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X-Parameter Generator

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X-Parameter Generator Basics

This is a description of X-Parameter Generator, including when to use it, how to set it up, the data it generates, and troubleshooting.

Overview

Using the X-Parameter Generator from the Simulation-X_Param palette enables you to obtain the X-parameters of a component, circuit, or subnetwork. The extracted X-parameter data can be used as a behavioral model in simulation by using the XnP component. For more information, refer to *XnP Components (X1P - X10P)* (ccsim).

Refer to following topics for details on X-Parameter Generator:

- Using X-Parameter Generator describes the minimum setup requirements for an X-parameter simulation.
- *Example of X-Parameter Generator* (xparam) gives detailed setups for running a basic X-parameter generation for an amplifier.
- *X-Parameter Generator Parameters* (xparam) provides details about the parameters available in the X-Parameters controller in ADS.

Using X-Parameter Generator

This section describes how to set up X-Parameter Generator.

License Requirements

The X-Parameter Generator uses the W2305 X-Parameter Generator license. You must have this license to run the X-Parameter Generator. You can work with examples described here and installed with the software without the license, but you will not be able to simulate them.

How to Use X-Parameter Generator

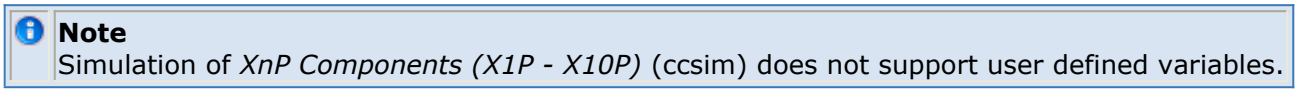
For a successful analysis:

- Apply *XP_Bias* (ccsrc) to DC ports, *XP_Source* (ccsrc) to large signal input ports, and *XP_Load* (ccsrc) to outputs. Those components are collectively called XP term components and can be found in the Simulation-X_Param palette.
- Check the Num field for each XP term component. The X-parameter port numbers are derived from these fields.
- Power sweep at a port has to be specified on the *Power source* tab of the XP_Source component connected to the port. Do not use ParamSweep to sweep source power.
- Load sweep at a port has to be specified on the *Load* tab of the XP_Load component connected to the port. Do not use ParamSweep to sweep load.
- DC bias sweep at a port has to be specified on the *DC* tab of the XP_Bias component connected to the port. Do not use ParamSweep to sweep DC bias.
- Add the X-Parameters controller to the schematic and double-click to edit it. For a

basic simulation, fill in the fields under the *Freq* tab:
    - Enter at least one fundamental frequency and the number (order) of harmonics to be considered in the simulation.
      Make sure that frequency definitions are established for all of the fundamentals of interest in a design. For example, mixers should include definitions for RF and LO frequencies.
    - If more than one fundamental is entered, set the maximum mixing order. This limits the number of mixing products to be considered in the simulation. For more information on this parameter, refer to *Harmonics and Maximum Mixing Order* (cktsimhb).
- If you want to sweep a fundamental, add VarEqn and SweepPlan for the fundamental, then specify the sweep under X-Parameters controller *Sweep* tab. Do not use ParamSweep to sweep fundamentals.
- The setup for parameters *Initial Guess* tab, *Oversample* tab and *Solver* tab is the same as those in *Harmonic Balance Simulation* (cktsimhb).
- X-parameter data is written to a dataset file. To output X-parameter data to GMDIF file, check the "Output GMDIF file" checkbox. GMDIF files are ASCII files and are suitable for cross-platform exchanges. Dataset files facilitate Data Display plotting.

Limitations

- X-Parameter Generator runs a series of Harmonic Balance simulations. So, all limitations to Harmonic Balance also apply to X-Parameter Generator. For Harmonic Balance limitation, see *Harmonics balance limitations* (cktsimhb).
- Sweeps of the fundamental frequencies have to be defined in the X-Parameters controller under the *Sweep* tab. Do not use ParamSweep to sweep fundamental frequencies.
- Sweeps of other user defined variables like temperature have to be defined in the X-Parameters controller under the *Sweep* tab. Do not use ParamSweep.



Troubleshooting a Simulation

For information on troubleshooting, refer to *Troubleshooting a simulation in Harmonic Balance* (cktsimhb).

X-Parameter Generator Parameters

ADS provides access to X-Parameter Generator parameters enabling you to define aspects of the simulation listed in the following table:

Tab Name	Description	For details, see...
Freq	Frequencies of fundamentals	Setting Fundamental Frequencies
Sweep	Sweep fundamentals and associated SweepPlans	Setting Up Fundamental Sweeps
Initial Guess	Set parameters related to initial guess	Setting Up the Initial Guess
Oversample	Sets the FFT oversampling ratio	*Defining Oversample* (cktsimhb)
Solver	Parameters enabling you to choose between a Direct or Krylov solver or an automatic selection. The automatic selection is the default and recommended choice, since it allows the simulator to choose the most effective solver for each particular circuit. Additional parameters manage memory usage	Selecting a Solver Technique
Display	Control the visibility of simulation parameters on the Schematic	*Displaying Simulation Parameters on the Schematic* (cktsim)

Setting Fundamental Frequencies

On the *Freq* tab, you can specify the frequency portion of the simulation. The following table describes the parameter details. Names listed in the Parameter Name column are used in netlists and on schematics.

X-Parameter Generator Frequency Parameters

Setup Dialog Name	Parameter Name	Description
Fundamental Frequencies		
Edit		
Frequency	Freq[n]	The frequency of the fundamental(s). Change by typing over the entry in the field. Select the units (None, Hz, kHz, MHz, GHz) from the drop-down list.
Order	Order[n]	The maximum order (harmonic number) of the fundamental(s) that will be considered. Change by typing over the entry in the field. Order[*n*] is raised to the value of Maxorder if Order[*n*] for any *n* is smaller than MaxOrder and there are more than one fundamental frequency. The number of harmonics needs to be sufficiently large to represent nonlinear signals (sharp transitions, square waves). An increase in the Order slows down the simulation considerably or results in excessive memory usage. Use the Krylov solver if the problem is too big for the Direct solver. The lower the Order, the greater the Harmonic Balance truncation error as a

		result of the Fourier truncation in the solution representation. As a rule of thumb, anything below 5-7 harmonics is unacceptable. Using the Manual Convergence Mode (ConvMode=1) and StatusLevel=4 or 5 will give an estimate of this error. The computational complexity of the Krylov solver is determined by the size of FFT (i.e. by the number of samples). With Krylov Harmonic Balance,set Order to 7, 15, 31, etc. Keep in mind that according to the Nyquist theorem at least 2 x Order + 1 samples are needed to represent the highest harmonic. The Oversample parameter increases the number of samples beyond the minimum by this factor, and, due to the nature of FFT, the number of samples is rounded up to the nearest power of 2.
Select		Contains the list of fundamental frequencies. *Add* enables you to add an item. *Cut* enables you to delete an item. *Paste* enables you to take an item that has been cut and place it in a different order.
Maximum mixing order	MaxOrder	The maximum order of the intermodulation terms in the simulation. The combined order is the sum of the individual frequency orders that are added or subtracted to make up the frequency list. For example, assume there are two fundamentals and Order (see below) is 3. If Maximum mixing order is 0 or 1, no mixing products are simulated. The frequency list consists of the fundamental and the first, second, and third harmonics of each source. If Maximum mixing order is 2, the sum and difference frequencies are added to the list. If Maximum mixing order is 3, the second harmonic of one source can mix with the fundamental of the others, and so on.
Levels		Enables you to set the level of detail in the simulation status report.
Status level	StatusLevel	Prints information about the simulation in the Status/Summary part of the Message Window. <\BR>-0 reports little or no information, depending on the simulation engine. -1 and 2 yield more detail. - Use 3 and 4 sparingly since they increase process size and simulation times considerably. The type of information printed may include the sum of the current errors at each circuit node, whether convergence is achieved, resource usage, and where the dataset is saved. The amount and type of information depends on the status level value and the type of simulation.

Reference Signal

The Large Signal Operating Point (LSOP) for X-parameters is always defined with one reference signal per fundamental frequency. In order to enforce time invariance and avoid duplicate measurements, the phase of this reference signal is defined to be zero and is never swept. A message is displayed on the status window indicating which signal was chosen as the reference signal.

To understand why a reference signal is needed, consider a simple LSOP consisting of one large tone at a single frequency. A large signal AM/AP with magnitude M and phase P is simply a time-delayed version of a large signal AN with magnitude M and phase 0. Time invariance principle states that the response to AM/AP should be exactly the same as the time-delayed response to AN, so there is no need to store X-parameters for both sets of

stimulus. Instead the X-parameters are always measured at phase 0, and the simulation of *XnP Components (X1P - X10P)* (ccsim) uses time invariance to predict the response to phase-shifted (or time-delayed) signals.

Selection of the reference signal(s) during X-parameter generation and while using X-parameter files with such reference data are both handled internally by the ADS simulator and requires no input from you.

Setting Up Fundamental Sweeps

On the *Sweep* tab, setting up the sweep portion of the simulation consists of two basic parts:

- Selecting the sweep type and setting the associated characteristics
- Optionally, specifying a sweep plan

To shorten simulation time in any parameter sweep, select a start point as close as possible to the convergence point and vary the parameter gradually. This yields better estimates for the next simulation, and achieves convergence more rapidly than if the parameter were changed abruptly. The following table describes the parameter details. Names listed in the Parameter Name column are used in netlists and on schematics.

X-Parameter Generator Sweep Parameters

Setup Dialog Name	Parameter Name	Description
Parameter to sweep	FreqSweep	The name of the fundamental variable to be swept. The fundamental variable needs to be defined in VarEqn.
Sweep plan	FreqSweep	The name of an existing sweep plan which is used for the fundamental variable to be swept. Enter the name of the plan or select it from the drop-down list.
Select		Contains the list of fundamental sweeps. Double-click in the Edit field to add fundamental sweeps to this window. *Add* enables you to add an item. *Cut* enables you to delete an item. *Paste* enables you to take an item that has been cut and place it in a different order.

Setting Up Other Sweeps

Power, DC bias and Load sweeps desired in X-parameter generation have to be set in *XP_Source* (ccsrc), *XP_Bias* (ccsrc) and *XP_Load* (ccsrc) components. Do not use ParamSweep components for those sweeps. All the sweeps are defined as nested sweeps. Therefore, the total number of sweep points established in all of the *XP_Source* (ccsrc), *XP_Bias* (ccsrc) and *XP_Load* (ccsrc) components is the product of the number of points in the individual sweeps. Furthermore, the Power and Load sweeps may require setting up two sweeps, as they are complex variables. For example, sweeping the magnitude of a power source with 11 points, DC bias voltage with 5 points, and a Load impedance with 6

magnitude values and 36 phase values will result in 11,880 of total sweep points. If the total number of sweep points is very large, you can expect long simulation time needed for the X-parameter generation. The progress of the generation process is shown at the bottom of the status window as the percentage of already handled sweep points.

Setting Up the Initial Guess

On the *Initial Guess* tab, you can set up the initial guess for X-Parameter Generator. The settings on the *Initial Guess* tab are similar to those of a Harmonic Balance controller *Initial Guess* tab. See *Setting Up the Initial Guess in Harmonic Balance* (cktsimhb).

Selecting a Solver Technique

The *Solver* tab enables you to select a Direct or Krylov solver, or to allow the simulator to assign one automatically. The settings on the *Solver* tab are identical as those of a Harmonic Balance controller. See *Selecting a Harmonic Balance Solver Technique* (cktsimhb).

Harmonics, Maximum Mixing Order and X-parameter Maximum Mixing Order

With multiple sources in a circuit, mixing products will occur. For more information, refer to *Harmonics and Maximum Mixing Order in Harmonic Balance* (cktsimhb).
The maximum harmonic indices sent to the X-parameter file are governed by a different parameter, as shown in the following table. This behavior is somewhat different from the harmonic balance simulation, particularly in the single-tone setup. The parameters "Order" and "MaxOrder" take effect for the HB simulation invoked for the X-parameter generation, but they are ignored for the data output. The highest harmonic indices, including mixing terms to be sent to the X-parameter file are exclusively controlled by the parameter "XParamMaxOrder" listed in the following table, and available for editing on screen.

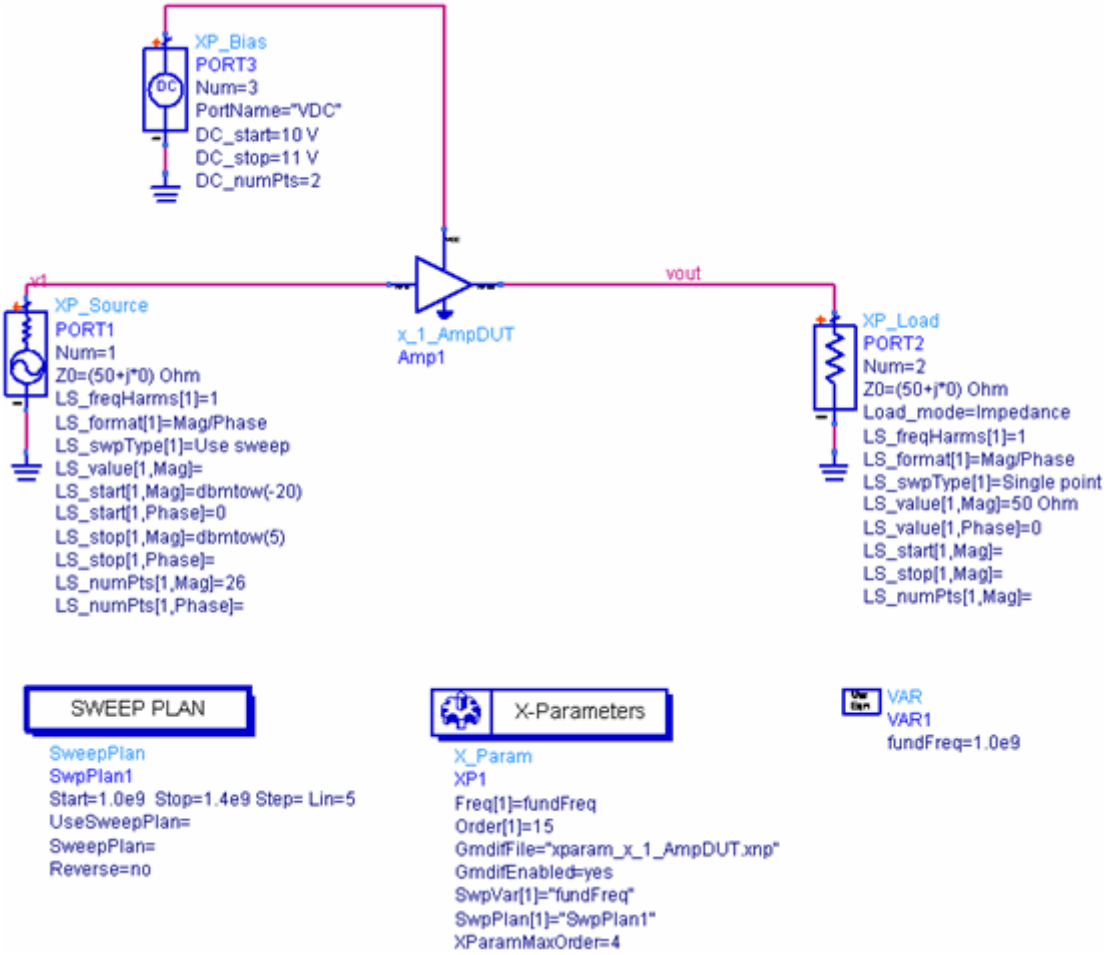
X-Parameter Generator MaxOrder Parameters

Setup Dialog Name	Parameter Name	Description
	XParamMaxOrder	The maximum order of the X-parameters to be sent to the X-parameter data file. For a single tone X-parameter generation, XParamMaxOrder must not exceed the Order of the fundamental. For multi-tone generation, the value must not exceed MaxOrder specified under *Freq* tab. To set the parameter value, enable the parameter display under *Display* tab. Edit the parameter value on the schematic. The default value is 4.

Example of X-Parameter Generator

This section gives detailed setups to perform an X-parameter generation with a fundamental frequency sweep. This example workspace can be found in the ADS *Examples* directory under *Tutorial/X_parameters_Generation_wrk*.

The following figure illustrates the setup for X-parameter generation.

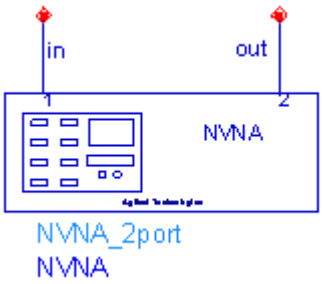


1. From **Simulation-X_Param** palette, select an **XP_Source** component and connect its "+" node to the input port of the circuit. Connect GROUND to the "-" node. Edit the component to set these values:
    1. Port Number = **1**
    2. Port Name = **"Input"**
    3. Reference impedance as default **50+j*0 Ohm**
    4. Select *DC* tab, then select Bias type as **None**
    5. Select *Power source* tab and set the following parameters:
        1. Set Frequency harmonic indices to **1**
        2. Select Sweep type as **Use sweep**
        3. Set Mag as
            - Start = **-20 dBm**
            - Stop = **5 dBm**
            - Num. of pts = **26**
    6. Click **Ok** to close the component dialog.

2. From **Simulation-X_Param** palette, select an **XP_Load** component and connect its "+" node to the output port of the circuit. Connect GROUND to the "-" node. Edit the component to set these values:
   1. Port Number = **2**
   2. Port Name = **"Output"**
   3. Reference impedance as default **50+j*0 Ohm**
   4. Ensure *DC* tab is selected, then select Bias type as **None**
   5. Select *Load* tab and set the following parameters:
      1. Select Load type as **Impedance**
      2. Set Frequency harmonic indices to **1**
      3. Select Format as **Mag/Phase**
      4. Select Sweep type as **Single point**
      5. Set Mag = **50 Ohm**
   6. Click **Ok** to close the component dialog.
3. From **Simulation-X_Param** palette, select an **XP_Bias** component and connect its "+" node to the DC port of the circuit. Connect GROUND to the "-" node. Edit the component to set these values:
   1. Port Number = **3**
   2. Port Name = **"VDC bias"**
4. Place a **VarEqn** on the schematic, add a Var fund_1 = **1.0e9**
5. From **Simulation-X_Param** palette, select and place a **SweepPlan** component **SwpPlan1** on the schematic. Edit the component to set these values:
   1. Start = **1.0e9**
   2. Stop = **1.4e9**
   3. Step = **0.1e9**
6. From **Simulation-X_Param** palette, select and place an **X-Parameters** controller on the schematic. Edit the controller as:
   1. Enable the Output GMDIF file checkbox, specify the output GMDIF file name as "xparam_test.xnp"
   2. Select *Freq* tab and set Frequency = **1**, Order = **15**
   3. Select *Sweep* tab and set Parameter to sweep = **fundFreq**, select **SwpPlan1** from the SweepPlan dropdown list, click **Add** button
   4. Click **OK** button to close the component edit dialog.
7. Save the design as *xparam_test*
8. **Simulate**. When the simulation is finished, X-parameter data is written to *xparam_test* and *xparam_test.xnp* in the data subdirectory.

NVNA_2port (1 Tone 2 port X-Parameter Generator)

Symbol



Parameters

Name	Description	Units	Default
Port number (or Num)	Port number 1 and 2 are used internally	None	1 and 2
Order	The maximum order (harmonic number) of the fundamental that will be considered	None	5
Fund_Start	Fundamental frequency sweep start (also used for single value), numerical value only	Hz	1 GHz
Fund_Stop	Fundamental frequency sweep stop, numerical value only	Hz	1 GHz
Fund_NumPts	number of points for fundamental frequency sweep, numerical value only	None	1
XParamMaxorder	The maximum order of the X-parameters to be sent to the X-parameter file	None	3
GmdifEnabled	Enable writing the GMDIF file	None	No
GmdifFile	Name of the GMDIF file (extension .xnp)	None	FileName.xnp
LS_SwpType	Sweep type for large signal power at port 1: Single point, Use sweep	None	Single point
LS_Start	Start power level at port 1, in dBm, for power sweep (also used for single value), numerical value only	dBm	-20
LS_Stop	Stop power level at port 1, in dBm, for power sweep, numerical value only	dBm	-10
LS_NumPts	Number of points for power sweep at port 1, numerical value only	None	2
DC_Mode_1	DC bias mode at port 1: None, Voltage, Current	None	"None"
DC_SwpType_1	Sweep type for DC bias at port 1: Single point, Use sweep	None	Single point
DC_Start_1	Start bias level, in V or A depending on DC_mode_1, for DC sweep at port 1 (also used for single value), numerical value only	V or A	3
DC_Stop_1	Stop bias level, in V or A depending on DC_mode_1, for DC sweep at port 1, numerical value only	V or A	4
DC_NumPts_1	Number of points for DC sweep at port 1, numerical value only	None	2
DC_Mode_2	DC bias mode at port 1: None, Voltage, Current	None	"None"
DC_SwpType	Sweep type for DC bias at port 2: Single point, Use sweep	None	Single point
DC_Start_2	Start bias level, in V or A depending on DC_mode_2, for DC sweep at port 2 (also used for single value), numerical value only	V or A	3
DC_Stop_2	Stop bias level, in V or A depending on DC_mode_2, for DC sweep at port 2, numerical value only	V or A	4
DC_NumPts_2	Number of points for DC sweep at port 2, numerical value only	None	2

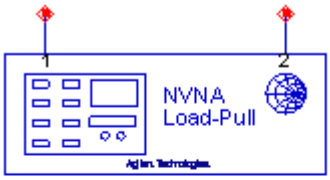
Notes/Equations

1. This component is designed for one-tone two-port X-Parameter Generator to establish frequency, power and DC sweeps for the large signal operating conditions. For more information, refer to *X-Parameter Generator Basics* (xparam).
2. There can be only one NVNA component (NVNA_2port or NVNA_LoadPull) instance per design.
3. Port Number 1 and 2 are used internally by the component. Num 1 and 2 cannot be used by any other XTerm (XP_Source, XP_Load or XP_Bias) component placed on the schematic.
4. The reference impedance for both port 1 and port 2 is 50 Ohm. Port 1 is input port and port 2 is output port. Both Port 1 and Port 2 are terminated with 50 Ohm.
5. When Fund_Start, Fund_Stop and Fund_NumPts are all specified, frequency sweep is performed. When any of Fund_Stop and Fund_NumPts is not specified, Fund_Start is

used for extraction at a single frequency point.

6. When *_SwpType is Single point, *_Start is used as single value.
7. This component must not interact with external sweeps. For that reason all the values (start, stop, num. of pts) must not be defined via external variables.
8. In order to provide a good coverage at all power levels, power sweep is performed in both logarithmic and linear scales. So the total number points for power sweep is 2*LS_NumPts-2.

NVNA_LoadPull (1 Tone 2 port X-Parameter Generator)



NVNA_LoadPull
NVNA
PortNum=1 & 2 used internally
Order=5
Fund_Start=1 GHz
LS_Start=-20
GammaMag_Start=0
GammaPhase_Start=0

Parameters

Name	Description	Units	Default
Port number (or Num)	Port number 1 and 2 are used internally	None	1
Order	The maximum order (harmonic number) of the fundamental that will be considered	None	5
Fund_Start	Fundamental frequency sweep start (also used for single value), numerical value only	Hz	1 GHz
Fund_Stop	Fundamental frequency sweep stop, numerical value only	Hz	1 GHz
Fund_NumPts	number of points for fundamental frequency sweep, numerical value only	None	1
XParamMaxorder	The maximum order of the X-parameters to be sent to the X-parameter	None	3
GmdifEnabled	Enable writing the GMDIF file	None	No
GmdifFile	Name of the GMDIF file (extension .xnp)	None	FileName.xnp
LS_SwpType	Sweep type for large signal power at port 1: Single point, Use sweep	None	Single point
LS_Start	Start power level at port 1, in dBm, for power sweep (also used for single value), numerical value only	dBm	-20
LS_Stop	Stop power level at port 1, in dBm, for power sweep, numerical value only	dBm	-10
LS_NumPts	Number of points for power sweep at port 1, numerical value only	None	2
DC_Mode_1	DC bias mode at port 1: None, Voltage, Current	None	"None"
DC_SwpType_1	Sweep type for DC bias at port 1: Single point, Use sweep	None	Single point
DC_Start_1	Start bias level, in V or A depending on DC_mode_1, for DC sweep at port 1 (also used for single value), numerical value only	V or A	3
DC_Stop_1	Stop bias level, in V or A depending on DC_mode_1, for DC sweep at port 1, numerical value only	V or A	4

DC_NumPts_1	Number of points for DC sweep at port 1, numerical value only	None	2
DC_Mode_2	DC bias mode at port 1: None, Voltage, Current	None	"None"
DC_SwpType_2	Sweep type for DC bias at port 2: Single point, Use sweep	None	Single point
DC_Start_2	Start bias level, in V or A depending on DC_mode_2, for DC sweep at port 2 (also used for single value), numerical value only	V or A	3
DC_Stop_2	Stop bias level, in V or A depending on DC_mode_2, for DC sweep at port 2, numerical value only	V or A	4
DC_NumPts_2	Number of points for DC sweep at port 2, numerical value only	None	2
GammaMag_SwpType	Sweep type for magnitude of gamma-load at port 2: Single point, Use sweep	None	Single point
GammaMag_Start	Start value for magnitude of gamma-load at port 2 (also used for single value), numerical value only	None	0
GammaMag_Stop	Stop value for magnitude of gamma-load at port 2, numerical value only	None	0.1
GammaMag_NumPts	Number of points for magnitude of gamma-load at port 2, numerical value only	None	2
GammaPhase_SwpType	Sweep type for phase of gamma-load at port 2: Single point, Use sweep	None	Single point
GammaPhase_Start	Start value for phase of gamma-load at port 2 (also used for single value), numerical value only	None	0
GammaPhase_Stop	Stop value for phase of gamma-load at port 2, numerical value only	None	30
GammaPhase_NumPts	Number of points for phase of gamma-load at port 2, numerical value only	None	2

Notes/Equations

1. This component is designed for one-tone two-port X-Parameter Generator to establish power and DC sweeps for the large signal operating conditions. Load sweep can be performed at port 2. For more information, refer to *X-Parameter Generator Basics* (xparam).
2. There can be only one NVNA component (NVNA_2port or NVNA_LoadPull) instance per design.
3. Port Number 1 and 2 are used internally by the component. Num 1 and 2 cannot be used by any other XTerm (XP_Source, XP_Load or XP_Bias) component placed on the schematic.
4. The reference impedance for both port 1 and port 2 is 50 Ohm. Port 1 is input port and port 2 is output port.
5. When Fund_Start, Fund_Stop and Fund_NumPts are all specified, frequency sweep is performed. When any of Fund_Stop and Fund_NumPts is not specified, Fund_Start is used for extraction at a single frequency point.
6. When *_SwpType is Single point, *_Start is used as single value.
7. This component must not interact with external sweeps. For that reason all the values (start, stop, num. of pts) must not be defined via external variables.
8. In order to provide a good coverage at all power levels, power sweep is performed in both logarithmic and linear scales. So the total number points for power sweep is 2*LS_NumPts-2.