Power: ---	1.00 kHz	-82.89
Date: 2018-02-23	Gain: 42 dB	10.00 kHz	-107.36
Time: 12:18:57	Acq: 3.221 s	100.00 kHz	-118.93
Temp: 0°C	Offset: 10.0 Hz	1.000 MHz	-124.20
Limit Test: None	# Correlations: 3	10.000 MHz	-126.60

14GHz - Holzworth HA7062C	DUT Info	Marker Freq	Value [dBc/Hz]
S/N: HA7062C-070	Freq: 14.000 GHz	100.0 Hz	-85.65
Type: Absolute	Power: ---	1.00 kHz	-101.26
Date: 2018-02-12	Gain: 42 dB	10.00 kHz	-109.63
Time: 12:47:18	Acq: 3.221 s	100.00 kHz	-117.24
Temp: 43.86°C	Offset: 10.0 Hz	1.000 MHz	-122.11
Limit Test: None	# Correlations: 1	10.000 MHz	-123.33

- **14GHz - Holzworth HA7062C (blue trace):** Used as a reference, this trace shows the HSM18001B phase noise as measured with the Holzworth HA7062C Phase Noise Analyzer, which uses the 'PLL Method' and thus requires the DUT be relatively stable for phase locking. The PLL method is ideal for lower noise DUT's and measurements across a very wide frequency offset range, but it cannot measure sources that tend to be noisier. Without the limitation of a delay line the HA7062C is able to measure the HSM18001B phase noise across the entire 10Hz - 40MHz offset range and provide a baseline for this demonstration.

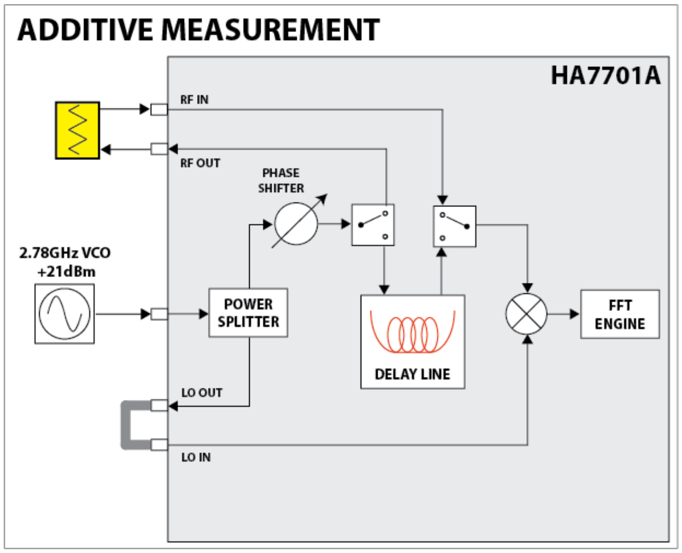
- **14GHz INT Delay Line - HA7701A (red trace):** With the internal delay line in use (T = 19.5ns), the HA7701A was able to measure the HSM18001B phase noise at approximately 1MHz offset and beyond. At < 1MHz offset the delay line limits the measurement sensitivity.

- **14GHz EXT Delay Line - HA7701A (orange trace):** With an external delay line now in use (T = ~120ns), it can be seen that the measurement sensitivity improved by approximately 10-20dB depending on offset frequency, however the first measurement null can now be seen at ~10MHz offset.

Longer Delay Lines	Shorter Delay Lines
• Greater sensitivity at lower offset freq's	• Reduced sensitivity at lower offset freq's
• Lower useful measurement offset freq	• Higher useful measurement offset freq

2.7 ADDITIVE MEASUREMENT SENSITIVITY

Additive measurement sensitivity (noise floor) is affected by the power levels achieved at HA7701A internal mixer. Careful approach is required to ensure suitable measurement sensitivity for the DUT. This can be demonstrated with the hardware configuration below.



The following measurements used an amplified 2.78GHz VCO as a source and show the change in sensitivity for different LO drive levels, and as the attenuator in the RF path is varied.

Initially +21dBm was driven into the DUT Input port in order to achieve +16dBm at the mixer LO port. From there the power was adjusted in order to show the effect of LO drive level on measurement sensitivity. Attenuation was also varied in the RF path to completely illustrate the effect of signal power on phase detector sensitivity.

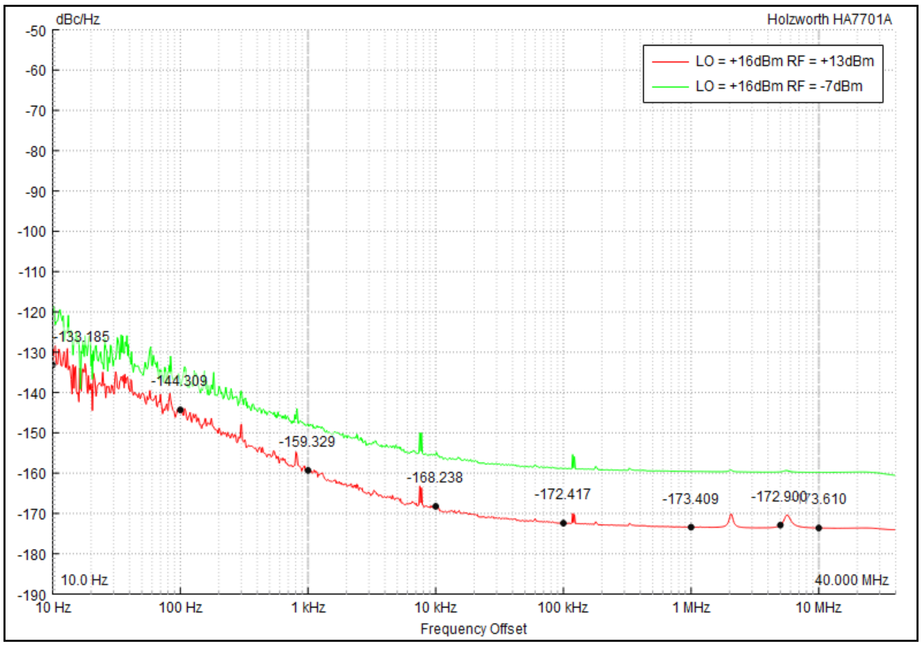
Measurement details and results begin on next page...

2.7.1 Additive Measurement Sensitivity (+16dBm LO Power)

Measurement details:

Measurement Statistics	
DUT	ZCOMM VCO
Frequency	2.78GHz
DUT Pwr	+21dBm
LO Pwr	+16dBm
RF Pwr	+13dBm (no attenuation) -7dBm (20dB attenuation)

Measurement results:



LO = +16dBm RF = +13dBm

Marker Freq	Value [dBc/Hz]
1.0 Hz	-124.69
10.0 Hz	-133.66
100.0 Hz	-145.35
1.00 kHz	-158.84
10.00 kHz	-168.34
100.00 kHz	-172.18
1.000 MHz	-173.25
10.000 MHz	-173.55

LO = +16dBm RF = -7dBm

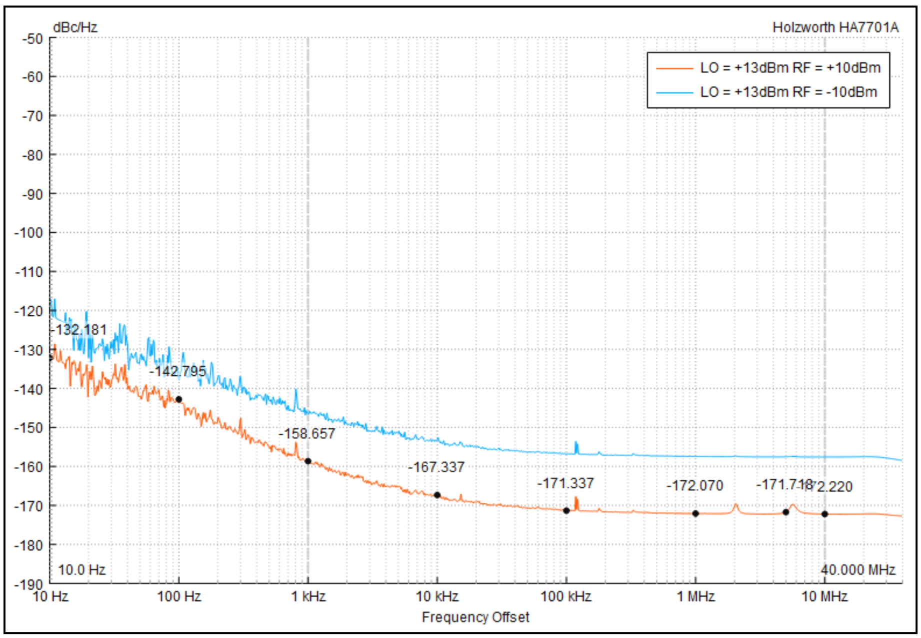
Marker Freq	Value [dBc/Hz]
1.0 Hz	-120.80
10.0 Hz	-124.66
100.0 Hz	-136.80
1.00 kHz	-147.67
10.00 kHz	-155.39
100.00 kHz	-158.64
1.000 MHz	-159.51
10.000 MHz	-159.81

2.7.2 Additive Measurement Sensitivity (+13dBm LO Power)

<u>Measurement details:</u>

Measurement Statistics	
DUT	ZCOMM VCO
Frequency	2.78GHz
DUT Pwr	+18dBm
LO Pwr	+13dBm
RF Pwr	+10dBm (no attenuation) -10dBm (20dB attenuation)

<u>Measurement results:</u>



LO = +13dBm RF = +10dBm

Marker Freq	Value [dBc/Hz]
1.0 Hz	-124.80
10.0 Hz	-133.57
100.0 Hz	-144.95
1.00 kHz	-158.18
10.00 kHz	-167.32
100.00 kHz	-171.00
1.000 MHz	-171.97
10.000 MHz	-172.17

LO = +13dBm RF = -10dBm

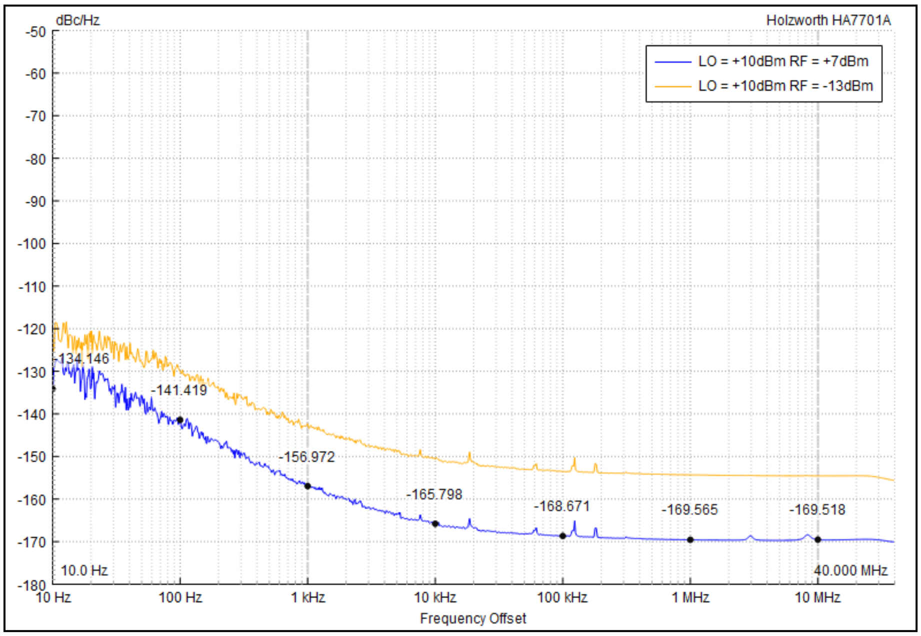
Marker Freq	Value [dBc/Hz]
1.0 Hz	-119.16
10.0 Hz	-121.28
100.0 Hz	-134.39
1.00 kHz	-145.59
10.00 kHz	-153.22
100.00 kHz	-156.49
1.000 MHz	-157.38
10.000 MHz	-157.62

2.7.3 Additive Measurement Sensitivity (+10dBm LO Power)

Measurement details:

Measurement Statistics	
DUT	ZCOMM VCO
Frequency	2.78GHz
DUT Pwr	+15dBm
LO Pwr	+10dBm
RF Pwr	+7dBm (no attenuation) -13dBm (20dB attenuation)

Measurement results:



LO = +10dBm RF = +7dBm

Marker Freq	Value [dBc/Hz]
1.0 Hz	-117.11
10.0 Hz	-134.15
100.0 Hz	-141.42
1.00 kHz	-156.97
10.00 kHz	-165.80
100.00 kHz	-168.67
1.000 MHz	-169.56
10.000 MHz	-169.52

LO = +10dBm RF = -13dBm

Marker Freq	Value [dBc/Hz]
1.0 Hz	-108.30
10.0 Hz	-120.68
100.0 Hz	-130.05
1.00 kHz	-142.38
10.00 kHz	-150.68
100.00 kHz	-153.53
1.000 MHz	-154.33
10.000 MHz	-154.56

3.0 PHASE NOISE ANALYZER INSTALLATION

This section outlines the basic requirements and procedures for the HA7701A Phase Noise Analyzer hardware and software installation.

The hardware purchase includes a C++ compiled GUI for hardware operation and viewing/saving data.

The HolzworthPNA software application is included on the thumb drive that ships with the HA7701A. If the thumb drive is missing another can be mailed or the software can be downloaded after contacting Holzworth support via email at: support@holzworth.com or by phone at +1.303.325.3473 (option 2).

The HA7701A performs all data processing internally. Measurement settings can be changed using serial commands sent to the HA7701A using any of the included communication options. Alternatively, measurement results can be read from the instrument directly without requiring a specific operating system. This capability provides unparalleled operational flexibility.

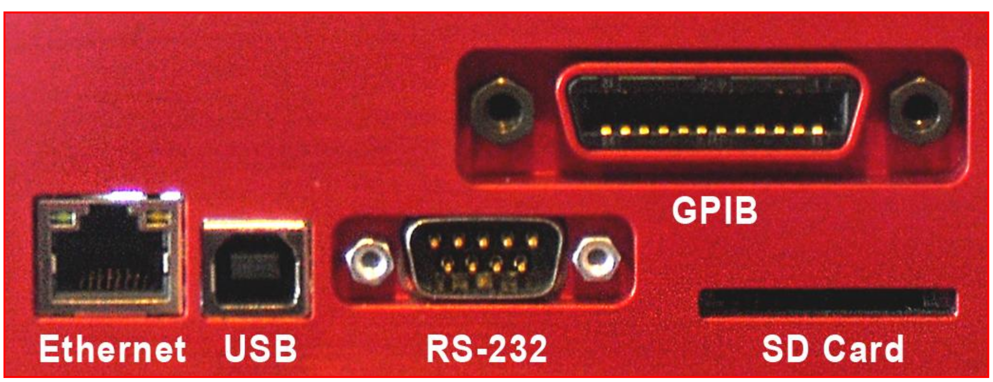
3.1 HARDWARE INSTALLATION

Prior to initializing the analyzer, connect the standard AC power cable between an AC outlet and the rear panel AC inlet. The instrument is shipped with the appropriate power cord for the final destination country/region.

The master power switch located at the right side of the front panel is equipped with a blue indicator light which illuminates when the DC power is active.

3.2 INSTRUMENT COMMUNICATION

The HA7701A comes with USB, Ethernet, RS-232 and GPIB communication standard. All communication ports are accessible from the rear panel of the instrument.

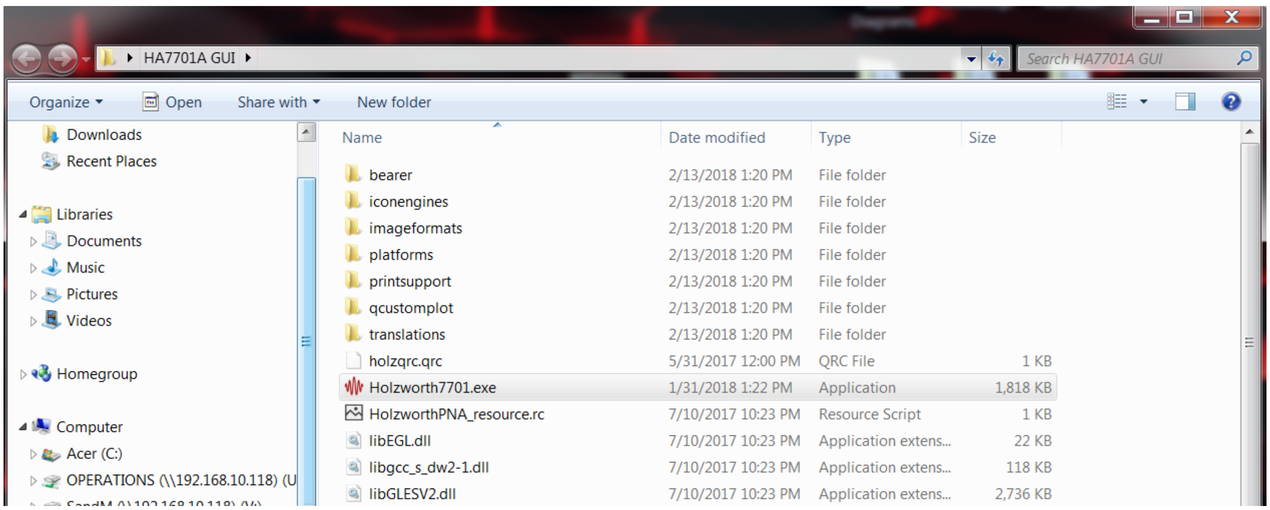


HA7701A Communication Ports

4.0 HOLZWORTH PNA SOFTWARE APPLICATION

NOTE: The HA7701A application GUI does not require any driver installation. Simply run the Holzworth7701 executable file to launch the software.

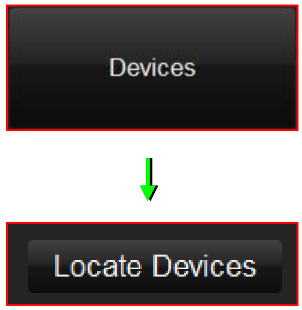
Analyzer GUI Application Folder



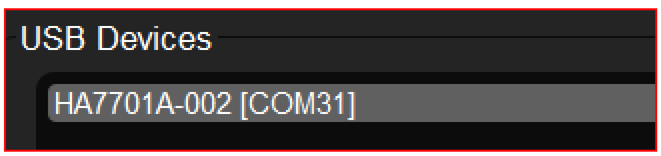
4.1 USB, RS-232, AND GPIB COMMUNICATION

With the HA7701A USB and RS-232 communication are handled similarly in Windows. USB communication requires FTDI drivers. Windows should install these drivers automatically when the instrument is connected to the computer via USB. If the instrument is not recognized, Windows may need to install updated USB drivers. These are also included on the thumb drive that ships with the instrument.

Click the **Devices** button on the right side of the GUI, followed by the **Locate Devices** button in the menu:



The software will then scan for instruments connected via Ethernet and via serial port. It will display serial port devices as shown below:



Identify your instrument by either serial # or COM port and select it. If the connection is successful the window above 'Devices' will turn blue to indicate a USB connection, and it will display the instrument serial number:

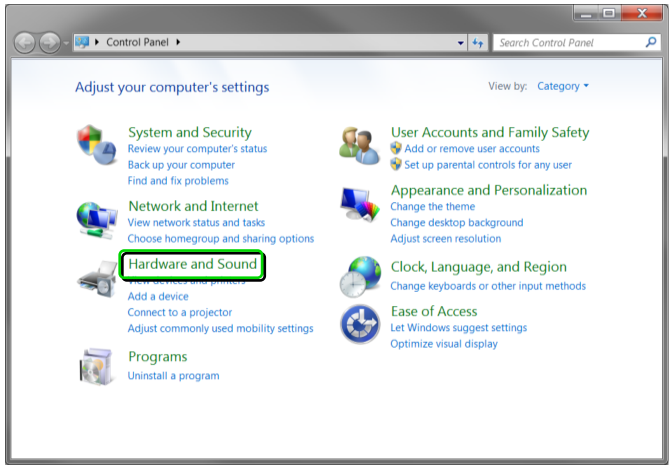
4.1.1 GPIB COMMUNICATION

Appendix C contains ASCII commands that can be used to configure the HA7701A GPIB settings.

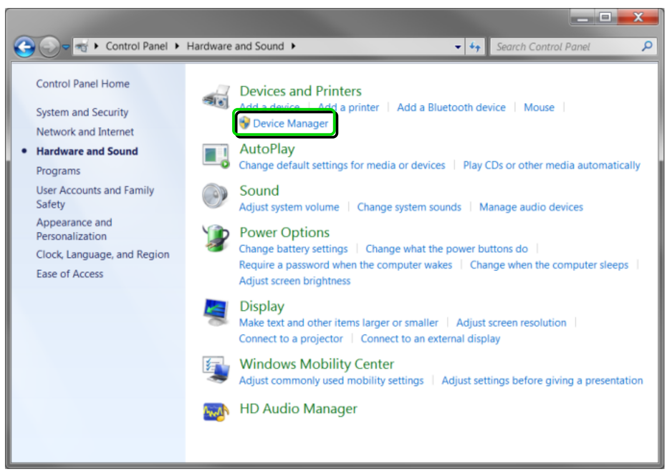
4.1.2 DETERMINING INSTRUMENT VIRTUAL COM PORT

The COM port associated with the USB connection to the HA7701A can be manually located using the Windows Device Manager. Steps to do this are as follows.

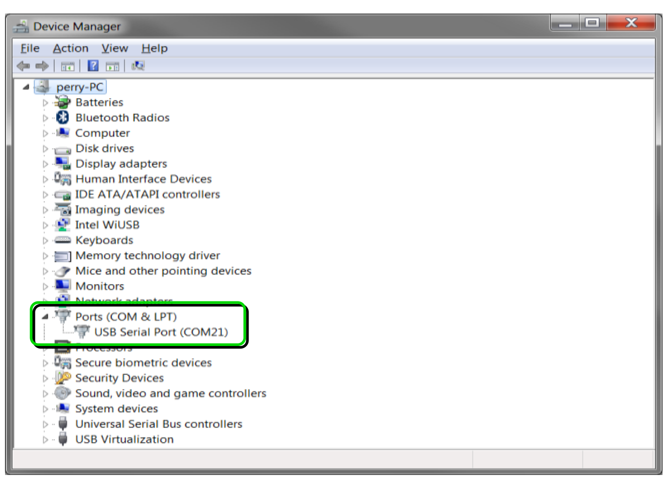
STEP ONE
Open the Windows Control panel from the start menu. Click on "Hardware and Sound"



STEP TWO
Under "Devices and Printers," select **Device Manager**



STEP THREE
Under Ports (COM & LPT) locate COM port associated with the HA7701A (identified as "USB Serial Port")



4.2 ETHERNET COMMUNICATION

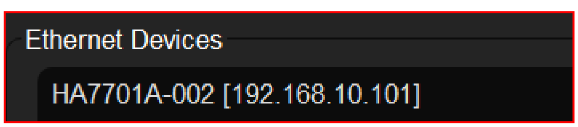
Ethernet communication can be established with the HA7701A by connecting the instrument to a local area network or directly to a PC. Locating the instrument is handled differently depending on the method of connection and DHCP settings that have been assigned. By default, the HA7701A is set to utilize DHCP when connected over a network. A TCP/IP socket is always opened using **port 9760**.

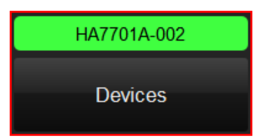
4.2.1 LAN CONNECTION

Communication with the HA7701A over a LAN connection defaults to the use of DHCP. If connected to a network with no DHCP server the HA7701A will default to the IP address of 169.254.117.11 and the instrument will need to be assigned an appropriate static IP address for the network. This default DHCP address can be used with the Console window or the Holzworth Ethernet Finder software to assign static network settings to the instrument.

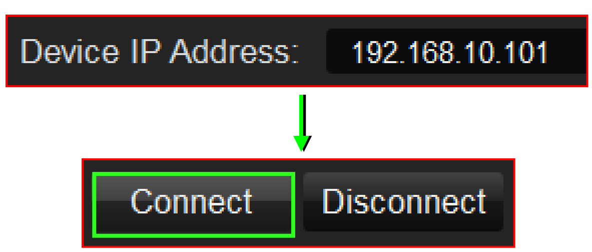
To search for devices, click the **Devices** button and then click **Locate Devices** in the sub-menu.

The software will then scan for instruments connected via Ethernet by sending out a UDP broadcast via port 30303. It will display detected Ethernet devices as shown below. Identify the instrument by either serial # or IP address and select it. If the connection is successful the window above 'Devices' will turn green (Ethernet) and display the instrument serial number:





Users can also enter the instruments IP address manually to connect. Enter the IP address into the 'Device IP Address' field and then press the **Connect** button.



4.2.2 DIRECT PC CONNECTION (DHCP)

When the HA7701A is connected directly to a PC and it is set to DHCP, the instrument's default IP address is:

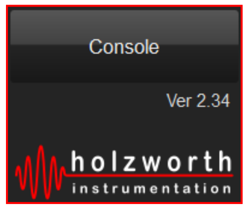
169.254.117.11

4.2.3 ASSIGNING A STATIC IP ADDRESS

Assigning a static IP address can be done using the Console window in the GUI to send the ASCII commands from Appendix B. Users can also use Holzworth Ethernet Finder.

1. Use the GUI to establish a USB connection or an Ethernet with the default DHCP address above.

2. Launch the **Console** window using the button at the bottom right of the GUI. The **Console** can be used to send ASCII commands to change static network settings or change from static mode to DHCP and vice versa.



4. Refer to Appendix B for Ethernet configuration commands. Type commands into the text field and then press Enter or click Send to send a command.

5. Begin by querying with the :IP:STATUS? command. Change status and/or re-configure the static network settings as necessary.

6. Power cycle the HA7701A if prompted. Any status change from DHCP to Static or vice versa will require a power cycle.

NOTE: If the instrument static IP address is unknown use a USB connection to reset to DHCP.

The Holzworth Ethernet Finder Tool can be used to assign a static IP address to the instrument. Instructions to do so are as follows. Email Holzworth support (support@holzworth.com) for a link to download the Holzworth Ethernet Finder GUI.

To assign a static IP address, launch the EthernetFinder.jar file. Click Locate Device and select your instrument by its serial number, then select the 'Static IP' radio button, enter the static IP settings, and press Save.

4.3 GUI OVERVIEW

The reference numbers on the dashboard image correspond with the descriptions contained on the following page.

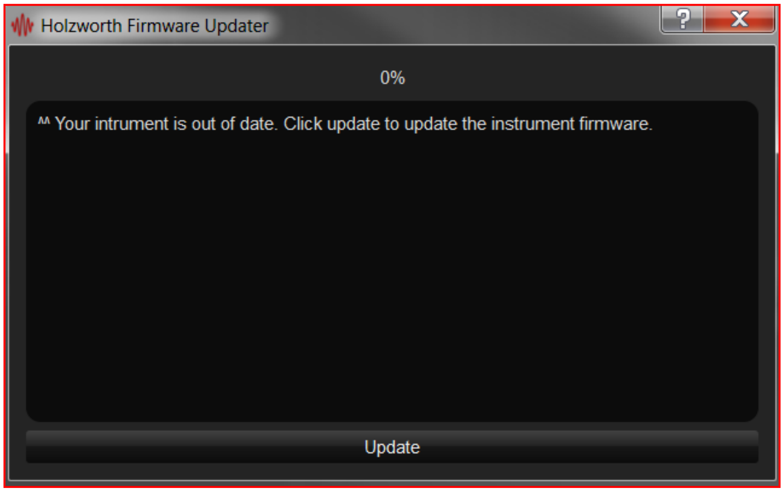
GUI OVERVIEW

1. **File/Tools/System:** The '*File*' menu allows users to save/load data, export plots, and generate reports. The report generator captures the current plot and any measurement statistics. '*Tools'* provides access to a DC Monitor which can be used to check quadrature at the internal mixer. '*System*' allows the user to create instrument setting presets (saving time for commonly used measurement setups), view/save measurement debug files, and perform firmware updates.
2. **Acquire / +:** The '*Acquire'* button initiates a phase noise measurement. When the *'+'* button is depressed, selecting *'Acquire'* will overlay new measurements to the measured data already captured in the plot area.
3. **Devices: '***Devices'* allows the user to view any HA7701A analyzer directly connected to the PC (USB or Ethernet) or over a LAN connection. Select the device by part number & serial number to establish a connection. The window located above *'Select Device'* will turn green (Ethernet) or blue (USB) once a successful connection is made.
4. **Measurement:** Users can change settings such as measurement type, offset, jitter analysis range, and # of correlations.
5. **Inputs:** Users must manually enter the DUT Frequency, and may select to use an external delay line.
6. **Outputs:** The '*Outputs'* button provides access to user controlled outputs which include the DUT Power Supply and Tune Voltage.
7. **Trace/Calcs:** Users can apply smoothing and spur removal functions to a data trace.
8. **Limits:** Apply test limit lines under pass/fail conditions to the plot area.
9. **Markers:** Allows the user to adjust the positioning of markers on a trace.
10. **Display:** Allows the user to modify the plot area. Users can edit the x/y axis max/min, plot title, x/y axis titles, trace names, plot export options, *etc.*
11. **Console:** The Console displays a log of instrument/measurement activity while also allowing the user to send ASCII commands directly to the instrument.
12. **Data Plot Area:** Displays acquired data: Absolute or Additive phase noise and spurious
13. **Status Indicator:** The Holzworth logo shockwave doubles as a status bar/indicator while measurements are in progress. Measurement time remaining is also shown above the shockwave.
14. **Measurement Statistics:** Displays statistics of the current measurement or currently selected trace.

4.4 FIRMWARE UPDATES

NOTE: Internet connection required to check for firmware updates. It is also recommended to use a desktop computer for firmware updates. If a laptop is used it is recommended that power be plugged in to the laptop.

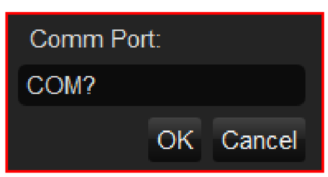
First establish a USB connection as shown in section **4.1.** After the connection has been made users can check for firmware updates by clicking **System** followed by **Update Firmware.** The firmware update window shown below will then open and determine whether or not an update is needed.



Click 'Update' if prompted that firmware is out of date, otherwise close the window.

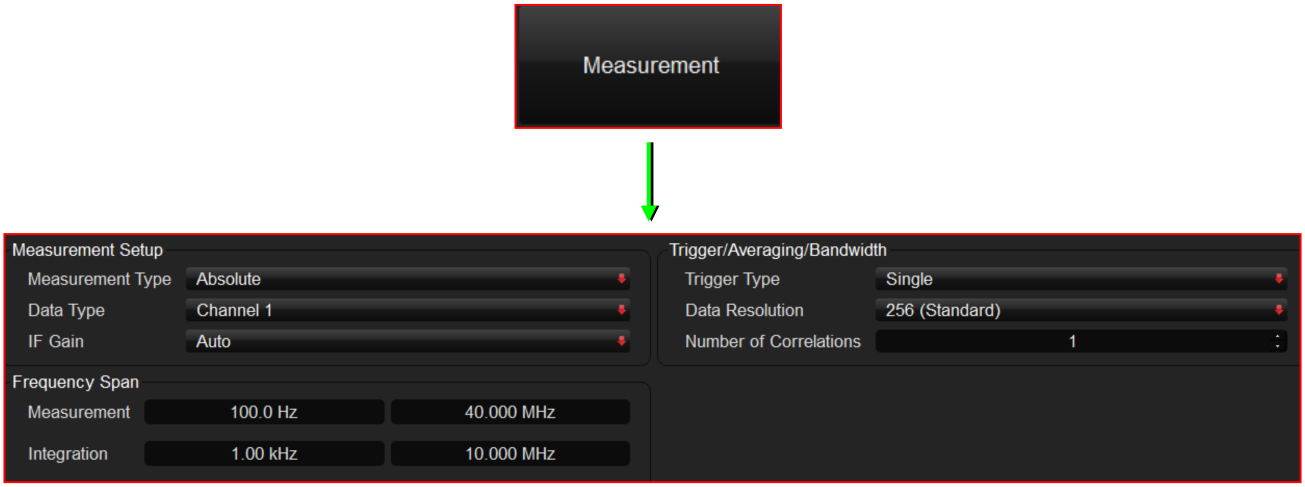
DO NOT turn off the instrument or break the USB connection while an update is in progress. Close the window when the update is complete.

If the Firmware Updater is opened without establishing a USB connection with the software, it will prompt you to enter the COM Port in use by the instrument in order to connect (as shown below). See section **4.1.2** to determine which COM port is in use.



4.5 MEASUREMENT

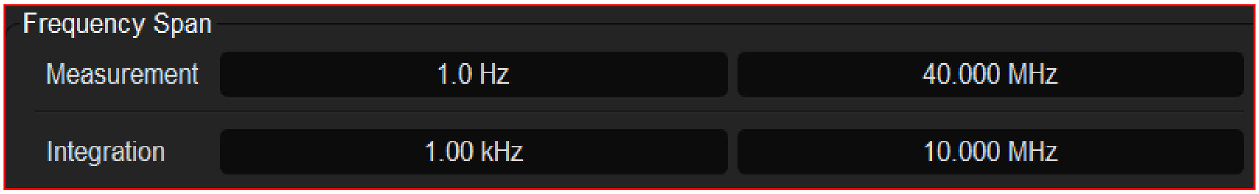
The **Measurement** menu provides access to measurement settings including frequency offset range, number of correlations, as well as the option to enable infinite correlations/averages (Persist) or a 'n' number of correlation/average measurement repeated indefinitely (Continuous).



4.5.1 MEASUREMENT SETUP

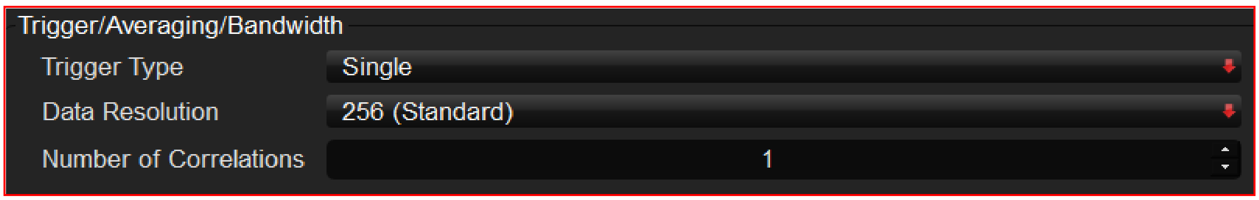
- **Measurement Type:** Set for Absolute or Additive.
- **Data Type:** Channel 1 (single channel measurement mode only).
- **IF Gain:** Can be adjusted to optimize the phase noise measurement. Factory default is *Auto*. Adjusting the gain setting is an advanced user control and Holzworth Support should be consulted for proper operation of the instrument with this setting.

4.5.2 FREQUENCY SPAN (OFFSET ADJUSTMENT)



- **Measurement:** Adjust the frequency offset start/stop of the measurement. Minimum start frequency is 0.1Hz, Maximum stop frequency is 40MHz.
- **Integration:** Adjust the integration range for calculating RMS Noise and RMS Jitter. Calculation results are displayed with other measurement stats below the plot area.

4.5.3 TRIGGER/AVERAGING/BANDWIDTH



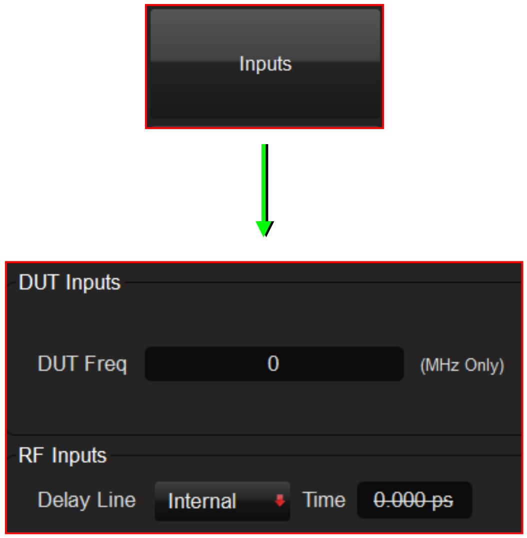
- **Trigger Type**
  - **Single:** The instrument will perform the set number of correlations and display data in the plot area when finished.
  - **Single (Display Each):** The instrument will perform the set number of correlations and update the plot area after each correlation.
  - **Continuous:** Continuously monitor phase noise for a given # of correlations/averages until user cancels the measurement (e.g. if correlations are set to 1, the instrument will repeat a measurement of 1 correlation/average indefinitely).
  - **Persist:** Increment correlations/averages indefinitely, until user cancels the measurement. Data will be available after each successive set number of correlations are completed.

- **Data resolution:** Sets the data resolution for the measurement. Can be set to 64, 128, 256, 512, or 1024.

- **Number of Correlations (Averages):** Sets the number of correlations/averages to be performed by the instrument.

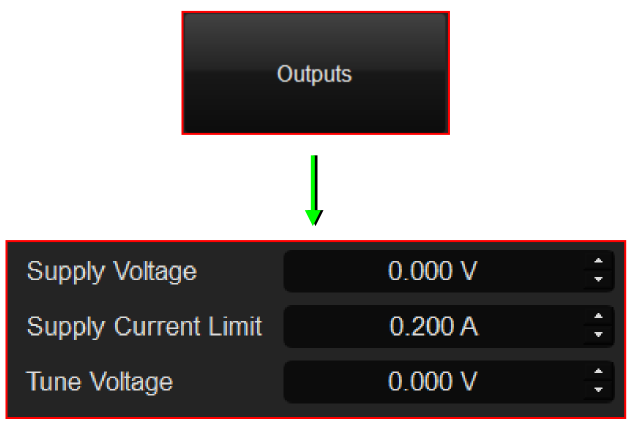
4.6 INPUTS

Use the **Inputs** menu to enter the DUT frequency (in MHz) and, if necessary, select for external Delay Line and enter the delay value of the external delay line.



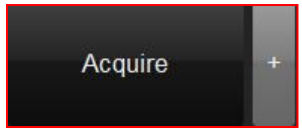
4.7 OUTPUTS

The **Outputs** button provides the user access to user adjustable Supply Voltage and Tune Voltage outputs at the HA7701A front panel.



- **Supply Voltage:** Adjustable from 0Vdc to 12Vdc
- **Supply Current Limit:** 500mA max current
- **Tune Voltage:** Adjustable from 0Vdc to 20Vdc (tune only, 5mA max current)

4.8 ACQUIRING DATA



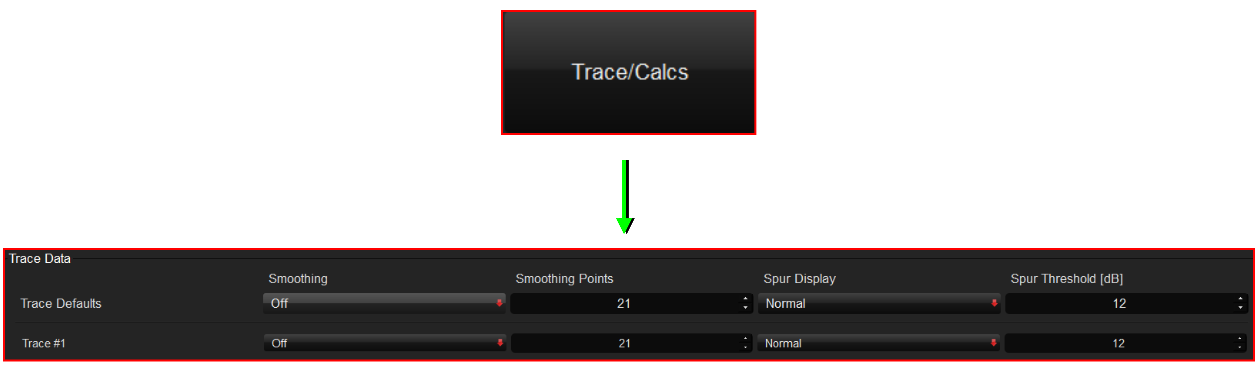
Once the test hardware is setup, and all necessary Measurement, Inputs, and Outputs menu parameters have been verified, users can initialize a measurement by clicking the Acquire button.

- **Acquire/+:** When the *'+'* button is depressed, selecting *'Acquire'* will overlay new measurements to the measured data already captured in the plot area. When the + button is not depressed, all traces will be cleared from the plot area when Acquire is pressed, and a single new measurement will be displayed.

- **Measurement Progress Bar/Time Remaining**: When a measurement is in progress, The Holzworth 'Shockwave' serves as a progress bar and the time remaining is also displayed as shown below.

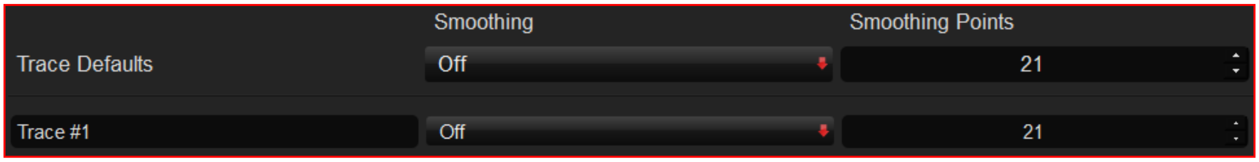
4.9 TRACE/CALCS

Trace/Calcs allows the user to apply a smoothing function to a trace in the plot area, and also apply spur removal or spur scaling to dBc or dBc/Hz (default).



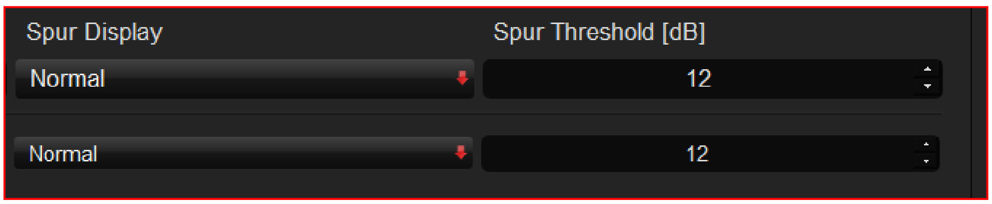
- **Note:** There are default smoothing and spur display settings for each acquired trace. By default, smoothing is set to off and Spur Display is set to Normal. The default settings will apply to every acquired trace.

4.9.1 SMOOTHING



- **Smoothing:** A *Smoothing* function can be applied to the data that applies a number of points (N) as a sliding-average algorithm to compute the smoothing curve. The user enters an odd value for the number of Points. If an even number is entered, the application will round up to the next odd number to apply the curve.

4.9.2 SPUR DISPLAY



- **Spur Threshold:** The spur threshold is relative to the smoothed trace and therefore affected by the # of smoothing points set. Even if *Smoothing* is not enabled the smoothed trace is computed in the background in order to be used as the reference for the Spur Threshold. Spurs greater than the threshold are recorded.

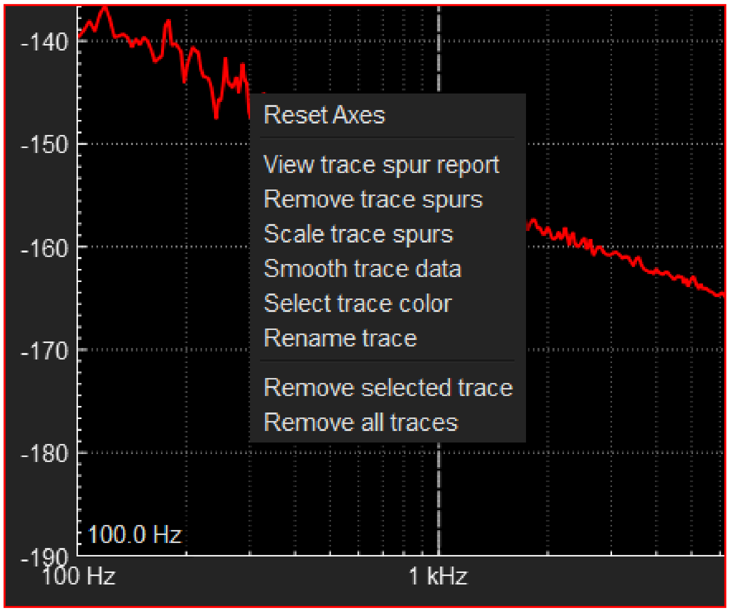
- **Spur Display:**
  - **Normal**: Spurs on trace in dBc/Hz. Data displayed is completely raw, no spurs are removed.
  - **Remove:** Remove any spurs from the trace that are greater than the spur threshold.
  - **Scale to dBc:** Calculates the spurs dBc value and corrects spur amplitude on the trace.

Note: When spurs are set to **Remove** or **Scale to dBc** a small '+' character will appear on the trace at the location of the spur. This is to indicate where raw data has been changed.

4.9.3 RIGHT CLICK FUNCTIONS

Select and right click a trace to perform the following functions:

- **Reset Axes** to the Measurement Range or to the range set in section **4.12 Display.**
- Quick access to the **Smoothing** and **Spur Display** functions.
- Rename traces, select trace colors, and remove selected or all traces.

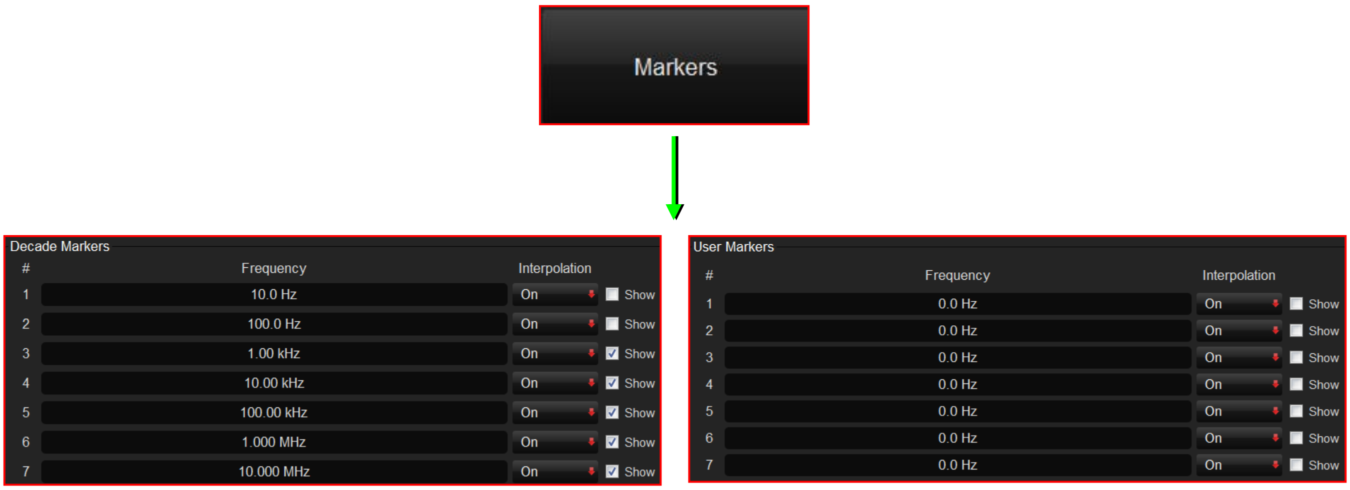


4.10 MARKERS

Markers provide the user with amplitude data at specific offset frequencies. There are two sets of Markers available, Decade Markers and User Markers.

NOTE: If Smoothing is applied to a trace, the Markers will appear on the value calculated by the smoothing function.

Dynamic Marker: Holding the 'CTRL' button with your mouse cursor in the plot area will enable a Dynamic Marker. The Dynamic Marker will follow the x-axis position of the mouse and move along the selected trace, while displaying frequency and amplitude.



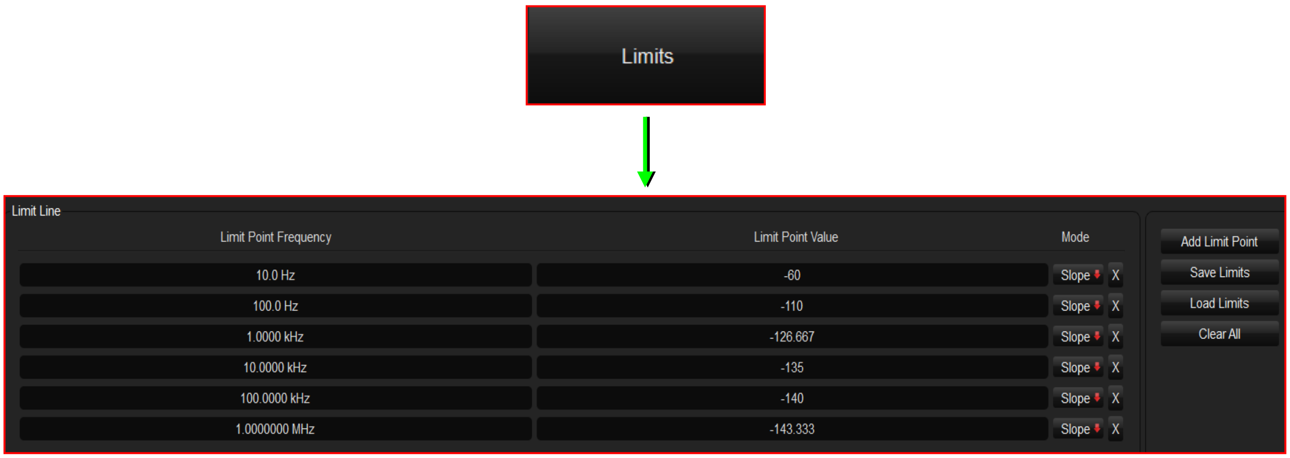
- **Decade Markers** are a set of 7 fixed markers. They display amplitude at every decade from 10Hz offset to 10MHz offset.

- **User Markers** are a set of 7 customizable markers that will display on the most recently selected trace if multiple traces are in the plot area. User Markers display the dBc/Hz value at the frequency entered above. Any given marker can be turned on or off with the 'Show' check box.

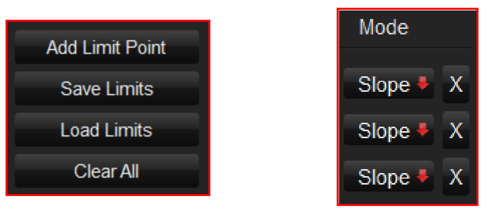
- **Frequency:** User Markers can be places at any frequency between 0.1Hz and 40MHz.

- **Interpolation:** With Interpolation turned on, the software will interpolate a data value if there is no data point at the exact marker frequency. With Interpolation off, the marker will snap to the nearest data point.

4.11 LIMITS (Pass/Fail Limit Lines)



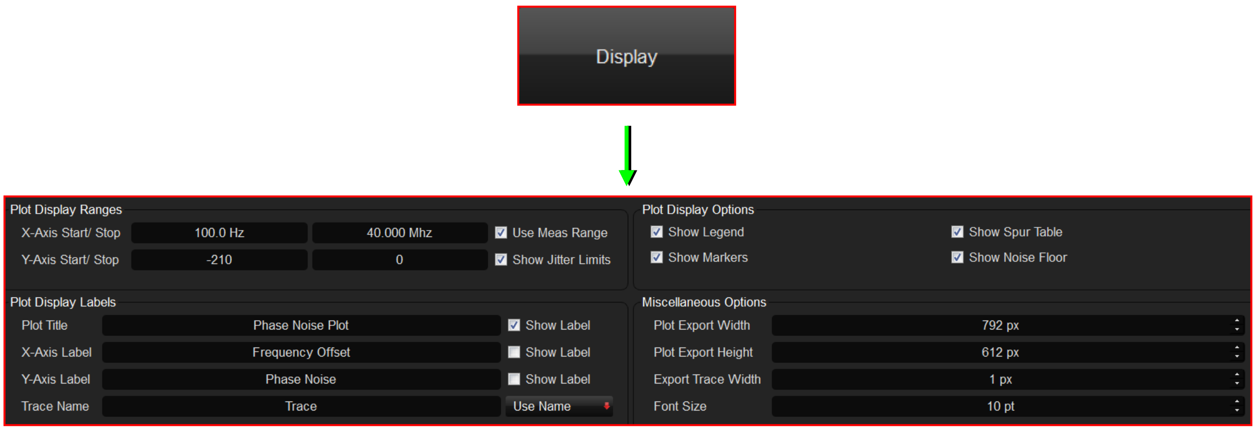
4.11.1 LIMIT CONTROLS & CONFIGURATION



- **Limit Points** are added by clicking the Add Limit Point button, and are added one by one to form a Limit Line. Use the 'X' button to remove a given limit point.
- **Save/ Load Limits** allows the user to save an already created limit line as a Holzworth Limit File (.hlf). Load Limits allows users to load a previous saved Holzworth Limit File or a .csv file.
- **Clear All** will remove the limit points/line from the plot area.
- **Limit Point Frequency** is user defined and sets the frequency for a given limit point.
- **Limit Point Value** sets the amplitude limit of a given point.
- **Mode:** Change the transition from one limit point to the next to either a Slope or a Step. The 'X' will remove the applicable limit point.

4.12 DISPLAY

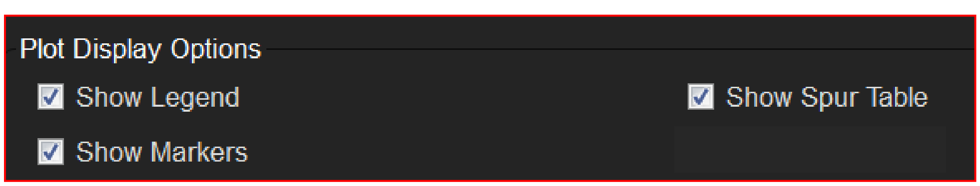
Display settings allow the user to manipulate the plot area, and have no effect on a measurement or any acquired data.



4.12.1 PLOT DISPLAY RANGES

- **X-Axis Start/Stop:** Manually adjust the x-axis (frequency), or check the 'Use Meas Range' box to have the display automatically use the measurement range set in the 'Measurement' menu.
- **Y-Axis Start/Stop:** Manually adjust the y-axis range (amplitude). This will not be automatically scaled.
- **Show Jitter Limits:** When checked, the jitter analysis range will be shown as two vertical dashed lines in the plot area. The jitter limits correspond with the integration range set in the 'Measurement' menu.

4.12.2 PLOT DISPLAY OPTIONS



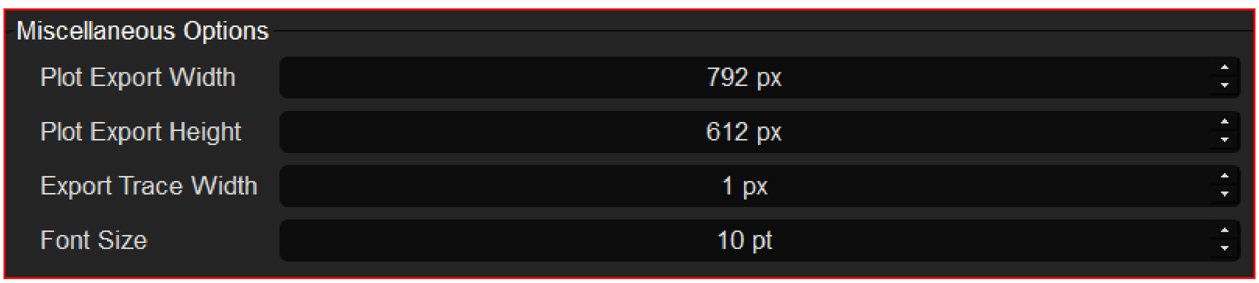
- **Show Legend**: Toggles the legend on/off in the top right of the plot area.
- **Show Spur Table**: Toggles the Spur Table on/off in the top left of the plot area.
- **Show Markers**: Master toggle for all markers in the plot area.

4.12.3 PLOT DISPLAY LABELS

- **Plot Title**, **X-Axis Label**, **Y-Axis Label** and **Trace Names** are completely customizable by the user by editing the text in the fields shown above. Also choose whether or not to show each label, and choose how to name traces in the legend. Traces can be names by the text in the Trace Name field, by frequency of the DUT signal, or by power level of the DUT signal.

- **Naming a Trace** can be done as mentioned above, or any of the following ways:
    - Right click a trace, select Rename trace
    - Double click a trace
    - Double click the current trace name displayed in the legend

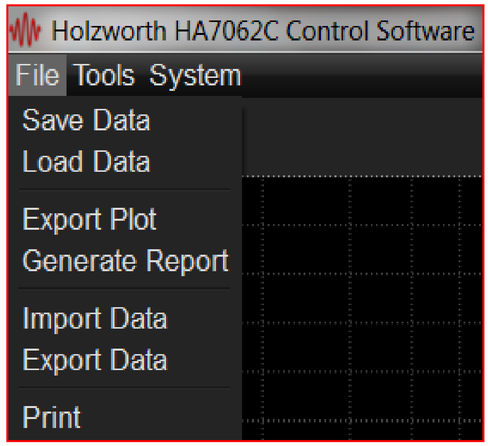
4.12.4 MISCELLANEOUS OPTIONS



- **Plot Export Settings**: Adjust the width and height of a plot that is exported (File → Export Plot), change the width of the trace(s) on an exported plot, and adjust font size.

4.13 FILE MENU

4.13.1 SAVE/LOAD DATA (HOLZWORTH TRACE FILE, .HTF)



Users can Save and Load data in the 'Holzworth Trace File' (.htf) file format via the File Menu. A 'Holzworth Trace File' can only be saved and opened by the HolzworthPNA software.

When a .htf file is loaded, the GUI will appear as it did when the moment the measurement was saved meaning. The trace will appear in the same color and with any smoothing, spur removal, or markers that were applied. Full measurement statistics will also populate below the plot area.

4.13.2 IMPORT/EXPORT DATA (COMMA SEPARATED VALUE, .CSV)

Users can utilize the Comma Separated Value (.csv) file format to save or load data by using Import Data or Export Data in the File Menu.

4.13.3 GENERATE REPORT

The 'Report Generation' feature allows the user to create a PDF report of all measurements in the plot area when the report is generated. The report will contain the plot area and a separate sections with comprehensive statistics pertaining to each trace in the plot area.

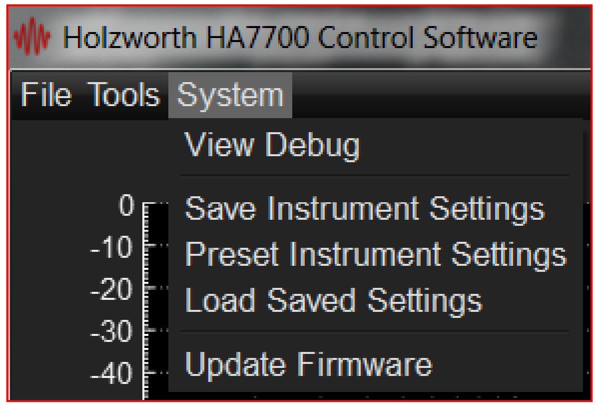
4.13.4 EXPORT PLOT AND PRINT

Note: Refer to section **4.12.4** to adjust 'Export Plot' and 'Print' image settings.

'Export Plot' allows the user to save a .png image of the plot area, including the measurement statistics beneath the plot area. The statistics will pertain to the last selected trace if there are multiple.

The 'Print' feature will produce the same image of the plot area, however it will be sent directly to print and will not be saved electronically.

4.14 SYSTEM MENU



Save Instrument Settings saves the current instrument configuration to internal memory. When power cycled the instrument will power on in this saved state.

Preset Instrument Settings returns the instrument to a factory default state. Once the factory default state is recalled users must save this state in order for the instrument to power on in this configuration.

Load Saved Settings returns the instrument to the configuration that was last saved to internal memory.

View Debug will open a text log of all instrument communication and activity from the moment it was most recently powered on. This can be saved as a PDF. If there are any errors or issues with the instrument this information should be sent to support@holzworth.com.

5.0 MEASUREMENT EXAMPLES & GUIDELINES

5.1 ABSOLUTE MEASUREMENT

General Guidelines

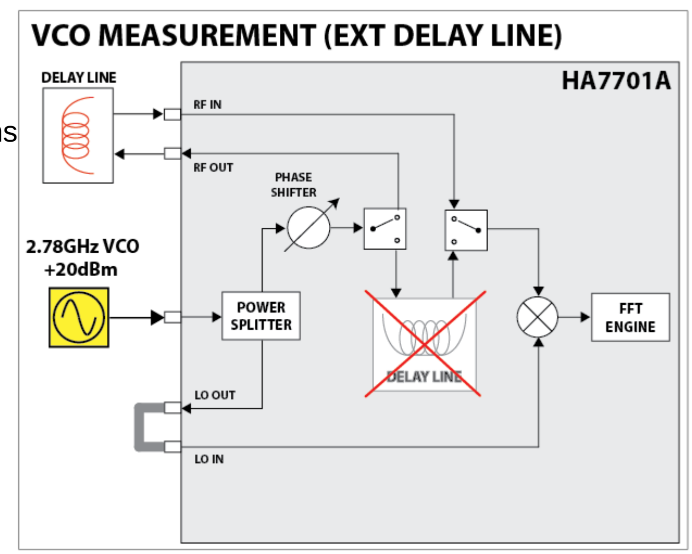
- Measurement null occurs at offset frequency f = 1/T.
- For internal delay line measurements the null occurs at approximately 51MHz, outside of the measurement range of the HA7701A.
- f = 1/T calculation can be used when using an external delay line to determine where first measurement null will occur and if it will be within the measurement offset range.
- Longer delay lines provide increased sensitivity, however the maximum offset to which the measurement is useful is reduced.
- Shorter delay lines reduce sensitivity, however the maximum offset to which the measurement is useful is increased.
- For internal delay line measurements the copper coaxial jumper cable supplied with the instrument should be in place connecting RF OUT to RF IN.

Hardware Configuration (EXTERNAL DELAY LINE Measurement)

This example uses an external delay line to measure the phase noise of a 2.78GHz VCO. Prior to the measurement the time delay of the delay line was measured in order to be input into the software.

NOTE: The VCO was amplified using an LNA to reach +20dBm.

T = 120ns

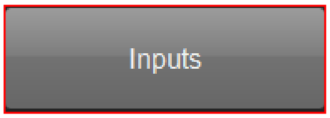


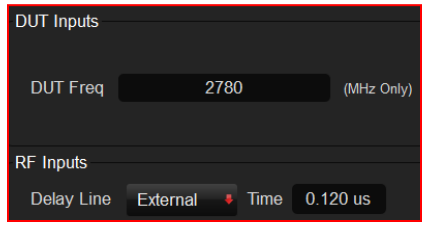
NOTE: Measurement null @ f = 1/T = 1/(120ns) = 8.33MHz

Software Configuration

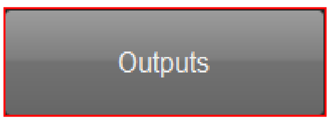
NOTE: For Absolute measurement with the HA7701A internal delay line, omit changing the internal/external delay line setting in step 1 below.

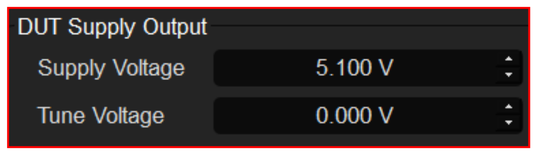
1. Once connected to the HA7701A via the Holzworth GUI, click the **Inputs** button in order to enter DUT frequency, set delay line to **External**, and enter the delay value.



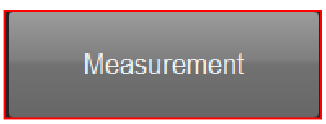


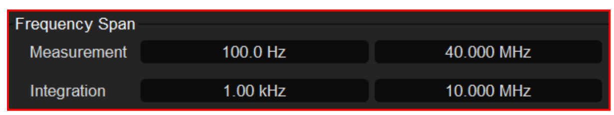
2. If necessary to power or tune the DUT via the HA7701A front panel, navigate to the **Outputs** menu to enable DUT supply and tune voltage outputs.

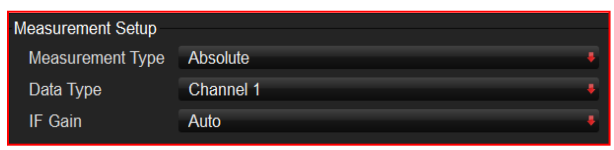


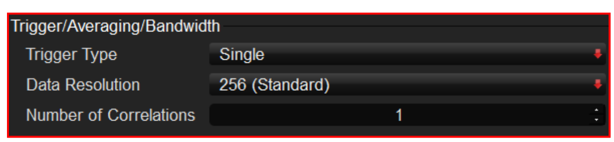


3. Navigate to the **Measurement** menu to adjust frequency offset, # of correlations, data resolution etc.

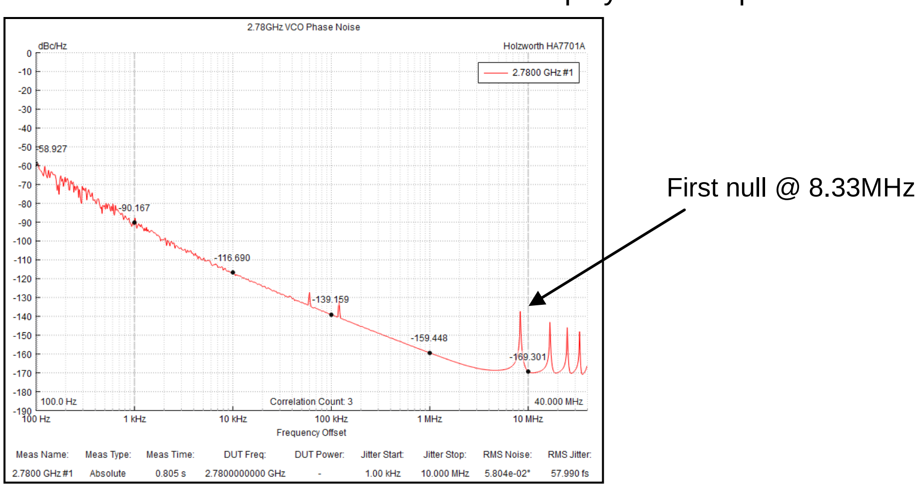








4. Click **Acquire** to initialize the measurement and view the results displayed in the plot area.

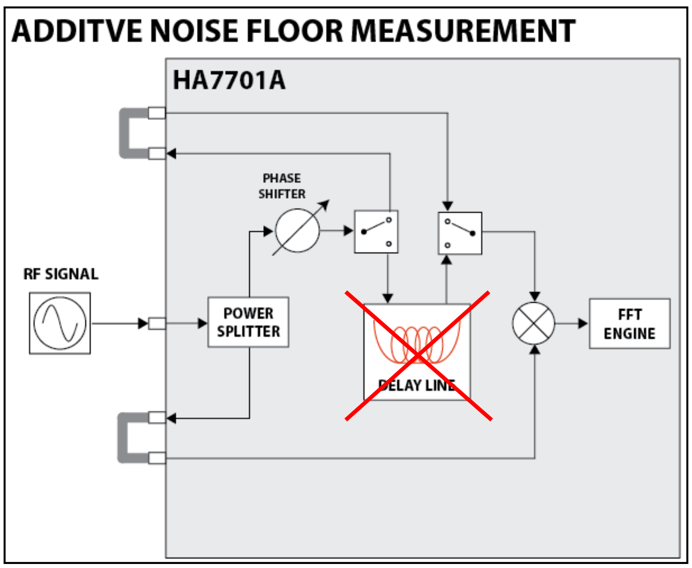


5.2 ADDITIVE MEASUREMENT

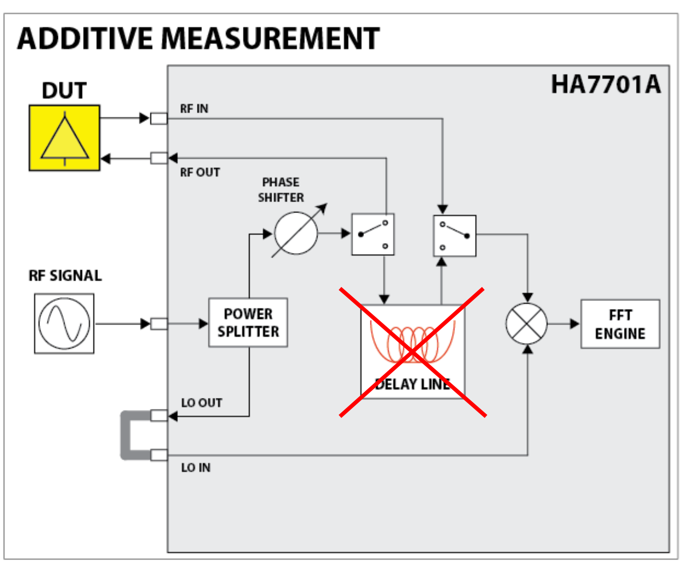
General Guidelines

- A baseline noise floor measurement should be taken prior to measuring a DUT. The baseline measurement should be made with the same power levels at the internal mixer in order to accurately reflect the noise floor of the system when the DUT is being measured.
- As a general rule, RF cable lengths in the RF and LO paths should be equal. Both paths must remain as close to the same length as possible otherwise the source will not cancel as effectively and this can degrade the measurement.
- A low noise fixed frequency source is recommended for additive measurements. If source phase noise is high enough above the DUT phase noise this can affect the source cancellation and degrade the measurement.
- Greatest measurement sensitivity is achieved with a +16dBm LO power level at internal mixer.

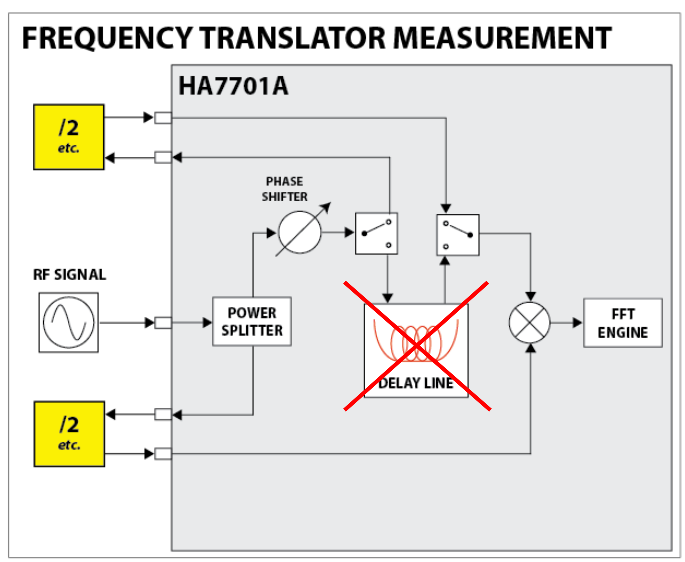
Hardware Configuration



Simplified diagram for noise floor measurement



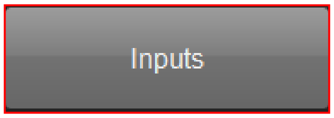
Simplified diagram for amplifier measurement

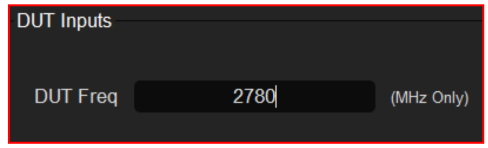


Simplified diagram for frequency translator measurement

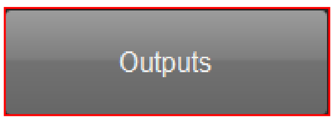
Software Configuration

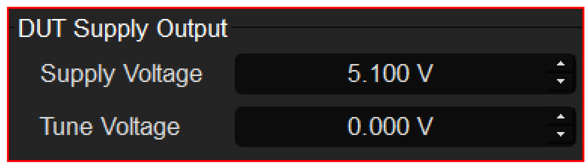
1. Once connected to the HA7701A via the Holzworth GUI, click the **Inputs** button in order to enter DUT frequency, select for external delay line, and enter the delay value.



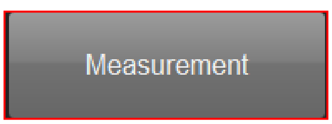


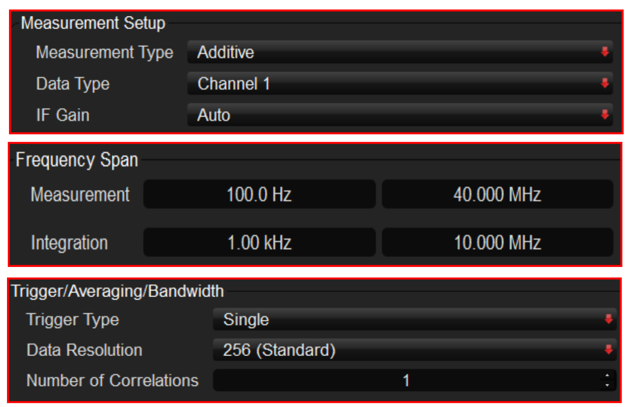
2. If necessary to power or tune the DUT via the HA7701A front panel, navigate to the **Outputs** menu to enable DUT supply and tune voltage outputs.





3. Navigate to the **Measurement** menu to set the measurement type to Additive and adjust frequency offset, # of correlations, data resolution etc. if necessary.

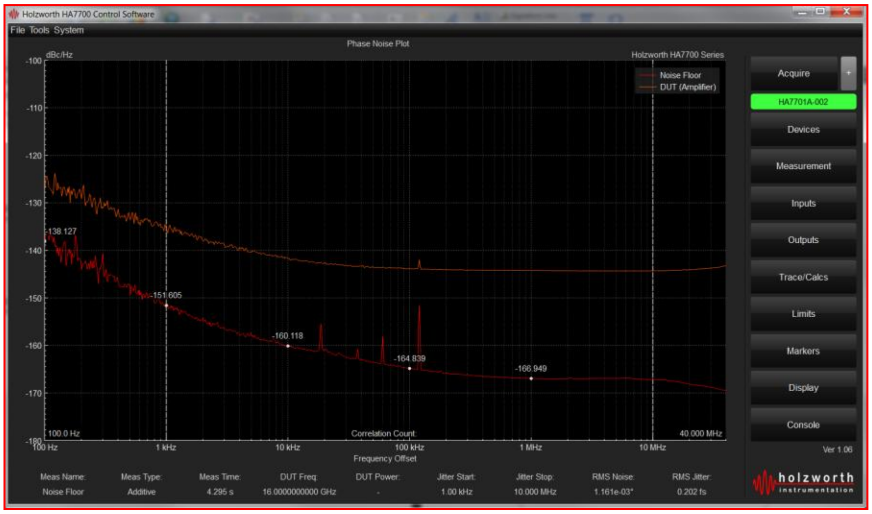




4. Verify the noise floor of the system by taking a measurement without the DUT in place but with the same power levels at the internal mixer.

5. Connect the DUT into the system.

6. Click **Acquire** to initialize the measurement and view the results displayed in the plot area.



6.0 CONTACT INFORMATION

Contact Holzworth directly for product support. A list of US Sales Representatives and non-US Distribution partners are listed on the Holzworth website.

Holzworth Instrumentation Sales Support

Phone: +1.303.325.3473 (option 1)

Email: sales@holzworth.com

Holzworth Instrumentation Technical Support

Phone: +1.303.325.3473 (option 2)

Email: support@holzworth.com

www.HOLZWORTH.com

APPENDIX A: ASCII PROGRAMMING COMMANDS

The Holzworth Instrumentation HA7000C phase noise analyzers allow users to communication with the instrument over a wide range of communication methods using their own application software.

The programming commands are ASCII commands sent over USB, Ethernet, RS-232 or GPIB. The ASCII commands begin with a colon (:) or asterisk (*).

If a command is not understood, the module will have in its buffer:

Invalid Command

The format for describing the command instruction is as follows:

:COMMAND:<value> A Description of the command here.

	<value>	Defined here, if any, queries typically have no value
Example	TX:	Example ASCII sent in transmission
	RX:	Example ASCII received back, if a receive transmission is made

Instrument Configuration
(stored in memory until power cycle, can be entered in any order)

Set Measurement Type

:SENS:PN:MEAS:TYPE:<value> — Sets the measurement type to be performed

Example TX: :SENS:PN:MEAS:TYPE:ADDITIVE
RX: Measurement type set

<value> = Absolute or Additive

:SENS:PN:MEAS:TYPE? — Reads back measurement type

Example TX: :SENS:PN:MEAS:TYPE?
RX: Additive

Set DUT Frequency

:SENS:PN:HA7701:DATA:CARR:<value> — Sets DUT frequency

Example TX: :SENS:PN:HA7701:DATA:CARR:3000 MHz
RX: Frequency set

:CALC:PN:DATA:CARR? — Reads back DUT frequency of last measurement

Example TX: :CALC:PN:DATA:CARR?
RX: 3000000000

Set # of Correlations

:SENS:PN:CORR:COUN:<value> Sets # of correlations

Example TX: :SENS:PN:MEAS:TYPE:10
RX: Number of correlations set

:SENS:PN:CORR:COUN? Reads back # of correlations

Example TX: :SENS:PN:CORR:COUN?
RX: 10

Set Frequency Offset Start/Stop

:SENS:PN:FREQ:STAR:<value>		Sets frequency offset start (how close to the carrier to measure)
Example	TX:	:SENS:PN:FREQ:STAR:100Hz
	RX:	Frequency start set
:SENS:PN:FREQ:STAR?		Query measurement start frequency
Example	TX:	:SENS:PN:FREQ:STAR?
	RX:	100
:SENS:PN:FREQ:STOP:<value>		Sets frequency offset stop (how far from the carrier to measure)
Example	TX:	:SENS:PN:FREQ:STAR:10MHz
	RX:	Frequency stop set
:SENS:PN:FREQ:STOP?		Query measurement stop frequency
Example	TX:	:SENS:PN:FREQ:STAR?
	RX:	10000000

Set Jitter Analysis Range

:CALC:PN:TRAC:BDM:X:STAR:<value> Sets the jitter integration start frequency

Example	TX:	:CALC:PN:TRAC:BDM:X:STAR:100
	RX:	Band marker start set

:CALC:PN:TRAC:BDM:X:START? Queries jitter integration start frequency

Example	TX:	:CALC:PN:TRAC:BDM:X:STAR?
	RX:	100

:CALC:PN:TRAC:BDM:X:STOP:<value> Sets the jitter integration stop frequency

Example	TX:	:CALC:PN:TRAC:BDM:X:STOP:10MHz
	RX:	Band marker stop set

:CALC:PN:TRAC:BDM:X:STOP? Queries jitter integration stop frequency

Example	TX:	:CALC:PN:TRAC:BDM:X:STOP?
	RX:	10000000

Set Trigger Type

:SENS:PN:MODE:<value> Sets the trigger type of the measurement

Example TX: :SENS:PN:MODE:PERSIST
RX: Persist mode set

<value> Single, Each, Continuous, Persist

:SENS:PN:MODE? Queries trigger type

Example TX: :SENS:PN:MODE?
RX: Persist

Set Data Resolution

:SENS:PN:SAMPLES:COUN:<value> Sets the data resolution for the measurement

Example TX: :SENS:PN:MEAS:TYPE:512
RX: Number of samples set

<value> 64, 128, 256, 512, 1024

:SENS:PN:SAMPLES:COUN? Queries data resolution

Example TX: :SENS:PN:SAMPLES:COUN?
RX: 512

DUT Power Supply

:SENS:PN:DUT:VSUPPLY:<value> Sets the DC voltage of the DUT supply

Example	TX:	:SENS:PN:DUT:VSUPPLY:12.000V
	RX:	12.000 Volts written to supply voltage output
		<value> 0.000 to 12.000

:SENS:PN:DUT:VSUPPLY? Queries DUT supply voltage

Example	TX:	:SENS:PN:DUT:VSUPPLY?
	RX:	12.000 Volts

:SENS:PN:DUT:ILIMIT:<value> Set DUT supply current limit

Example	TX:	:SENS:PN:DUT:ILIMIT:0.2
	RX:	0.200 Amps written to supply current limit

:SENS:PN:DUT:ILIMIT? Queries DUT supply current limit

Example	TX:	:SENS:PN:DUT:ILIMIT?
	RX:	0.200 Amps

DUT Tune Voltage

:SENS:PN:DUT:VTUNE:<value> Sets the DUT tune voltage

Example	TX:	:SENS:PN:DUT:VTUNE:8.000V
	RX:	8.000 Volts written to tune output
		<value> 0.000 to 20.000

:SENS:PN:DUT:VTUNE? Queries DUT tune voltage

Example	TX:	:SENS:PN:DUT:VTUNE?
	RX:	8.000 Volts

Measurement Command Sequence

Initialize Measurement

:INIT:PN:IMM Begins the measurement

Example TX: :INIT:PN:IMM
RX: Phase noise measurement initialized

Check Measurement Status

:SENS:PN:CORE:STATUS? Queries measurement status

Example TX: :SENS:PN:CORE:STATUS?
RX: "Phase noise measurement initialized" OR "Data not ready"

Loop issuing this command until you receive "Phase noise measurement initialized". If you receive "Data not ready" the measurement has failed.

If the measurement fails, check for errors using the :SENS:PN:CORE:ERROR? command below, otherwise proceed to the 'Check Instrument Status' command.

:SENS:PN:CORE:ERROR? Checks for error messages

Example TX: :SENS:PN:CORE:ERROR?
RX: Responses will vary

If the measurement fails repeatedly send the command below to read back the debug contents and send the contents to support@holzworth.com

:SENS:PN:CORE:DEBUG? Reads back debug information

Example TX: :SENS:PN:CORE:DEBUG?
RX: Responses will vary

Check Instrument Status

:STAT:OPER:COND? Returns the status of the instrument

Example	TX:	:STAT:OPER:COND?
	RX:	"Instrument Busy" OR "Instrument Ready"

Loop issuing this command until you receive "Instrument Ready"

Number of Points

:SENS:PN:SWE:POIN? Returns the number of measurement points

Example	TX:	:SENS:PN:SWE:POIN?
	RX:	Integer value will vary based on measurement settings

Pull Amplitude Data From Instrument

:CALC:PN:DATA:FDAT? Returns the amplitude data

Example	TX:	:CALC:PN:DATA:FDAT?
	RX:	Returns amplitude data in comma separated string

Continue reading data until the number of points match the number returned from the previous command.

Pull Frequency Data From Instrument

:CALC:PN:DATA:XDAT? Returns the frequency data

Example	TX:	:CALC:PN:DATA:XDAT?
	RX:	Returns frequency data in comma separated string

Continue reading data until the number of points match the number returned from the previous command.

Jitter Measurement

Jitter Measurement Settings

:CALC:PN:TRAC:BDM:X:STAR:<value> Jitter integration frequency start

Example	TX:	:CALC:PN:TRAC:BDM:X:STAR:1kHz
	RX:	Band marker start set

:CALC:PN:TRAC:BDM:X:STOP:<value> Jitter integration frequency stop

Example	TX:	:CALC:PN:TRAC:BDM:X:STOP:10MHz
	RX:	Band marker stop set

Jitter settings are stored in memory until a power cycle. They can be entered in any order and can be modified repeatedly without re-initializing a measurement.

Pull Jitter Data

:CALC:PN:TRAC:FUNC:INT:DATA? Returns the jitter integration data

Example	TX:	:CALC:PN:TRAC:FUNC:INT:DATA?
	RX:	Comma separated values: frequency range, RMS noise, RMS jitter

Smoothing and Spur Removal Functions

Spur Removal

:CALC:PN:TRAC:SPUR:OMIS:<value> Turn spur removal on/off

Example	TX:	:CALC:PN:TRAC:SPUR:OMIS:ON
	RX:	Spur removal on
		<value> ON, OFF

:CALC:PN:TRAC:SPUR:OMIS? Queries spur removal status

Example	TX:	:CALC:PN:TRAC:SPUR:OMIS?
	RX:	ON

:CALC:PN:TRAC:SPUR:THR:<value> Sets spur removal threshold

Example	TX:	:CALC:PN:TRAC:SPUR:THR:5
	RX:	5 dB spur threshold set
		<value> 0 to 99

:CALC:PN:TRAC:SPUR:THR? Queries spur removal threshold

Example	TX:	:CALC:PN:TRAC:SPUR:THR?
	RX:	5

:SENS:PN:SWE:SPUR:POIN? Read back number of spurs found

Example	TX:	:SENS:PN:SWE:SPUR:POIN?
	RX:	11

:CALC:PN:DATA:SDAT? Read back spurs data

Example	TX:	:CALC:PN:DATA:SDAT?
	RX:	Freq, dBc, freq, dBc..........

Smoothing

:CALC:PN:TRAC:SMO:STAT:<value> Turn smoothing on/off

Example	TX:	:CALC:PN:TRAC:SMO:STAT:ON
	RX:	Smoothing on
		<value> ON, OFF

:CALC:PN:TRAC:SMO:STAT? Queries smoothing status

Example	TX:	:CALC:PN:TRAC:SMO:STAT?
	RX:	ON

:CALC:PN:TRAC:SMO:PNTS:<value> Sets number of smoothing points

Example	TX:	:CALC:PN:TRAC:SMO:PNTS:25
	RX:	25 smoothing points set
		<value> 3 to 99

:CALC:PN:TRAC:SMO:PNTS? Queries number of smoothing points

Example	TX:	:CALC:PN:TRAC:SMO:PNTS?
	RX:	25

:CALC:PN:DATA:FDAT? Read back smoothed data

Example	TX:	:CALC:PN:DATA:FDAT?
	RX:	Freq, dBc, freq, dBc.........

APPENDIX B: ETHERNET CONFIGURATION COMMANDS

Ethernet programming commands may be used to configure static network settings. These commands may be sent via the Console window in the software application.

If a command is not understood, the module will have in its buffer:

Invalid Command

The format for describing the command instruction is as follows:

:COMMAND:<value>		A Description of the command here.
	<value>	Defined here, if any, queries typically have no value
Example	TX:	Example ASCII sent in transmission
	RX:	Example ASCII received back, if a receive transmission is made

Network Configuration Commands

:IP:STATUS:<value>		Set IP status to Static IP or DHCP
	<value>	STATIC <or> DHCP
Example	TX:	:IP:STATUS:STATIC
	RX:	DHCP status changed. Restart Device

:IP:STATUS?		Query IP status
Example	TX:	:IP:STATUS?
	RX:	Static IP Address <or> DHCP

:IP:ADDR:<value> Set Static IP Address

	<value>	IP Address
Example	TX:	:IP:ADDR:192.168.10.11
	RX:	Static IP address changed

:IP:ADDR? Query Static IP Address

Example	TX:	:IP:ADDR?
	RX:	192.168.10.11

:IP:GATEWAY:<value> Set Gateway IP Address for Static IP

	<value>	Gateway address
Example	TX:	:IP:GATEWAY:192.160.10.1
	RX:	Gateway address changed.

:IP:GATEWAY? Query Gateway Address

Example	TX:	:IP:GATEWAY?
	RX:	192.160.10.1

:IP:SUBNET:<value> Set Subnet for Static IP Address

	<value>	Subnet Address
Example	TX:	:IP:SUBNET:255.255.0.0
	RX:	Subnet address changed

:IP:SUBNET? Query Subnet Address

Example	TX:	:IP:SUBNET?
	RX:	255.255.0.0

APPENDIX C: GPIB CONFIGURATION COMMANDS

:GPIB:ADDR:<value>			Set instrument GPIB address
	<value>	0 thru 30	
Example	TX:	:GPIB:ADDR:5	
	RX:	GPIB Address: 5	

:GPIB:ADDR?			Query GPIB address
Example	TX:	:GPIB:ADDR?	
	RX:	GPIB Address: 5	

:GPIB:EOIWLC:<value>			Set Instrument GPIB EOI with last character
	<value>	ON <or> OFF	
Example	TX:	:GPIB:EOIWLC:ON	
	RX:	EOI with last character enabled	

:GPIB:EOIWLC?			Query instrument GPIB EOI with last character
Example	TX:	:GPIB:EOIWLC?	
	RX:	EOI with last character disabled <or> EOI with last character enabled	

:GPIB:RESPOND:<value>			Set Instrument GPIB to always return a response
	<value>	ON <or> OFF	
Example	TX:	:GPIB:RESPOND:ON	
	RX:	GPIB responds with every command <or> GPIB only responds to queries	

:GPIB:RESPOND?			Query instrument GPIB response status
Example	TX:	:GPIB:RESPOND?	
	RX:	GPIB only responds to queries <or> GPIB responds with every command	

USER NOTES

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Revision 1.04

November 2018