Agilent Technologies

Advanced Design System 2011.01

Feburary 2011
Sources

Acknowledgments

UMFPACK Availability: http://www.cise.ufl.edu/research/sparse/umfpack UMFPACK (including versions 2.2.1 and earlier, in FORTRAN) is available at http://www.cise.ufl.edu/research/sparse . MA38 is available in the Harwell Subroutine Library. This version of UMFPACK includes a modified form of COLAMD Version 2.0, originally released on Jan. 31, 2000, also available at http://www.cise.ufl.edu/research/sparse . COLAMD V2.0 is also incorporated as a built-in function in MATLAB version 6.1, by The MathWorks, Inc. http://www.mathworks.com . COLAMD V1.0 appears as a column-preordering in SuperLU (SuperLU is available at http://www.netlib.org). UMFPACK v4.0 is a built-in routine in MATLAB 6.5. UMFPACK v4.3 is a built-in routine in MATLAB 7.1.

 Qt Availability: http://www.qtsoftware.com/downloads Patches Applied to Qt can be found in the installation at: $HPEESOF_DIR/prod/licenses/thirdparty/qt/patches. You may also contact Brian Buchanan at Agilent Inc. at brian_buchanan@agilent.com for more information.

Sources, Controlled

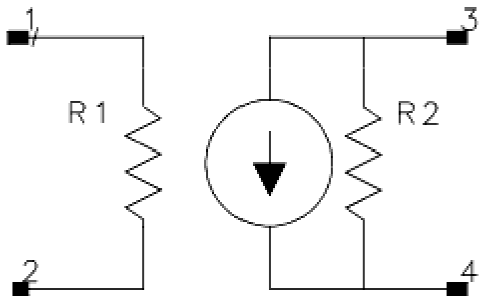
Introduction

> **Note**
> Refer to *Simulator Expressions* (expsim) for predefined functions that can be used to build more complicated expressions.

- *CCCS (Linear Current-Controlled Current Source)* (ccsrc)
- *CCCS Z (Current-Controlled Current Source, Z-Domain)* (ccsrc)
- *CCVS (Linear Current-Controlled Voltage Source)* (ccsrc)
- *CCVS Z (Current-Controlled Voltage Source, Z-Domain)* (ccsrc)
- *VCCS_PR (Linear Voltage-Controlled Current Source, Pole-Residue)* (ccsrc)
- *VCCS (Linear Voltage-Controlled Current Source)* (ccsrc)
- *VCCS PZR (Linear Voltage-Controlled Current Source, Pole-Zero)* (ccsrc)
- *VCCS Z (Voltage-Controlled Current Source, Z-Domain)* (ccsrc)
- *VCVS_PR (Linear Voltage-Controlled Voltage Source, Pole-Residue)* (ccsrc)
- *VCVS (Linear Voltage-Controlled Voltage Source)* (ccsrc)
- *VCVS PZR (Linear Voltage-Controlled Voltage Source, Pole-Zero)* (ccsrc)
- *VCVS Z (Voltage-Controlled Voltage Source, Z-Domain)* (ccsrc)

CCCS (Linear Current-Controlled Current Source)

Symbol



Parameters

Name	Description	Units	Default
G	complex current gain; for example, polar(10, 45) or P(j×omega)/Q(j×omega)	S	1
T	time delay associated with current gain	nsec	0.0
R1	input resistance	Ohm	0
R2	output resistance	Ohm	1e100 †
F	frequency at which current gain magnitude is down by 3 dB	GHz	0.0
ImpNoncausalLength	Non-causal function impulse response order	Integer	None
ImpMode	Convolution mode	Integer	None
ImpMaxFreq	Maximum Frequency to which device is evaluated		None
ImpDeltaFreq	Sample spacing in frequency		None
ImpMaxOrder	Maximum allowed impulse response order	Integer	None
ImpWindow	Smoothing window	Integer	None
ImpRelTol	Relative impulse response truncation factor	None	None
ImpAbsTol	Absolute impulse response truncation factor	None	None

† see Note #2 below

Range of Usage

Setting	Result
F = 0	F = ∞
T = 0	T = 0
R1 = 0	R1 = 0
R2 = 0	R2 = ∞

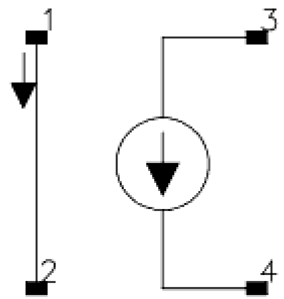
Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. If the default of Rx is large (1e100), then: the entry of 0.0 means infinity and any value greater then 1e20, including the default value, means infinity.
   If the default value of Rx = 0 (short-circuit), no modification to the value of Rx is

made.
3. This source is assumed to be noiseless.
4. $$\beta(f) = G \times \frac{e^{-j(2\pi fT)}}{1 + j(f/F)} \text{ (for F > 0)}$$
$$\beta(f) = G \times e^{-j(2\pi fT)} \text{ (for F = 0)}$$
where
f = simulation frequency in hertz
F = reference frequency in hertz
T = CCCS time delay in seconds
β(*f*) = frequency-dependent current gain
5. For time-domain analysis, the frequency-domain analytical model is used.
6. This source has no default artwork associated with it.

CCCS_Z (Current-Controlled Current Source, Z-Domain)

Symbol



Parameters

Name	Description	Units	Default
Gain	constant gain term	None	1
Num	numerator coefficients of transfer function	None	list(1)
Den	denominator coefficients of transfer function	None	list(1,sqrt(2),1
TimeStep	sampling time period	None	timestep

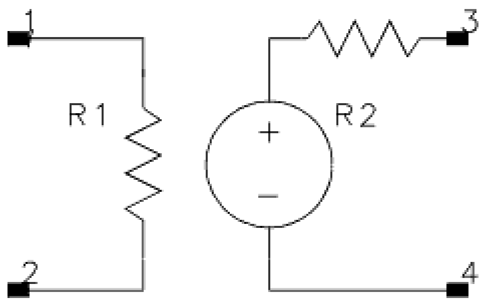
Notes/Equations

1. This model is a current source whose output is linearly proportional to its short circuit input current. It is similar to the CCCS model; instead of specifying the current gain transfer function Ai as a function of frequency, this model allows the transfer function to be defined as a rational polynomial in the Z-Domain. This model can be used in all analysis modes, but becomes especially efficient in the transient and circuit envelope time-domain modes where direct recursive convolution is used instead of inverse FFT convolution. In other modes, the rational polynomial is simply evaluated at
$$z^{-1} = e^{-j \times 2\pi \times freq \times TimeStep}$$
where freq is the analysis frequency.
The transfer function is
$$Ai(z) = \frac{Iout(z)}{Iin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$
The a_i coefficients are defined by the Num parameter list, which can be created by either a LIST ARRAY equation or a DATASET ARRAY equation. a_0 is first and a_M is last in the list. Similarly, the b_i coefficients are defined by the Den parameter list. The value if b_0 must not be 0. If the Den parameter is not given, it is assumed to equal 1.0.
2. The Gain parameter must be a constant and must not depend on frequency. It, and the polynomial coefficients, should not be complex valued.
3. The TimeStep parameter determines the unit delay time of each z^{-1} block and, in a

sampled system, would correspond to the sampling interval. The input to this transfer function is not automatically sampled in this model. For a sampled signal, preface this model with either the sample-hold or sampler model. Note that the frequency response of the Z-domain transfer function is cyclical and repeats every 1/TimeStep Hertz.
4. In circuit envelope simulation, only the baseband spectral component is filtered by the transfer function.

CCVS (Linear Current-Controlled Voltage Source)

Symbol



Parameters

Name	Description	Units	Default
G	complex transresistance; for example, polar(10 Ohm, 45) or P(j×omega)/Q(j×omega)	Ohm	1
T	time delay associated with transresistance	nsec	0.0
R1	input resistance	Ohm	0
R2	output resistance	Ohm	0
F	frequency at which transresistance magnitude is down by 3dB	GHz	0.0
ImpNoncausalLength	Non-causal function impulse response order; an integer	Integer	None
ImpMode	Convolution mode; an integer	Integer	None
ImpMaxFreq	Maximum Frequency to which device is evaluated	None	None
ImpDeltaFreq	Sample spacing in frequency	None	None
ImpMaxOrder	Maximum allowed impulse response order; an integer	Integer	None
ImpWindow	Smoothing window; an integer	Integer	None
ImpRelTol	Relative impulse response truncation factor	None	None
ImpAbsTol	Absolute impulse response truncation factor	None	None

Range of Usage

Setting	Result
F = 0	F = ∞
T = 0	T = 0
R1 = 0	R1 = 0
R2 = 0	R2 = 0

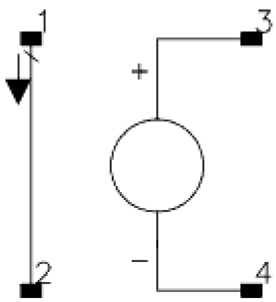
Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.

2. This source is assumed to be noiseless.
3. $$R(f) = G \times \frac{e^{-j(2\pi fT)}}{1 + j(f/F)} \text{ (for F > 0)}$$
   $$R(f) = G \times e^{-j(2\pi fT)} \text{ (for F = 0)}$$
   where
   R (*f*) = frequency-dependent transresistance
   f = simulation frequency in hertz
   F = reference frequency in hertz
   T = CCVS time delay in seconds
4. For transient analysis, the transresistance is independent of frequency, and there is no phase shift or time delay associated with the transresistance.
5. For convolution analysis, the frequency-domain analytical model is used.
6. This source has no default artwork associated with it.

CCVS_Z (Current-Controlled Voltage Source, Z-Domain)

Symbol



Parameters

Name	Description	Units	Default
Gain	constant gain term	None	1
Num	numerator coefficients of transfer function	None	list(1)
Den	denominator coefficients of transfer function	None	list(1,sqrt(2),1)
TimeStep	sampling time period	None	timestep

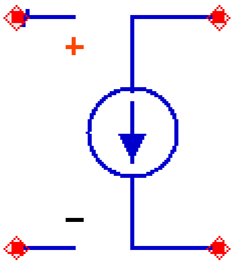
Notes/Equations

1. This model is a voltage source whose output is linearly proportional to its short circuit input current. Similar to the CCVS model, instead of specifying the transfer function Z21 as a function of frequency, this model allows the transfer function to be defined as a rational polynomial in the Z-Domain.
   This model can be used in all analysis modes, but becomes especially efficient in the transient and circuit envelope time-domain modes where direct recursive convolution is used instead of inverse FFT convolution. In the other modes, the rational polynomial is simply evaluated at
   $z^{-1} = e^{-j \times 2\pi \times freq \times TimeStep}$
   where freq is the analysis frequency.
   The transfer function is
   $$Z21(z) = \frac{Vout(z)}{Iin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$
   The a_i *coefficients are defined by the Num parameter list, which can be created by either a LIST ARRAY equation or a DATASET ARRAY equation. _*a_0 is first and a_M is last in the list. Similarly, the b_i coefficients are defined by the Den parameter list. The value if b_0 must not be 0. If the Den parameter is not given, it is assumed to equal 1.0.
2. The Gain parameter must be a constant and not depend on frequency. It, and the polynomial coefficients, should not be complex valued.

3. The TimeStep parameter determines the unit delay time of each z^{-1} block and, in a sampled system, would correspond to the sampling interval. The input to this transfer function is not automatically sampled in this model. For a sampled signal, preface this model with either the sample-hold or sampler model. Note that the frequency response of the Z-domain transfer function is cyclical and repeats every 1/TimeStep Hertz.
4. In circuit envelope simulation, only the baseband spectral component is filtered by the transfer function.

VCCS_PR (Linear Voltage-Controlled Current Source, Pole-Residue)

Symbol



Parameters

Name	Description	Units	Default
Poles	Specification for the denominators in the transfer function. See details below.	None	list(1)
Residues	Specification for the residues, capacitance term and constant term. See details below.	None	list(0,1)
Scale	Amplitude scaling factor	None	1.0
TC1	Temperature coefficient, per degree Celsius	1/°C	0
TC2	Temperature coefficient, per degree Celsius squared	$1/°C^2$	0

Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. The relation between the output and the input signals are determined by
   $I_{out} = V_{in} * Scale * [1 + TC1 * (Temp - Tnom) + TC2 * (Temp - Tnom)^2] * H(s)$
   where *H*(*s*) is a transfer function defined as
   $$H(s) = s * Cap + Const + \frac{1}{b}\sum_{i=1}^{N}\frac{Re_i + jIm_i}{s + \alpha_{pi} + j2\pi f_{pi}}$$
   where *N* is the total number of poles.
3. *H*(*s*) is specified by parameters Poles and Residues in the following format.
   $Poles = list(b, \alpha_{p1}, f_{p1}, \ldots, \alpha_{pm}, f_{pm})$
   $Residues = list(Cap, Const, Re_1, Im_1, \ldots, Re_{1m}, Im_{1m})$
   Parameters Poles and Residues are lists of real numbers. See Example 1.
4. The poles of *H*(*s*) are either real numbers or in complex conjugate pairs. For a real pole, the *f* value must be specified as 0. See Example 2. For a complex conjugate pair of poles, only one of the two complex values should be specified. See Example 3.
5. Each residue specified in parameter Residues is paired with the corresponding pole specified in parameter Poles, as shown in the transfer function. The number of residues must be equal to the number of poles. For a real residue, the *Im* value must be specified as 0.
6. Note the sign difference between the *α* values and the actual real parts of poles. For example, Poles=list(1,1,2), Residues=list(1,1,3,2) specifies the transfer function

$$H(s) = s + 1 + \frac{3 + j2}{s + 1 + j2\pi} + \frac{3 - j2}{s + 1 - j2\pi}$$

which has the actual poles at $-1 \pm j2\pi$.

7. Duplicated poles are not supported currently.
8. This component is assumed to be noiseless.

Examples

1. To specify the transfer function

$$H(s) = \frac{1+j0.3}{(s+0.2+j2\pi*10^5)} + \frac{1-j0.3}{(s+0.2-j2\pi*10^5)} + \frac{3}{(s+0.5+j2\pi*10^7)} + \frac{3}{(s+0.5-j2\pi*10^7)}$$

   Poles and Residues should be set to

   Poles=list(1,0.2,1e5,0.5,1e7)

   Residues=list(0,0,1,0.3,3,0)

2. For $H(s)$=1/(s+1), the correct setup is

   Poles=list(1,1,0)

   Residues=list(0,0,1,0)

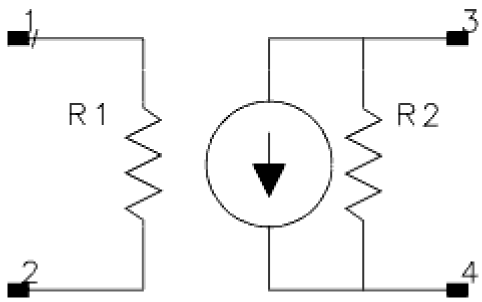
3. For the transfer function

$$H(s) = \frac{1}{(s + 0.2 + j2\pi * 10^5)} + \frac{1}{(s + 0.2 - j2\pi * 10^5)}$$

   Poles can be set to either list(1,0.2,1e5) or list(1,0.2,-1e5).

VCCS (Linear Voltage-Controlled Current Source)

Symbol



Parameters

Name	Description	Units	Default
G	complex current gain; for example, polar(1 S, 45) or P(j×omega)/Q(j×omega)	S	1
T	time delay associated with current gain	nsec	0.0
R1	input resistance	Ohm	1e100 †
R2	output resistance	Ohm	1e100 †
F	frequency at which current gain magnitude is down by 3 dB	GHz	0.0
ImpNoncausalLength	Non-causal function impulse response order	Integer	None
ImpMode	Convolution mode	Integer	None
ImpMaxFreq	Maximum Frequency to which device is evaluated	None	None
ImpDeltaFreq	Sample spacing in frequency	None	None
ImpMaxOrder	Maximum allowed impulse response order	Integer	None
ImpWindow	Smoothing window	Integer	None
ImpRelTol	Relative impulse response truncation factor	None	None
ImpAbsTol	Absolute impulse response truncation factor	None	None

† See Note #2 below

Setting	Result
F = 0	F = ∞
T = 0	T = 0
R1 = 0	R1 = ∞
R2 = 0	R2 = ∞

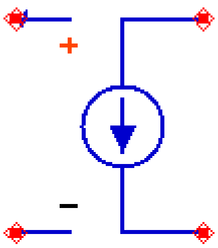
Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. If the default of Rx is large (1e100), then: the entry of 0.0 means infinity and any value greater then 1e20, including the default value, means infinity.
   If the default value of Rx = 0 (short-circuit), no modification to the value of Rx is made.
3. This source is assumed to be noiseless.

4. $$G(f) = G \times \frac{e^{-j(2\pi fT)}}{1 + j(f/F)} \text{ (for F0} \neq 0\text{)}$$
$$G(f) = G \times e^{-j(2\pi fT)} \text{ (for F} = 0\text{)}$$
where
f = simulation frequency in hertz
F = reference frequency in hertz
T = VCCS time delay in seconds
G (*f*) = frequency-dependent transconductance
5. For time-domain analysis, the frequency-domain analytical model is used.
6. This component has no default artwork associated with it.

VCCS_PZR (Linear Voltage-Controlled Current Source, Pole-Zero)

Symbol



Parameters

Name	Description	Units	Default
Poles	Specification for the transfer function's denominator. See details below.	None	list(1)
Zeros	Specification for the transfer function's numerator. See details below.	None	list(1)
Scale	Amplitude scaling factor	None	1.0
TC1	Temperature coefficient, per degree Celsius	1/°C	0
TC2	Temperature coefficient, per degree Celsius squared	$1/°C^2$	0

Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. The relation between the output and the input signals are determined by
   $I_{out} = V_{in} \cdot \mathrm{Scale} \cdot [1 + \mathrm{TC1} \cdot (\mathrm{Temp} - \mathrm{Tnom}) + \mathrm{TC2} \cdot (\mathrm{Temp} - \mathrm{Tnom})^2] \cdot H(s)$
   where *H*(*s*) is a rational transfer function defined as
   $$H(s) = \frac{a(s + \alpha_{z1} - j2\pi f_{z1})(s + \alpha_{z1} + j2\pi f_{z1})\ldots(s + \alpha_{zn} - j2\pi f_{zn})(s + \alpha_{zn} + j2\pi f_{zn})}{b(s + \alpha_{p1} - j2\pi f_{p1})(s + \alpha_{p1} + j2\pi f_{p1})\ldots(s + \alpha_{pm} - j2\pi f_{pm})(s + \alpha_{pm} + j2\pi f_{pm})}$$
3. *H*(*s*) is specified by Poles and Zeros in the following format.
   $\mathrm{Poles} = \mathrm{list}(b, \alpha_{p1}, f_{p1}, \ldots, \alpha_{pm}, f_{pm})$
   $\mathrm{Zeros} = \mathrm{list}(a, \alpha_{z1}, f_{z1}, \ldots, \alpha_{zn}, f_{zn})$
   Poles and Zeros are lists of real numbers. See Example 1.
   Note that α values specify the real part of poles/zeros in the unit of rad/s and f values specify the imaginary part in the unit of Hz.
4. Poles and zeros of *H*(*s*) are either real numbers or in complex conjugate pairs. For a real pole/zero, the *f* value must be specified as 0. See Example 2. For a complex conjugate pair, only one of the two complex values should be specified. See Example 3.
5. Note the sign difference between the *α* values and the actual real parts of poles/zeros. For example, Poles=list(1,1,2), Zeros=list(1,1,0) specifies the transfer function
   $$H(s) = \frac{s + 1}{(s + 1 + j2\pi)(s + 1 - j2\pi)}$$
   which has the actual poles at $-1 \pm j2\pi$ and zero at -1.
   The order of the numerator of *H*(*s*) cannot be greater than the order of the

6. denominator plus 1.
7. Duplicated poles or zeros currently are not supported.
8. This component is assumed to be noiseless.

Examples

1. To specify the transfer function

$$H(s) = \frac{V_{out}}{V_{in}}$$

$$= \frac{10(s+1)(s+7*10^3+j2\pi\cdot 10^3)(s+7*10^3-j2\pi\cdot 10^3)}{(s+2*10^5+j2\pi\cdot 10^5)(s+2*10^5-j2\pi\cdot 10^5)(s+5*10^7+j2\pi\cdot 2*10^3)(s+5*10^7-j2\pi\cdot 2*10^3)}$$

Poles and Zeros should be set to

Poles=list(1,2e5,1e5,5e7,2e3)

Zeros=list(10,1,0,7e3,1e3)

Fig. 1 and Fig. 2 show the magnitude and phase (in degrees) of the above transfer function.

Figure 1: Magnitude of the transfer function in Example 1

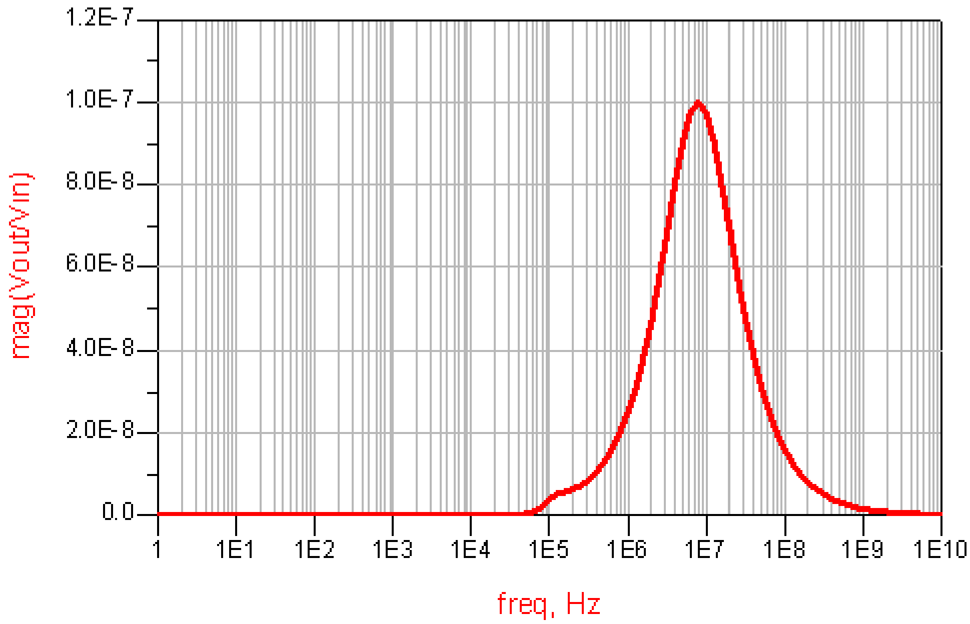
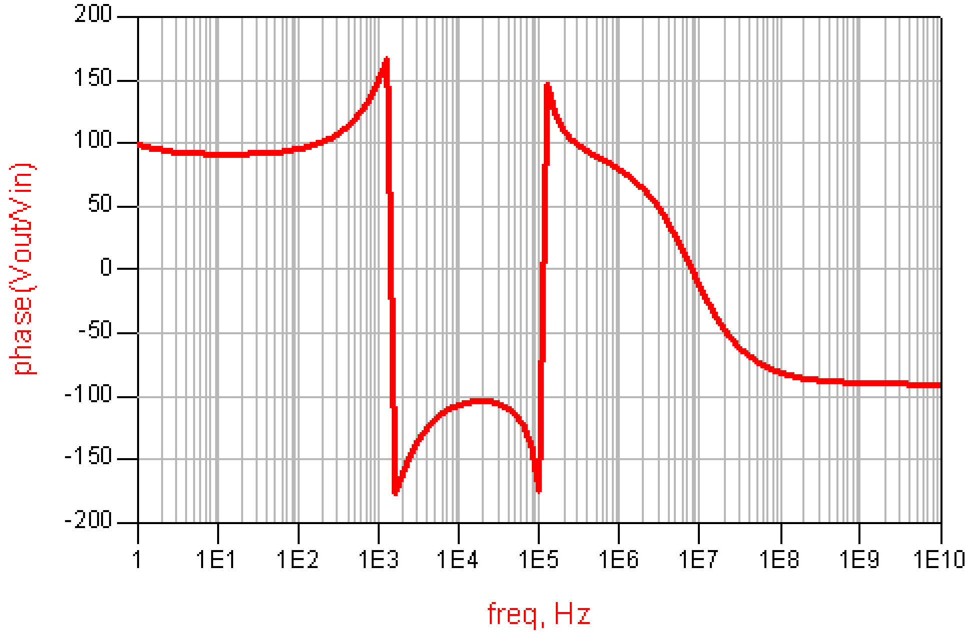


Figure 2: Phase (in degrees) of the transfer function in Example 1



2. For $H(s)$=s+1, the correct setup is

   Poles=list(1)

   Zeros=list(1,1,0)

   Zeros cannot be set to list(1,1).
3. For the function

   $$H(s)=\frac{1}{(s+0.2+j2\pi\cdot 10^5)(s+0.2-j2\pi\cdot 10^5)}$$

   Poles can be set to list(1,0.2,1e5) or list(1,0.2,-1e5). If Poles is set to list(1,0.2,1e5,0.2,-1e5), the resultant transfer function would be

   $$H(s)=\frac{1}{(s+0.2+j2\pi\cdot 10^5)^2(s+0.2-j2\pi\cdot 10^5)^2}$$

   which contains duplicated poles and is not currently supported.
4. In Channel Simulation, a different format, the complex pole/zero format is used to define the transfer function for the CTLE equalization. For example, we take the transfer function in Example 1:

   $$H(s)=\frac{10\,(s+1)(s+7*10^3+j2\pi\cdot 10^3)(s+7*10^3-j2\pi\cdot 10^3)}{(s+2*10^5+j2\pi\cdot 10^5)(s+2*10^5-j2\pi\cdot 10^5)(s+5*10^7+j2\pi\cdot 2*10^3)(s+5*10^7-j2\pi\cdot 2*10^3)}$$

   It can be defined in the complex pole/zero format by specifying

   Zero[1]=-1

   Zero[2]=-7e3-j*2*pi*1e3

   Pole[1]=-2e5-j*2*pi*1e5

   Pole[2]=-5e7-j*2*pi*2e3

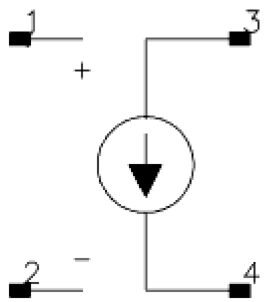
   Pre-factor = 10

Comparing the above specification with Example 1, we can see that the following steps are needed to convert the complex pole/zero format (referenced as format(A) below) to the format used for VCCS PZR (referenced as format (B) below).

- Set scaling factor: take the parameter Pre-factor in (A) and put it as the first number in the list() for Zeros in (B). Then set the first number in the list() for Poles in (B) to 1. This is the easiest way but not the only way to translate Pre-factor. For instance, one can also set the first number in the list() for Poles in (B) to the value of 1/Pre-factor and set the first number in the list() for Zeros to 1.
- Add zeros and poles: suppose Zero[i] in (A) is a complex number a+jb. Append the two real numbers –a and – b/(2*pi) to the list() for Zeros in (B). If Zero[i] is real, i.e., b=0, append two real numbers –a and 0 to the list() for Zeros in (B). Use the same approach for adding poles to the list() for Poles in (B).
  It should not be difficult to convert format (B) to format (A). One thing to be noted is the calculation of Pre-factor in format (A). Suppose in format (B), the first number in the list() for Zeros is a and the first number in the list() for Poles is b. Then Pre-factor = Scale*a/b, where Scale is the amplitude scaling factor in format (B).

VCCS_Z (Voltage-Controlled Current Source, Z-Domain)

Symbol



Parameters

Name	Description	Units	Default
Gain	constant gain term	None	1
Num	numerator coefficients of transfer function	None	list(1)
Den	denominator coefficients of transfer function	None	list(1,sqrt(2),1)
TimeStep	sampling time period	None	timestep

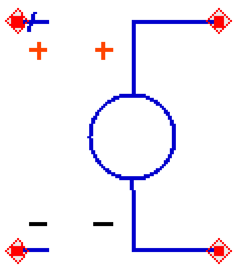
Notes/Equations

1. This model is a current source whose output is linearly proportional to its short circuit input voltage. Similar to the VCCS model, instead of specifying the transfer function Y21 as a function of frequency, this model allows the transfer function to be defined as a rational polynomial in the Z-Domain. This model can be used in all simulations, but becomes especially efficient in the transient and circuit envelope time-domain modes where direct recursive convolution is used instead of inverse FFT convolution. In the other modes, the rational polynomial is simply evaluated at
   $$z^{-1} = e^{-j \times 2\pi \times freq \times TimeStep}$$
   where freq is the analysis frequency.
   The transfer function is
   $$Y21(z) = \frac{Iout(z)}{Vin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$
   The a_i coefficients are defined by the Num parameter list, which can be created by either a LIST ARRAY equation or a DATASET ARRAY equation. a_0 is first and a_M is last in the list. Similarly, the b_i coefficients are defined by the Den parameter list. The value if b_0 must not be 0. If the Den parameter is not given, it is assumed to equal 1.0.
2. The Gain parameter must be a constant and not depend on frequency. It, and the polynomial coefficients, should not be complex valued.

3. The TimeStep parameter determines the unit delay time of each z^{-1} block, and, in a sampled system, would correspond to the sampling interval. The input to this transfer function is not automatically sampled in this model.
   For a sampled signal, preface this model with either the sample-hold or sampler model. Note that the frequency response of the Z-domain transfer function is cyclical and repeats every 1/TimeStep Hertz.
   The default value for TimeStep is *timestep*, which is a global variable. If using Circuit Envelope analysis, it is set using the TimeStep parameter. For AC simulation, TimeStep is zero.
4. In circuit envelope analysis, only the baseband spectral component is filtered by the transfer function.

VCVS_PR (Linear Voltage-Controlled Voltage Source, Pole-Residue)

Symbol



Parameters

Name	Description	Units	Default
Poles	Specification for the denominators in the transfer function. See details below.	None	list(1)
Residues	Specification for the residues, capacitance term and constant term. See details below.	None	list(0,1)
Scale	Amplitude scaling factor	None	1.0
TC1	Temperature coefficient, per degree Celsius	1/°C	0
TC2	Temperature coefficient, per degree Celsius squared	1/°C^2	0

Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. The relation between the output and the input signals are determined by
   $$V_{out} = V_{in} * Scale * [1 + TC1 * (Temp - Tnom) + TC2 * (Temp - Tnom)^2] * H(s)$$
   where $H(s)$ is a transfer function defined as
   $$H(s) = s * Cap + Const + \frac{1}{b}\sum_{i=1}^{N}\frac{Re_i + jIm_i}{s + \alpha_{pi} + j2\pi f_{pi}}$$
   where N is the total number of poles.
3. $H(s)$ is specified by parameters Poles and Residues in the following format.
   $$Poles = list(b, \alpha_{p1}, f_{p1}, \ldots, \alpha_{pm}, f_{pm})$$
   $$Residues = list(Cap, Const, Re_1, Im_1, \ldots, Re_{1m}, Im_{1m})$$
   Parameters Poles and Residues are lists of real numbers. See Example 1.
4. The poles of $H(s)$ are either real numbers or in complex conjugate pairs. For a real pole, the f value must be specified as 0. See Example 2. For a complex conjugate pair of poles, only one of the two complex values should be specified. See Example 3.
5. Each residue specified in parameter Residues is paired with the corresponding pole specified in parameter Poles, as shown in the transfer function. The number of residues must be equal to the number of poles. For a real residue, the *Im* value must be specified as 0.
6. Note the sign difference between the α values and the actual real parts of poles. For example, Poles=list(1,1,2), Residues=list(1,1,3,2) specifies the transfer function

$$H(s) = s + 1 + \frac{3 + j2}{s + 1 + j2\pi} + \frac{3 - j2}{s + 1 - j2\pi}$$

which has the actual poles at $-1 \pm j2\pi$.

7. Duplicated poles are not supported currently.
8. This component is assumed to be noiseless.

Examples

1. To specify the transfer function

$$H(s) = \frac{1+j0.3}{(s+0.2+j2\pi*10^5)} + \frac{1-j0.3}{(s+0.2-j2\pi*10^5)} + \frac{3}{(s+0.5+j2\pi*10^7)} + \frac{3}{(s+0.5-j2\pi*10^7)}$$

   Poles and Residues should be set to

   Poles=list(1,0.2,1e5,0.5,1e7)

   Residues=list(0,0,1,0.3,3,0)

2. For *H*(*s*)=1/(s+1), the correct setup is

   Poles=list(1,1,0)

   Residues=list(0,0,1,0)

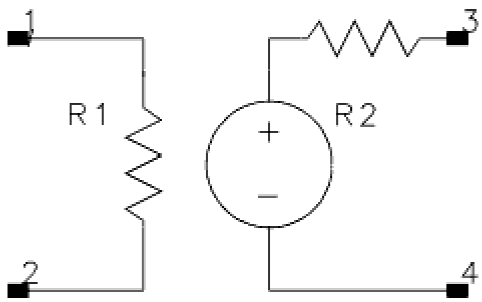
3. For the transfer function

$$H(s) = \frac{1}{(s + 0.2 + j2\pi * 10^5)} + \frac{1}{(s + 0.2 - j2\pi * 10^5)}$$

   Poles can be set to either list(1,0.2,1e5) or list(1,0.2,-1e5).

VCVS (Linear Voltage-Controlled Voltage Source)

Symbol



Parameters

Name	Description	Units	Default
G	complex current gain; for example, polar(1 S, 45) or P(j×omega)/Q(j×omega)	None	1
T	time delay associated with current gain	nsec	0.0
R1	input resistance	Ohm	1e100 †
R2	output resistance	Ohm	0
F	frequency at which current gain magnitude is down by 3 dB	GHz	0.0
ImpNoncausalLength	Non-causal function impulse response order	Integer	None
ImpMode	Convolution mode	Integer	None
ImpMaxFreq	Maximum Frequency to which device is evaluated	None	None
ImpDeltaFreq	Sample spacing in frequency	None	None
ImpMaxOrder	Maximum allowed impulse response order	Integer	None
ImpWindow	Smoothing window	Integer	None
ImpRelTol	Relative impulse response truncation factor	None	None
ImpAbsTol	Absolute impulse response truncation factor	None	None

† See Note #2 below

Setting	Result
F = 0	F = ∞
T = 0	T = 0
R1 = 0	R1 = ∞
R2 = 0	R2 = 0

Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. If the default of Rx is large (1e100), then: the entry of 0.0 means infinity and any value greater then 1e20, including the default value, means infinity.
   If the default value of Rx = 0 (short-circuit), no modification to the value of Rx is made.
3. This component is assumed to be noiseless.

4. Voltage gain =

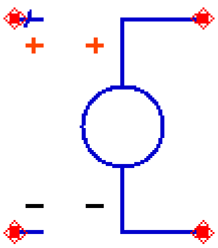
$$\mu(f) = G \times \frac{e^{-j(2\pi f T)}}{1 + j\frac{f}{F}} \text{ (for F} \neq 0\text{)}$$

$$\mu(f) = G \times e^{-j(2\pi f T)} \text{ (for F} = 0\text{)}$$

   where
   f = simulation frequency in hertz
   F = reference frequency in hertz
   T = VCVS time delay in seconds
   μ(*f*) = frequency-dependent voltage gain
5. For time-domain analysis, the frequency-domain analytical model is used.
6. This component has no default artwork associated with it.

VCVS_PZR (Linear Voltage-Controlled Voltage Source, Pole-Zero)

Symbol



Parameters

Name	Description	Units	Default
Poles	Specification for the transfer function's denominator. See details below.	None	list(1)
Zeros	Specification for the transfer function's numerator. See details below.	None	list(1)
Scale	Amplitude scaling factor	None	1.0
TC1	Temperature coefficient, per degree Celsius	1/°C	0
TC2	Temperature coefficient, per degree Celsius squared	$1/°C^2$	0

Notes/Equations

1. This is a purely linear, dependent source model. Nonlinear controlled sources are available in the Eqn Based-Nonlinear component palette.
2. The relation between the output and the input signals are determined by
   $V_{out} = V_{in} \cdot \mathrm{Scale} \cdot [1 + \mathrm{TC1} \cdot (\mathrm{Temp} - \mathrm{Tnom}) + \mathrm{TC2} \cdot (\mathrm{Temp} - \mathrm{Tnom})^2] \cdot H(s)$
   where *H*(*s*) is a rational transfer function defined as
   $$H(s) = \frac{a(s + \alpha_{z1} - j2\pi f_{z1})(s + \alpha_{z1} + j2\pi f_{z1}) \ldots (s + \alpha_{zn} - j2\pi f_{zn})(s + \alpha_{zn} + j2\pi f_{zn})}{b(s + \alpha_{p1} - j2\pi f_{p1})(s + \alpha_{p1} + j2\pi f_{p1}) \ldots (s + \alpha_{pm} - j2\pi f_{pm})(s + \alpha_{pm} + j2\pi f_{pm})}$$
3. *H*(*s*) is specified by Poles and Zeros in the following format.
   $\mathrm{Poles} = \mathrm{list}(b, \alpha_{p1}, f_{p1}, \ldots, \alpha_{pm}, f_{pm})$
   $\mathrm{Zeros} = \mathrm{list}(a, \alpha_{z1}, f_{z1}, \ldots, \alpha_{zn}, f_{zn})$
   Poles and Zeros are lists of real numbers. See Example 1.
   Note that α values specify the real part of poles/zeros in the unit of rad/s and *f* values specify the imaginary part in the unit of Hz.
4. Poles and zeros of *H*(*s*) are either real numbers or in complex conjugate pairs. For a real pole/zero, the *f* value must be specified as 0. See Example 2. For a complex conjugate pair, only one of the two complex values should be specified. See Example 3.
5. Note the sign difference between the *α* values and the actual real parts of poles/zeros. For example, Poles=list(1,1,2), Zeros=list(1,1,0) specifies the transfer function
   $$H(s) = \frac{s + 1}{(s + 1 + j2\pi)(s + 1 - j2\pi)}$$
   which has the actual poles at $-1 \pm j2\pi$ and zero at -1.

6. The order of the numerator of $H(s)$ cannot be greater than the order of the denominator plus 1.
7. Duplicated poles or zeros currently are not supported.
8. This component is assumed to be noiseless.

Examples

1. To specify the transfer function

$$H(s) = \frac{V_{out}}{V_{in}}$$

$$= \frac{10(s+1)(s+7*10^3+j2\pi\cdot10^3)(s+7*10^3-j2\pi\cdot10^3)}{(s+2*10^5+j2\pi\cdot10^5)(s+2*10^5-j2\pi\cdot10^5)(s+5*10^7+j2\pi\cdot2*10^3)(s+5*10^7-j2\pi\cdot2*10^3)}$$

Poles and Zeros should be set to

Poles=list(1,2e5,1e5,5e7,2e3)

Zeros=list(10,1,0,7e3,1e3)

Fig. 1 and Fig. 2 show the magnitude and phase (in degrees) of the above transfer function.

Figure 1: Magnitude of the transfer function in Example 1

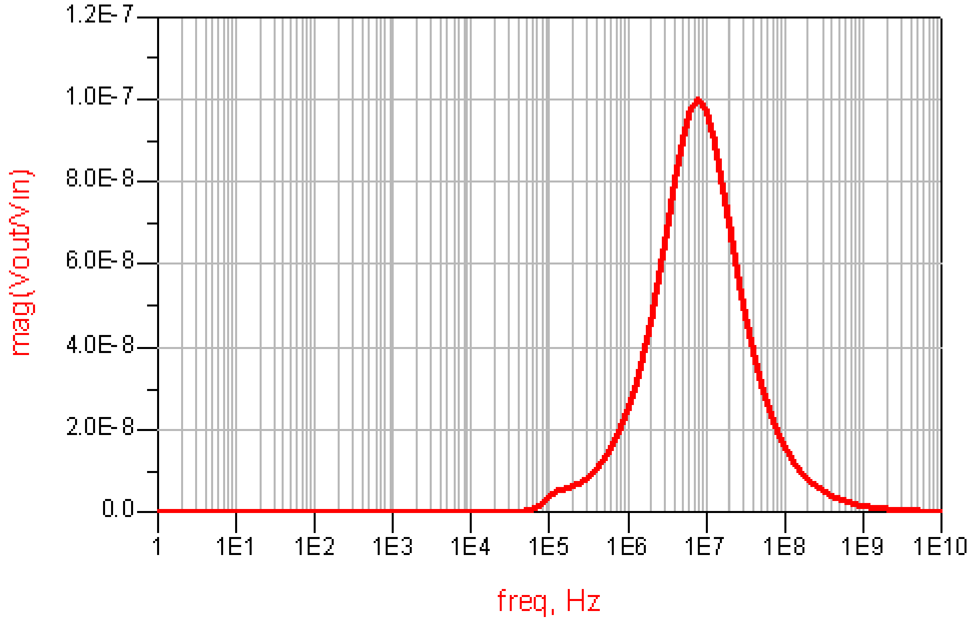
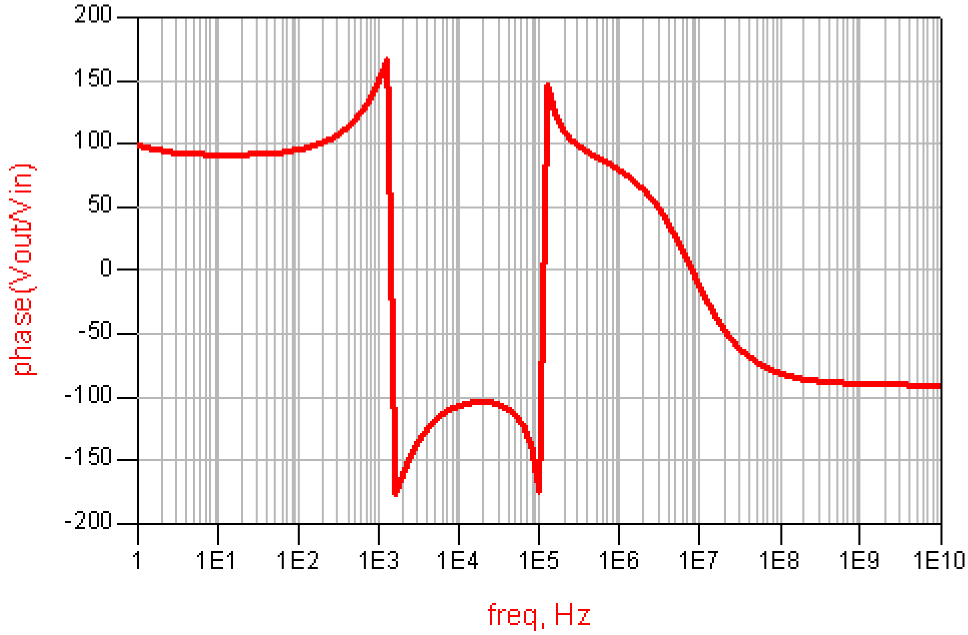


Figure 2: Phase (in degrees) of the transfer function in Example 1



2. For *H*(*s*)=s+1, the correct setup is

   Poles=list(1)

   Zeros=list(1,1,0)

   Zeros cannot be set to list(1,1).
3. For the function

   $$H(s)=\frac{1}{(s+0.2+j2\pi\cdot10^5)(s+0.2-j2\pi\cdot10^5)}$$

   Poles can be set to list(1,0.2,1e5) or list(1,0.2,-1e5). If Poles is set to list(1,0.2,1e5,0.2,-1e5), the resultant transfer function would be

   $$H(s)=\frac{1}{(s+0.2+j2\pi\cdot10^5)^2(s+0.2-j2\pi\cdot10^5)^2}$$

   which contains duplicated poles and is not currently supported.
4. In Channel Simulation, a different format, the complex pole/zero format is used to define the transfer function for the CTLE equalization. For example, we take the transfer function in Example 1:

   $$H(s)=\frac{10\,(s+1)(s+7*10^3+j2\pi\cdot10^3)(s+7*10^3-j2\pi\cdot10^3)}{(s+2*10^5+j2\pi\cdot10^5)(s+2*10^5-j2\pi\cdot10^5)(s+5*10^7+j2\pi\cdot2*10^3)(s+5*10^7-j2\pi\cdot2*10^3)}$$

   It can be defined in the complex pole/zero format by specifying

   Zero[1]=-1

   Zero[2]=-7e3-j*2*pi*1e3

   Pole[1]=-2e5-j*2*pi*1e5

   Pole[2]=-5e7-j*2*pi*2e3

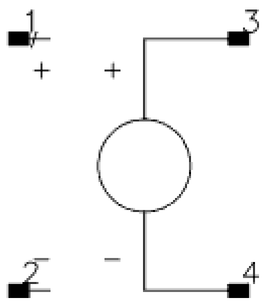
   Pre-factor = 10

Comparing the above specification with Example 1, we can see that the following steps are needed to convert the complex pole/zero format (referenced as format(A) below) to the format used for VCVS PZR (referenced as format (B) below).

- Set scaling factor: take the parameter Pre-factor in (A) and put it as the first number in the list() for Zeros in (B). Then set the first number in the list() for Poles in (B) to 1. This is the easiest way but not the only way to translate Pre-factor. For instance, one can also set the first number in the list() for Poles in (B) to the value of 1/Pre-factor and set the first number in the list() for Zeros to 1.
- Add zeros and poles: suppose Zero[i] in (A) is a complex number a+jb. Append the two real numbers –a and – b/(2*pi) to the list() for Zeros in (B). If Zero[i] is real, i.e., b=0, append two real numbers –a and 0 to the list() for Zeros in (B). Use the same approach for adding poles to the list() for Poles in (B).
  It should not be difficult to convert format (B) to format (A). One thing to be noted is the calculation of Pre-factor in format (A). Suppose in format (B), the first number in the list() for Zeros is a and the first number in the list() for Poles is b. Then Pre-factor = Scale*a/b, where Scale is the amplitude scaling factor in format (B).

VCVS_Z (Voltage-Controlled Voltage Source, Z-Domain)

Symbol



Parameters

Name	Description	Units	Default
Gain	constant gain term	None	1
Num	numerator coefficients of transfer function	None	list(1)
Den	denominator coefficients of transfer function	None	list(1,sqrt(2),1)
TimeStep	sampling time period	None	timestep

Notes/Equations

1. This model is a voltage source whose output is linearly proportional to its open circuit input voltage. Similar to the VCVS model, instead of specifying the voltage gain transfer function Av as a function of frequency, this model allows the transfer function to be defined as a rational polynomial in the Z-Domain. This model is usable in all analysis modes, but becomes especially efficient in the transient and circuit envelope time-domain modes, where direct recursive convolution is used instead of inverse FFT convolution. In the other analysis modes, the rational polynomial is simply evaluated at
   $$z^{-1} = e^{-j \times 2\pi \times freq \times TimeStep}$$
   where freq is the analysis frequency.
   The transfer function is
   $$Av(z) = \frac{Vout(z)}{Vin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$
   The a_i coefficients are defined by the Num parameter list, which can be created by either a LIST ARRAY equation or a DATASET ARRAY equation.
   a_0 is first in the list and a_M is last. Similarly, the b_i coefficients are defined by the Den parameter list. The value if b_0 must not be 0. If the Den parameter is not given, it is assumed to equal 1.0.
2. The Gain parameter must be a constant and must not depend on frequency. It, and the polynomial coefficients, should not be complex valued.

3. The TimeStep parameter determines the unit delay time of each z^{-1} block, and, in a sampled system, would correspond to the sampling interval. The input to this transfer function is not automatically sampled in this model.
   For a sampled signal, preface this model with either the sample-hold or sampler model. Note that the frequency response of the Z-domain transfer function is cyclical and repeats every 1/TimeStep Hertz.
   The default value for TimeStep is *timestep*, which is a global variable. If using Circuit Envelope analysis, it is set using the TimeStep parameter. For AC simulation, TimeStep is zero.
4. In circuit envelope analysis, only the baseband spectral component is filtered by the transfer function.

Sources, Frequency Domain

Introduction

A frequency domain source generates a periodic waveform or a superposition of periodic waveforms. Frequency domain sources are often used as stimuli to find the steady-state response of a circuit.

Independent voltage sources, current sources, and power source are provided in Advanced Design System. Power sources have built-in impedances that can also be used as reference impedance for S-parameter simulation.

Frequency domain sources can be used in all simulations. In S-parameter simulation, voltage sources are treated as short circuits, current sources are treated as open circuits, and power sources are treated as impedances.

Amplitudes in frequency domain sources can be set to complex values such as V = Re + j × Im, I=polar (Mag, Angle), P=polar(dbmtow(dBm), Angle). When these sources are used in baseband transient simulation, only the real part of the signal is used, the imaginary part is dropped.

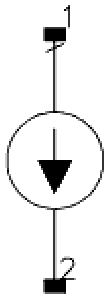
Note
Refer to the *Simulator Expressions* (expsim) for predefined functions that can be used to build more complicated expressions.

- *I 1Tone (Current Source, Single Frequency)* (ccsrc)
- *I AC (AC current source)* (ccsrc)
- *I DC (DC current source)* (ccsrc)
- *I HB Dataset (Current Source, HB Dataset Variable)* (ccsrc)
- *I nHarm (Current Source, Fundamental Frequency with N-Harmonics)* (ccsrc)
- *I nTone (Current Source, N Frequencies and Amplitudes)* (ccsrc)
- *I SpectrumDataset (Current Source, Frequency Spectrum Defined in Dataset)* (ccsrc)
- *OSCwPhNoise (Oscillator with Phase Noise)* (ccsrc)
- *P 1Tone (Power Source, Single Frequency)* (ccsrc)
- *P AC (AC Power Source)* (ccsrc)
- *P nHarm (Power Source, Fundamental Frequency with N-Harmonics)* (ccsrc)
- *P nTone (Power Source, N Frequencies and Power Levels)* (ccsrc)
- *P SpectrumDataset (Power Source, Frequency Spectrum Defined in Dataset)* (ccsrc)
- *V 1Tone (Voltage Source, Single Frequency)* (ccsrc)
- *V AC (AC Voltage Source)* (ccsrc)
- *V DC (DC Voltage Source, Frequency Domain)* (ccsrc)
- *Vf BitSeq (Fourier Transform of Bit Sequence Waveform)* (ccsrc)
- *Vf Pulse (Voltage Source, Fourier Series Expansion of Period Pulse Wave)* (ccsrc)
- *Vf Sawtooth (Voltage Source, Fourier Series Expansion of Periodic Sawtooth)* (ccsrc)
- *Vf Square (Voltage Source, Fourier Series Expansion of Period Square Wave)* (ccsrc)
- *Vf Triangle (Voltage Source, Fourier Series Expansion of Period Triangle Wave)* (ccsrc)
- *V HB Dataset (Voltage Source, HB Dataset Variable)* (ccsrc)
- *V nHarm (Voltage Source, Fundamental Frequency with N-Harmonics)* (ccsrc)
- *V nTone (Voltage Source, N Frequencies and Amplitudes)* (ccsrc)

- *V SpectrumDataset (Voltage Source, Frequency Spectrum Defined in Dataset)* (ccsrc)
- *XP_Bias (Bias Source for X-Parameter Generator)* (ccsrc)
- *XP_Load (Port Load for X-Parameter Generator)* (ccsrc)
- *XP_Source (Source for X-Parameter Generator)* (ccsrc)

I_1Tone (Current Source, Single Frequency)

Symbol



Parameters

Name	Description	Units	Default
I	Current at center frequency, use polar() for phase	mA	polar(1,0)
Freq	center frequency	GHz	1
PhaseNoise	list of offset frequency, phase noise data pairs	None	None
I_USB	Current of upper sideband small signal tone, use polar() for phase		None
I_LSB	Current of lower sideband small-signal tone, use polar() for phase		None
Idc	DC current		None
Iac	AC current; use polar() for phase	mA	polar(1,0)
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None
Other	output string to netlist	None	None

Range of Usage

Freq > 0

Notes/Equations

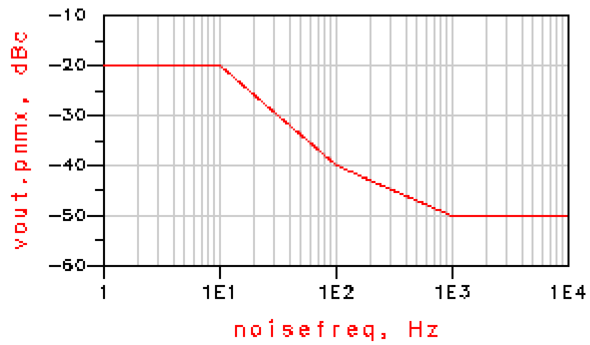
1. This current source is defined by its frequency and its current and can be used in all simulations. The phase of the source is specified by a complex value I, such as I=polar(1mA, 45).
   For ac simulations, only Iac is used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source current is set to 0 for that analysis. In envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated.
   This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. When this source represents a real only, baseband current (that is, transient or the baseband part of an envelope signal), then only the real part of the signal is generated. Otherwise, the full complex value of I is used to define both the amplitude and phase relationships.
2. For time-domain analyses, transient and envelope, the I current parameter can be an

expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the I current parameter is a function of frequency, since this is not fully supported in all analysis modes.

3. A dc term can be defined on this device.
4. In small signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands must be set such that they have no effect on the operating point of the circuit.
5. Positive current flows into pin 1 and out of pin 2.
6. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

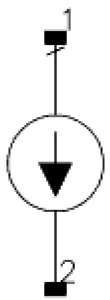
7. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following image shows the phase noise results for the sample data list given above.



Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
Noise is not generated by this source during Circuit Envelope or transient analysis.
8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

I_AC (AC current source)

Symbol



Parameters

Name	Description	Units	Default
Idc	DC current	mA	0
Iac	AC current; use polar() for phase	mA	polar(1,0)
Freq	frequency		freq
I_Noise	noise current magnitude, per sqrt(Hz)	pA	0

Notes/Equations

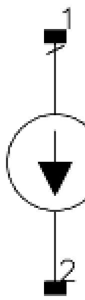
1. I_AC is an ideal ac current source. Positive current flows into the source at pin 1 and out of the source at pin 2.
2. This source is used in all simulations. When not in use, it is treated as an open circuit.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

I_DC (DC current source)

Symbol



Parameters

Name	Description	Units	Default
Idc	DC current	mA	1
Iac	AC current; use polar() for phase		None

Notes/Equations

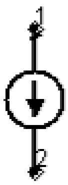
1. I_DC is an ideal dc current source. Positive current flows into the source at pin 1 and out of the source at pin 2.
2. This source is used in all simulations. When not in use, it is treated as an open circuit.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc). For general information regarding time domain sources, refer to the *Introduction* (ccsrc)

I_HB_Dataset (Current Source, HB Dataset Variable)

Symbol



Parameters

Name	Description	Units	Default
Dataset	Dataset name	None	None
Variable	Dataset variable	None	None
Idc	DC component	mA	0
Iac	AC current; use polar() for phase	mA	polar(1,0)

Notes/Equations

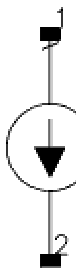
1. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

2. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

I_nHarm (Current Source, Fundamental Frequency with N-Harmonics)

Symbol



Parameters

Name	Description	Units	Default
Freq	fundamental frequency	GHz	1
PhaseNoise	list of offset frequency, phase noise data pairs	None	None
I	N-th harmonic amplitude (use "Add" for more harmonics), use polar() for phase	mA	polar(1,0)
Idc	DC component	mA	0
Iac	AC current; use polar() for phase	mA	polar(1,0)
Other	output string to netlist	None	None

Range of Usage

Freq > 0

Notes/Equations

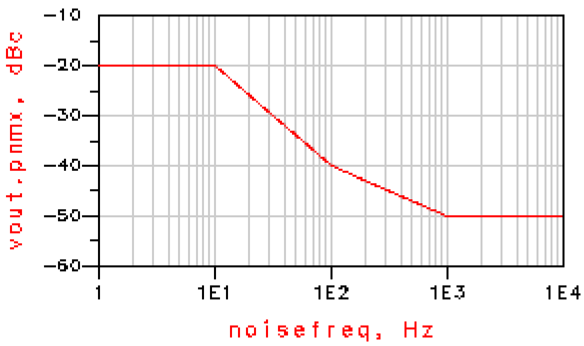
1. This current source has a fundamental frequency component and N harmonics of the fundamental frequency, where $I \leq N < \infty$. The phase of each harmonic is specified by a complex I, such as I=polar(1mA, 45).
   For ac simulations, only Iac is used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source current is set to 0 for that analysis. In envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated.
   This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. When this source represents a real only, baseband current (that is, transient or the baseband part of an envelope signal), then only the real part of the signal is generated.
   Otherwise, the full complex value of I is used to define both the amplitude and phase relationships.
2. For time-domain analyses, transient and envelope, the I current parameter can be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used.

Care must be exercised if the I current parameter is a function of frequency, since this is not fully supported in all analysis modes.

3. A dc term can be defined on this device.
4. In small signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands must be set such that they have no effect on the operating point of the circuit.
5. Positive current flows into pin 1 and out of pin 2.
6. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

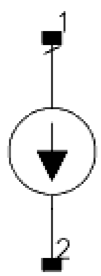
7. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following figure shows the phase noise results for the sample data list given above.



Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
Noise is not generated by this source during Circuit Envelope or transient analysis.
8. The phase noise is only specified for the fundamental. Phase noise is generated by the rest of the specified harmonics using the fundamental phase noise specification plus 20*log10(N) dB, where N is the harmonic number.
9. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

I_nTone (Current Source, N Frequencies and Amplitudes)

Symbol



Parameters

Name	Description	Units	Default
Freq	N-th frequency tone (use "Add" for more tones)	GHz	1
PhaseNoise	List of frequency, phase noise data pairs (repeatable)	None	None
I	Corresponding N-th tone amplitude, (use "Add" for more amplitudes), use polar() for phase	mA	polar(1.0)
Idc	DC component	mA	0
Iac	AC current, use polar() for phase	mA	polar(1,0)
Other	output string to netlist	None	None

Range of Usage

Freq > 0

Notes/Equations

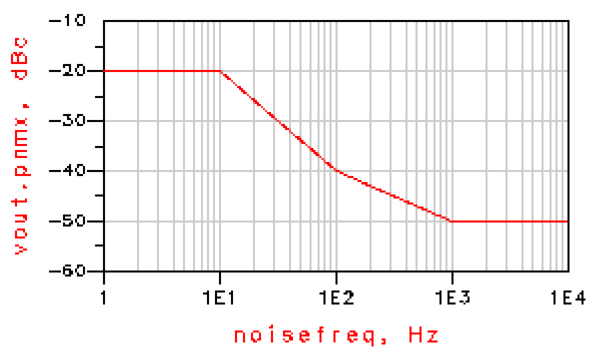
1. This current source can have an arbitrary number ($1 \le N < \infty$) of harmonically independent tones, and can be used in all simulations. The phase of each tone is specified by a complex I value such as I=polar(1mA, 45).
   For ac simulations, only Iac is used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source current is set to 0 for that analysis. In envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency

is still properly generated.
This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. When this source represents a real only, baseband current (that is, transient or the baseband part of an envelope signal), then only the real part of the signal is generated. Otherwise, the full complex value of I is used to define both the amplitude and phase relationships.

2. For time-domain analyses, transient and envelope, the I current parameter can be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the I current parameter is a function of frequency, since this is not fully supported in all analysis modes.
3. A dc term can be defined on this device.
4. In small signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands must be set such that they have no effect on the operating point of the circuit.
5. Positive current flows into pin 1 and out of pin 2.
6. *DC Operating Point Information* lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
Phase Noise Results shows the phase noise results for the sample data list given above.



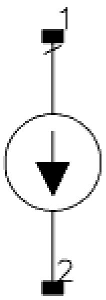
Phase Noise Results

Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz

and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
Noise is not generated by this source during Circuit Envelope or transient analysis.
8. Phase noise can be specified for each of the independent tones. If the phase noise is not specified for one of the tones, then that tone generates no phase noise but the other tones do.
9. For general information regarding frequency domain sources, refer to the *Introduction".* (ccsrc)

I_SpectrumDataset (Current Source, Frequency Spectrum Defined in Dataset)

Symbol



Parameters

Name	Description	Units	Default
Dataset	Dataset name	None	None
Expression	Dataset variable or expression	None	None
Freq	fundamental frequency	GHz	1
Idc	DC component	mA	0

Notes/Equations

1. Each dataset-based source has these fields:
   - Dataset, for the name of the dataset.
   - Expression, for an expression or a dataset variable. Values of this expression will be used as the harmonics for this source.
   - Freq, for the fundamental frequency of this source.
2. The frequency of the fundamental is specified on this source. It is not affected by the actual value of the fundamental associated with the harmonic data in a dataset.
3. Expression must evaluate to a one-dimensional array with two or more entries. The entries in this array are interpreted as dc, fundamental, second harmonic, third harmonic, etc. There cannot be gaps in the list of harmonics; if the list of harmonics includes the 6th harmonic, harmonics 0-5 must be present.
4. Because no interpolation or extrapolation is done by the system, the harmonic data must be single-dimensional. While multi-dimensional data is handled for dataset variables, it is not handled for this source.
5. The harmonic values must be numeric and can be given as real (integer) or complex values. If given as real values, they will be converted to complex (zero imaginary part) before being used in a simulation.
6. The designer must ensure the rationality of the expression that is used. If an expression is used that actually evaluates to a value of resistance, the system has no way of detecting this and will treat these resistance values as harmonics in a harmonic balance simulation.
7. The independent data extracted from the design system expression will be ignored;

only the dependent data will be used, and it will be treated as harmonics. The independent data is ignored so that the source can be frequency shifted (the fundamental value can be changed to something other than that associated with the harmonics in a dataset).

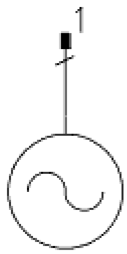
8. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

9. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

OSCwPhNoise (Oscillator with Phase Noise)

Symbol



Parameters

Name	Description	Units	Default
Freq	frequency	GHz	1
P	output power	W	dbmtow(0)
Rout	output resistance	Ohm	50
PhaseNoise	phase noise data	None	list(10Hz,-20dB, 100Hz,-40dB, 1KHz,-50dB)

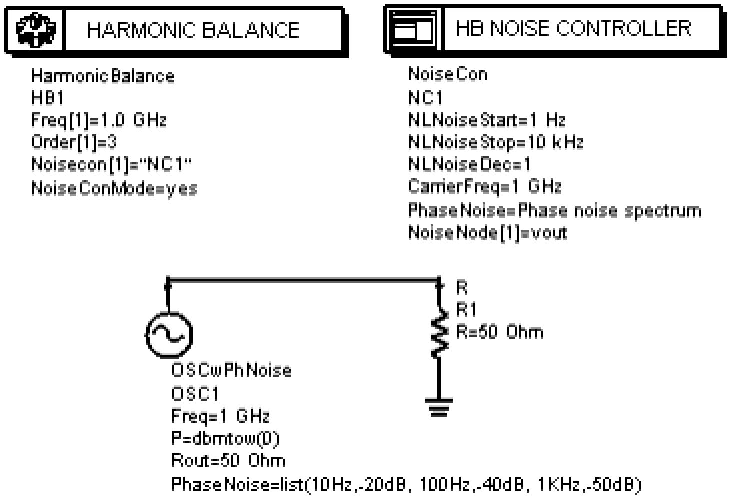
Range of Usage

All phase noise dBc values should be less than −10

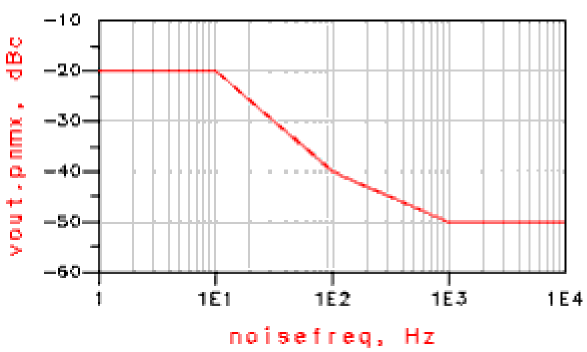
Notes/Equations

1. In Circuit Envelope simulation, the output power P of OSCwPhNoise represents the total power output from this source over the entire simulation bandwidth. This implies that the phase noise level specified in this source should be small enough with respect to this total power such that the specified phase noise level below the carrier signal can be maintained without violating the conservation of total power. In the event that this specified phase noise is too high, the overall power output from this source will be fixed at P, and the phase noise level and the carrier signal power from the source will be adjusted by the program to be different from the levels specified in order to maintain the total power over the bandwidth to be P.
2. OSCwPhNoise can be used in harmonic balance and Circuit Envelope simulations-it is not recommended for use in transient simulation.
   A harmonic balance simulation example is shown in the Harmonic Balance Setup and Harmonic Balance Noise Simulation Results images.
3. For new designs that use harmonic balance, the use of the P_1Tone source is preferred. The P_1Tone source can specify phase noise using the same syntax as this element. The P_1Tone with phase noise generates the proper broadband phase noise necessary when analyzing circuits and systems with mixers and/or multiple closely-spaced tones.
   The OSCwPhNoise is implemented using a PhaseNoiseMod component. This circuit phase modulates one large signal frequency with noise to produce pure phase noise without amplitude noise. Because of the nature of harmonic balance, the noise exists at sidebands above and below this one large signal tone, but not around any other large signal frequencies. Thus, if phase noise is specified at an offset frequency large

enough that it could appear around another nearby large signal frequency, the noise will not appear if viewed around that other large signal frequency. This can be a limitation when attempting to combine two sources that are close together in frequency. In that case, the P_1Tone with phase noise should be used instead for harmonic balance analysis.



Harmonic Balance Setup

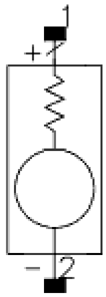


Harmonic Balance Noise Simulation Results

4. If Circuit Envelope analysis with noise is required, then OSCwPhNoise should be used as P_1Tone does not generate phase noise in Circuit Envelope analysis.

P_1Tone (Power Source, Single Frequency)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
P	Power at center frequency, use polar(dbmtow(0),0) for phase		polar(dbmtow(0),0)
Freq	center frequency	GHz	1
PhaseNoise	List of frequency, phase noise data pairs	None	None
P_USB	Power of upper sideband small signal tone, use polar(dbmtow(0),0) for phase		None
P_LSB	Power of lower sideband small-signal tone, use polar(dbmtow(0),0) for phase		None
Mod	modulation function	None	None
Noise	Enable/disable port noise: yes or no	None	yes
Pac	AC power, use polar(dbmtow(0),0) for phase	None	polar(dbmtow(0),0)
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None
Vdc	open circuit DC voltage	None	None
Temp	Temperature of port	°C	None
Other	output string to netlist	None	None

Notes/Equations

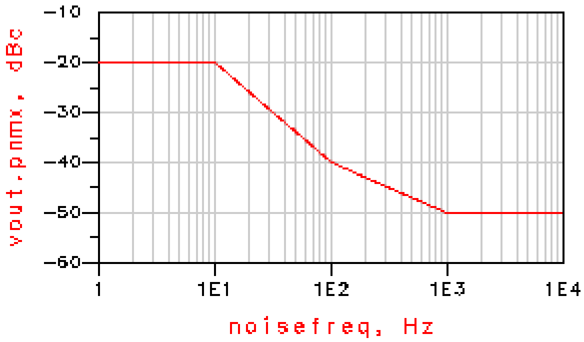
1. The power of the source is specified by a complex value P such as P=polar(dbmtow(0), 45). The same applies to P_USB and P_LSB. The unit for power is W, mW, and so on; dBm must be converted to W by using dbmtow().
2. This power source is defined by its frequency, power, impedance, and linear modulation. It can be used in all circuit simulations.
   For ac analysis, only Z and Pac are used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source generates no signal for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given

frequency is still properly generated.
This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. The time domain output waveform of P_1Tone is a cosine. In order to get a sinusoidal waveform, set P=polar(magnitude, -90), where magnitude is the power magnitude. The transient waveform amplitude is affected by the load termination such that, for a matched load this amplitude is scaled by 1/2.

3. The output impedance of the source is defined by the Z-parameter. The output impedance may be complex, but dc, transient, and baseband envelope analyses do not support non-real impedances.
4. The signal level is defined by the power parameter P and the Mod parameter. The signal level is set such that the power delivered to a conjugately matched load is equal to P, assuming the Mod parameter is equal to 1.0. The Mod parameter can be used to apply complex, linearly scaled, modulation to the output signal. When this source represents a real-only, baseband signal (transient or the baseband part of an envelope signal), only the real part of the signal is generated. Otherwise, the full complex value of Mod can be used to modify both the amplitude and phase of the signal.
5. For time-domain analyses, transient and envelope, both the P and Mod parameters can be expressions of time. A time varying P provides a logarithmically scaled modulation, but is limited to scalar, magnitude-only variations. A time varying Mod provides both linearly scaled amplitude modulation as well as a linear phase modulation by using a complex expression. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if these parameters are expressed as a function of frequency, because this is not fully supported in all analysis modes.
6. In small-signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands have no effect on the operating point of the circuit.
7. Set Noise=0 to have no noise generated by this source.
8. The Temp parameter only affects the amount of noise generated by the port. If Noise=yes, the amount of noise generated is based on this temperature. This parameter is not used on the input and output ports when calculating noise figure, as the noise figure definition requires the input port temperature to be 290K and the output port is noiseless.
9. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Iport	Current	A
Power	DC power dissipated	W
Vport	Voltage	V

10. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following image shows the phase noise results for the sample data list given above.



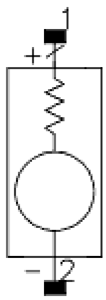
Phase Noise Results

Noise is generated by this source in AC, S-parameter and HB analyses. The IncludePortNoise parameter on the analysis controller and the instance parameter Noise must be set to yes for this source to generate phase noise. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
This source also adds white thermal noise based on the reference impedance. If this extra white noise is not desired, use a separate V_1Tone with a noiseless resistor.

11. During Circuit Envelope analysis:
    - Harmonic Balance noise is generated by this source
    - Monte Carlo noise is not generated by this source
      See Knowledge Center doc 249492 , for a description of these two types of noise.
12. Noise is not generated by this source using transient analysis.
13. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

P_AC (AC Power Source)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	reference impedance, use 1+j*0 for complex	Ohm	50
Pac	AC power, use polar(dbmtow(0), 0) for phase	None	polar(dbmtow(0),0)
Freq	frequency		freq
Noise	enable/disable port thermal noise: yes, no	None	yes
Vdc	open circuit DC voltage		None
Temp	temperature of port	°C	None

Notes/Equations

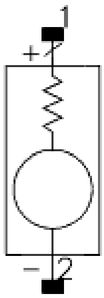
1. P_AC is an ac power source used for ac simulation. When not in use it is treated as an impedance.
2. The Noise parameter only affects the amount of noise generated by the port. If Noise=yes, the amount of noise generated is based on this temperature. This parameter is not used on the input and output ports when calculating the noise figure, as the noise figure definition requires the input port temperature to be 290K and the output port is noiseless.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Iport	Current	A
Power	DC power dissipated	W
Vport	Voltage	V

4. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

P_nHarm (Power Source, Fundamental Frequency with N-Harmonics)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
Freq	fundamental frequency	GHz	1
PhaseNoise	list of offset frequency, phase noise pairs	None	None
P	N-th harmonic power level (use "Add" for more harmonics), use polar(dbmtow(0),0) for phase		polar(dbmtow(0),0)
Noise	Enable/disable port thermal noise: yes or no	None	yes
Pac	AC power, use polar(dbmtow(0),0) for phase		polar(dbmtow(0),0)
Vdc	open circuit DC voltage		None
Temp	Temperature of port	°C	None
Other	output string to netlist	None	None

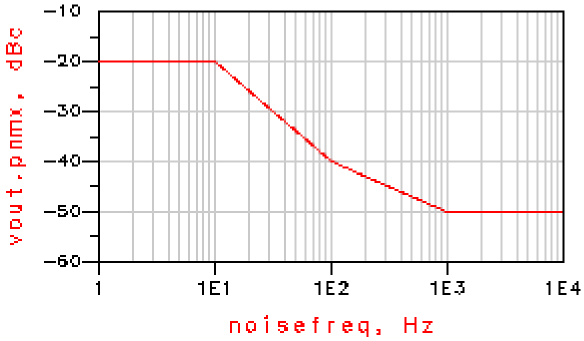
Notes/Equations

1. The phase of the source is specified by a complex value P such as P = polar(dbmtow(0), 45). The unit for power is W, mW, and so on; dBm must be converted to W by using dbmtow().
2. This power source is defined by a fundamental frequency component, and N harmonics of the fundamental frequency. It can be used in all circuit simulations. For ac analysis, only Z and Pac are used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source generates no signal for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated. This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency.
3. The output impedance of the source is defined by the Z-parameter. The output impedance may be complex, but dc, transient, and baseband envelope analyses do not support non-real impedances.

4. The signal level is defined by the power parameter P. The signal level is set such that the power delivered to a conjugately matched load is equal to P. When this source represents a real-only, baseband signal (transient or the baseband part of an envelope signal), only the real part of the signal is generated.
5. For time-domain analyses, transient and envelope, the P parameter may be an expression of time. A time varying P provides a logarithmically scaled modulation, but is limited to scalar, magnitude-only variations. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if these parameters are expressed as a function of frequency, since this is not fully supported in all analysis modes.
6. Set Noise=0 to have no noise generated by this source.
7. The Temp parameter only affects the amount of noise generated by the port. If Noise=yes, the amount of noise generated is based on this temperature. This parameter is not used on the input and output ports when calculating noise figure, as the noise figure definition requires the input port temperature to be 290K and the output port is noiseless.
8. *DC Operating Point Information* lists the DC operating point parameters that can be sent to the dataset.

Name	**Description**	**Units**
Iport	Current	A
Power	DC power dissipated	W
Vport	Voltage	V

9. The phase noise is specified using the list function:
```
list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)
```
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored. The following image shows the phase noise results for the sample data list given above.



Phase Noise Results

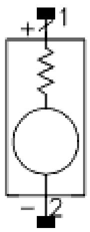
Noise is generated by this source in AC, S-parameter and HB analyses. The IncludePortNoise parameter on the analysis controller and the instance parameter Noise must be set to yes for this source to generate phase noise. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz

is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
This source also adds white thermal noise based on the reference impedance. If this extra white noise is not desired, use a separate V_1Tone with a noiseless resistor.

10. Noise is not generated by this source during Circuit Envelope or transient analysis.
11. The phase noise is only specified for the fundamental. Phase noise is generated by the rest of the specified harmonics using the fundamental phase noise specification plus 20*log10(N) dB, where N is the harmonic number.
12. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

P_nTone (Power Source, N Frequencies and Power Levels)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
Freq	N-th frequency tone (use "Add" for more tones)	GHz	1
PhaseNoise	List of frequency, phase noise data pairs (repeatable)	None	None
P	Corresponding N-th tone power level, (use "Add" for more power levels), use polar(dbmtow(0),0) for phase		polar(dbmtow(0),0)
Noise	Enable/disable port noise: yes or no	None	yes
Pac	AC power, use polar(dbmtow(0),0) for phase		polar(dbmtow(0),0)
Vdc	open circuit DC voltage		None
Temp	Temperature of port	°C	None
Other	output string to netlist	None	None

Notes/Equations

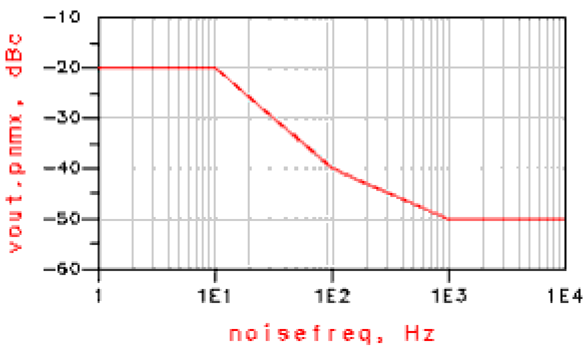
1. The power of the source is specified by a complex value P such as P = polar(dbmtow(0), 45). The unit for power is W, mW, and so on; dBm must be converted to W by using dbmtow().
2. This power source can have an arbitrary number ($1 \le N < \infty$) of harmonically independent tones. It can be used in all circuit simulations.
   For ac analysis, only Z and Pac are used-all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source generates no signal for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated. This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency.
3. The output impedance of the source is defined by the Z-parameter. The output impedance may be complex, but dc, transient, and baseband envelope analyses do not support non-real impedances.
4. The signal level is defined by the power parameter P. The signal level is set such that the power delivered to a conjugately matched load is equal to P. When this source

represents a real-only, baseband signal (transient or the baseband part of an envelope signal), only the real part of the signal is generated.

5. For time-domain analyses, transient and envelope, the P parameter may be an expression of time. A time varying P provides a logarithmically scaled modulation, but is limited to scalar, magnitude-only variations. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if these parameters are expressed as a function of frequency, since this is not fully supported in all analysis modes.
6. Set Noise=0 to have no noise generated by this source.
7. The Temp parameter only affects the amount of noise generated by the port. If Noise = yes, the amount of noise generated is based on this temperature. This parameter is not used on the input and output ports when calculating noise figure, as the noise figure definition requires the input port temperature to be 290K and the output port is noiseless.
8. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Iport	Current	A
Power	DC power dissipated	W
Vport	Voltage	V

9. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following image shows the phase noise results for the sample data list given above.



Phase Noise Results

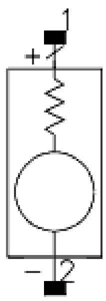
Noise is generated by this source in AC, S-parameter and HB analyses. The IncludePortNoise parameter on the analysis controller and the instance parameter Noise must be set to yes for this source to generate phase noise. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.

This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
This source also adds white thermal noise based on the reference impedance. If this extra white noise is not desired, use a separate V_1Tone with a noiseless resistor

10. Noise is not generated by this source during Circuit Envelope or transient analysis.
11. Phase noise can be specified for each of the independent tones. If the phase noise is not specified for one of the tones, then that tone generates no phase noise but the other tones do.
12. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

P_SpectrumDataset (Power Source, Frequency Spectrum Defined in Dataset)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
Freq	fundamental frequency	GHz	1
Dataset	Dataset name	None	None
Expression	Dataset variable or expression	None	None

Notes/Equations

1. Each dataset-based source has these fields:
   - A field Dataset, for the name of the dataset.
   - A field Expression, for an expression or a dataset variable. The values of this expression will be used as the harmonics for this source.
   - A field Freq for the fundamental frequency of this source.
2. The frequency of the fundamental is specified on this source. It is not affected by the actual value of the fundamental associated with the harmonic data in a dataset.
3. Expression must evaluate to a one-dimensional array with two or more entries. The entries in this array are interpreted as dc, fundamental, second harmonic, third harmonic, etc. There cannot be gaps in the list of harmonics; if the list of harmonics includes the 6th harmonic, harmonics 0-5 must be present.
4. Because no interpolation or extrapolation is done by the system, the harmonic data must be single-dimensional. While multi-dimensional data is handled for dataset variables, it is not handled for this source.
5. The harmonic values must be numeric and can be given as real (integer) or complex values. If given as real values, they will be converted to complex (zero imaginary part) before being used in a simulation.
6. The designer must ensure the rationality of the expression that is used. If an expression is used that actually evaluates to a value of resistance, the simulator has no way of detecting this, and will treat these resistance values as harmonics in a harmonic balance simulation.
   The independent data extracted from the design system expression will be ignored; only the dependent data will be used, and it will be treated as harmonics. The

independent data is ignored so that the source can be frequency shifted (the fundamental value can be changed to something other than that associated with the harmonics in a dataset).

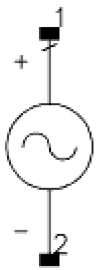
7. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	**Description**	**Units**
Iport	Current	A
Power	DC power dissipated	W
Vport	Voltage	V

8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_1Tone (Voltage Source, Single Frequency)

Symbol



Parameters

Name	Description	Units	Default
V	Voltage at center frequency, use polar() for phase	V	polar(1,0)
Freq	Center frequency	GHz	1
PhaseNoise	List of frequency, phase noise data pairs	None	None
V_USB	Voltage of upper sideband small signal tone, use polar() for phase		None
V_LSB	Voltager of upper sideband small signal tone, use polar() for phase		None
Vdc	DC voltage		None
Vac	AC voltage, use polar() for phase	V	polar(1,0)
SaveCurrent	Flag to save branch current; yes or no	None	yes
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None
Other	Output string to netlist	None	None

Range of Usage

Freq > 0

Notes/Equations

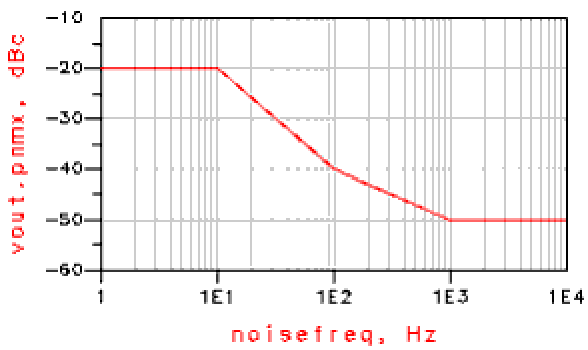
1. This single frequency voltage source is defined by its frequency and its voltage and can be used in all circuit simulations. The phase of the source is specified by a complex value V, such as V=polar(1V, 45).
   For ac simulation, only Vac is used and all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and circuit envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source voltage is set to 0 for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated.
   This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. When this source represents a real-only, baseband voltage (that is, transient or the baseband part of an envelope signal), then only the real part of the signal is generated. Otherwise, the full complex value of V is used to

define both the amplitude and phase relationships.

2. For time-domain analyses, transient and envelope, the voltage parameter may be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the voltage parameter is a function of frequency, since this is not fully supported in all analysis modes.
3. A dc term can be defined for this device. Also, as with the other voltage sources, a SaveCurrent parameter is available to disable the storing of the voltage source current to the dataset.
4. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. In small signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands must be set such that they have no effect on the operating point of the circuit.
6. In S-parameter analysis, this component is treated as an ideal short circuit.
7. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following image shows the phase noise results for the sample data list given above.



Phase Noise Results

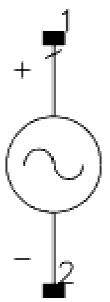
Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the

phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
Noise is not generated by this source during Circuit Envelope or transient analysis.

8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_AC (AC Voltage Source)

Symbol



Parameters

Name	Description	Units	Default
Vdc	DC voltage	V	0.0
Vac	AC voltage, use polar() for phase	V	polar(1,0)
Freq	frequency		freq
V_Noise	Noise voltage amplitude, per sqrt(Hz)	uV	0
SaveCurrent	flag to save branch current; yes or no	None	yes

Notes/Equations

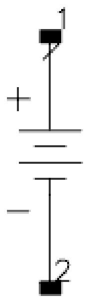
1. For AC simulations with no mixer component, leave Freq equal to freq, where freq is a global variable.
   For frequency-conversion AC analysis, Freq = source frequency.
2. V_AC is only meaningful in AC simulation. When used in other simulations, it is treated as a short circuit.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V DC (DC Voltage Source, Frequency Domain)

Symbol



Parameters

Name	Description	Units	Default
Vdc	DC voltage	V	1.0
Vac	AC voltage, use polar() for phase		None
SaveCurrent	flag to save branch current; yes or no	None	yes

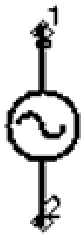
Notes/Equations

1. V_DC can be used in all simulations. When not in use, it is treated as a short circuit.
2. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

Vf_BitSeq (Fourier Transform of Bit Sequence Waveform)

Symbol



Parameters

Name	Description	Units	Default
Vlow	minimum voltage level	V	0
Vhigh	maximum voltage level	V	5
Rate	bit rate	MHz	500
Rise	rise time of pulse	nsec	1
Fall	fall time of pulse	nsec	1
BitSeq	bit sequence	None	"1101011100111100"
Tstart	start time of bit sequence	sec	0.0
Tstop	stop time of bit sequence	nsec	32
Tstep	time step	nsec	0.01

Notes/Equations

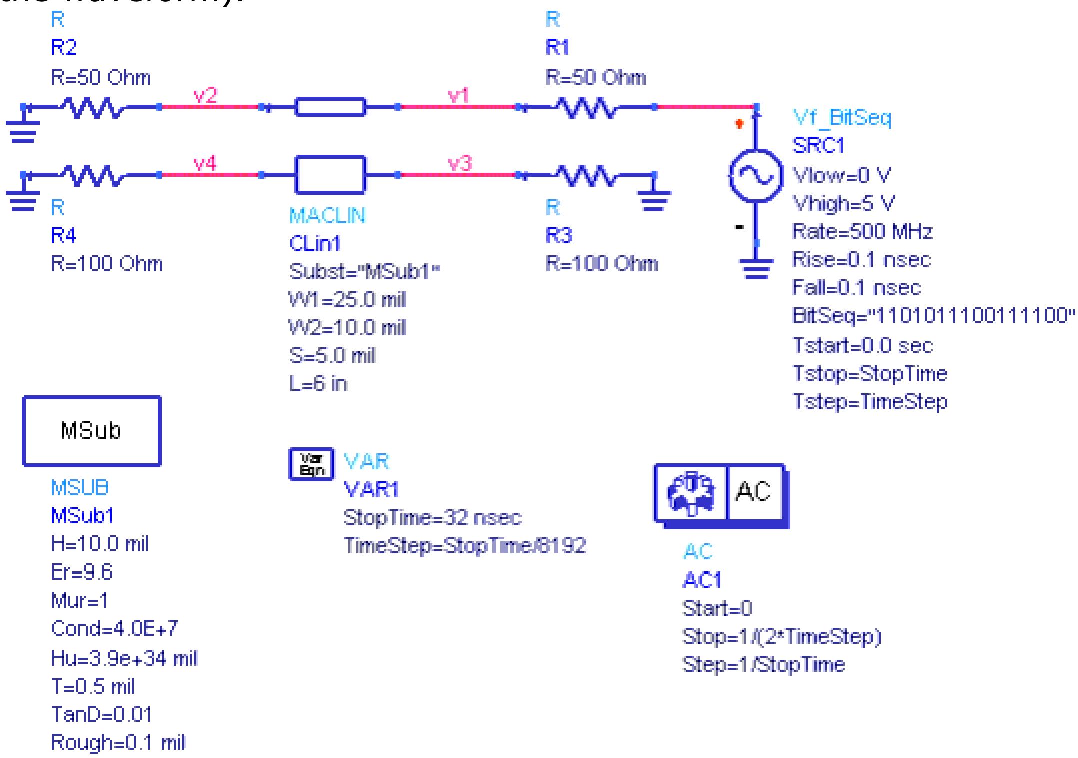
1. Vf_BitSeq is recommended for use in frequency domain analyses only; for time domain analyses (such as transient simulations) use the VtBitSeq component for comparable functionality.
2. The BitSeq parameter enables you to input the waveform of a pulse via an arbitrary bit pattern such as 1101011100111100 (default). When the end of the sequence is reached, the sequence is repeated. A specification of 1 sets voltage to Vhigh, 0 sets it to Vlow.

   Note
   To edit BitSeq, enter a value enclosed with double quote symbols.

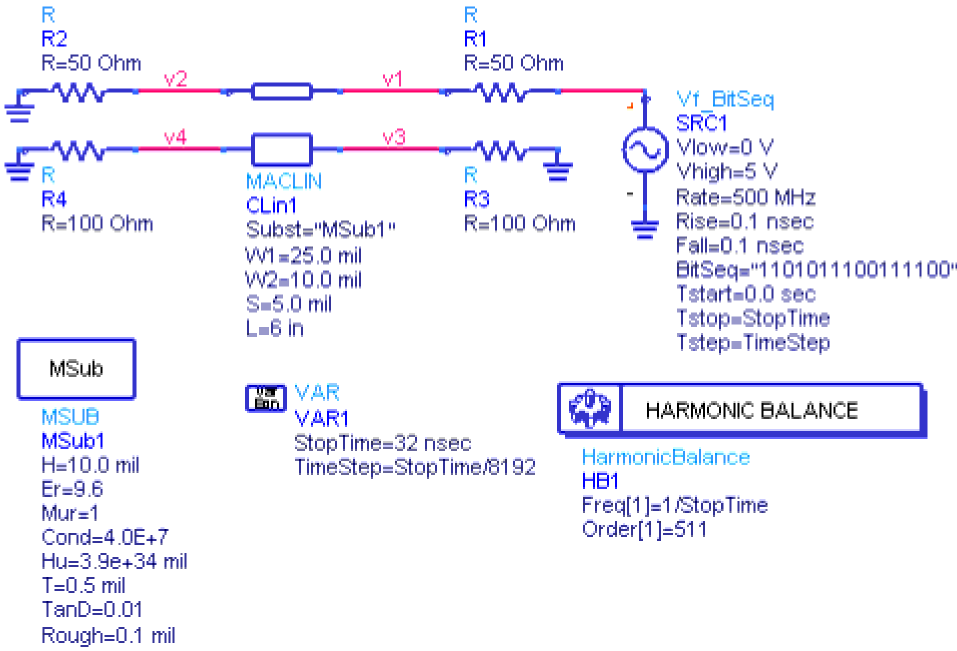
   The bit sequence is generated over the time range [Tstart, Tstop] and its time domain resolution is expressed in Tstep. For good results, Tstop should be exactly one cycle of the complete sequence. For example, if Rate=500MHz, then bit period=1/Rate=1/500MHz=2nsec. For a 16-bit sequence, for example BitSeq="1101011100111100", define Tstop=32nsec (16bits × 2nsec). (Refer to the Vf_BitSeq in Typical AC Simulation Analysis and Vf_BitSeq in Typical Harmonic Balance Simulation Analysis images.)

> **Note**
> Prior to ADS 2003C, an explicit VAR block for specification of Tstart, Tstop and Tstep was required. The use of an explicit VAR block is no longer necessary as these variables are included as component parameters.

3. For Harmonic Balance simulations the recommended controller setting for Freq[1]=1/Tstop. Increasing Order[1] to a large value (as shown in Vf_BitSeq in Typical Harmonic Balance Simulation Analysis), ensures that a sufficient number of harmonics are included to give an accurate Fourier series representation of the user-defined pulse waveform.
4. Vf_BitSeq in Typical AC Simulation Analysis and Vf_BitSeq in Typical Harmonic Balance Simulation Analysis show the use of Vf_BitSeq in typical AC and Harmonic Balance analysis scenarios in ADS.
   Select AC analysis and perform a linear frquency sweep from 0 to 1/(2*StepT), in steps of 1/(StopT). Or, when performing a harmonic balance analysis, set Frequency to 1/StopT and Order to 511 (or set the order to a large enough value to represent the waveform).



Vf_BitSeq in Typical AC Simulation Analysis



Vf_BitSeq in Typical Harmonic Balance Simulation Analysis

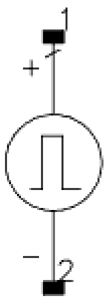
5. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

Vf_Pulse (Voltage Source, Fourier Series Expansion of Period Pulse Wave)

Symbol



Parameters

Name	Description	Units	Default
Vpeak	Peak voltage amplitude of pulse	V	1
Vdc	DC offset	V	0
Freq	Fundamental frequency component (1 / T_0, where T_0 is the pulse-period) of pulse-train	GHz	1
Width	Pulse-width	nsec	0.3
Rise	Rise-time	nsec	0.1
Fall	Fall-time	nsec	0.1
Delay	Time delay	nsec	0
Weight	Compensation for Gibb's Phenomenon if rise- or fall-time is 0; activated when Weight=yes; ignored if both Rise and Fall are > 0	None	no
Harmonics	Number of harmonics	None	16
SaveCurrent	Flag to save branch current	None	yes
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None

Range of Usage

Width ≥ 0
Freq > 0
Rise ≥ 0
Fall ≥ 0
Delay ≥ 0
Rise + Fall + Width ≤ T_0 = 1/Freq

Notes/Equations

1. Vf_Pulse is a time-periodic rectangular pulse-train voltage source that can be used in all simulations. However, the Vf_Pulse source is short-circuited for AC simulation. The time-periodic signal is converted to discrete frequency components that are harmonically related and represented using the signal's equivalent Fourier series.

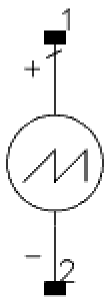
2. The source produces a positive voltage with respect to pin 1.
3. If either rise-time (Rise) or fall-time (Fall) is 0, the discontinuity in the pulse gives rise to Gibb's Phenomenon when the pulse is synthesized from its Fourier components. The ripple effect at the discontinuity can be smoothed by specifying Weight=yes, which scales the Fourier coefficients of the source by Lanczos factors or weights.
4. The number of terms in the Fourier series used to represent this source in the frequency domain is equivalent to the order chosen for the harmonic balance simulation.
5. You can synthesize a similar time-periodic signal by connecting in series a number of sinusoidal steady-state sources at harmonically related frequencies and having amplitudes and phases that are the corresponding Fourier coefficients.
6. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

Vf_Sawtooth (Voltage Source, Fourier Series Expansion of Periodic Sawtooth)

Symbol



Parameters

Name	Description	Units	Default
Vpeak	peak amplitude of wave	V	1
Vdc	DC component	V	0
Freq	frequency	GHz	1
Delay	time delay	nsec	0
Weight	compensation for Gibb's Phenomenon if rise- or fall-time is 0; activated when Weight=yes; ignored if rise and fall are non-0	None	no
Harmonics	number of harmonics	None	16
SaveCurrent	flag to save branch current; yes or no	None	yes
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None

Range of Usage

Delay ≥ 0

Notes/Equations

1. This item is a time-periodic sawtooth voltage source that can be used in all simulations. However, the Vf_Sawtooth source is short circuited for AC simulation. The time-periodic signal is converted to discrete frequency components that are harmonically related and represented using the signal's equivalent Fourier series.
2. The source produces a positive voltage with respect to pin 1.
3. The discontinuity in the pulse caused by 0 fall-time gives rise to Gibb's Phenomenon when the pulse is synthesized from Fourier components. The ripple effect at the discontinuity can be smoothed by specifying Weight=yes, which scales the Fourier coefficients of the source by Lanczos factors or weights.
4. The number of terms in the Fourier series used to represent this source in the frequency domain is equivalent to the order chosen for the harmonic balance simulation.
5. You can synthesize a similar time-periodic signal by connecting in series a number of sinusoidal steady-state sources at harmonically related frequencies and having amplitudes and phases that are the corresponding Fourier coefficients.

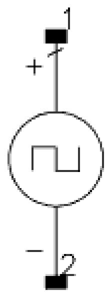
6. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

Vf_Square (Voltage Source, Fourier Series Expansion of Period Square Wave)

Symbol



Parameters

Name	Description	Units	Default
Vpeak	peak amplitude of pulse	V	1
Vdc	DC component	V	0
Freq	frequency	GHz	1
Rise	rise-time	nsec	0.1
Fall	fall-time	nsec	0.1
Delay	time delay	nsec	0
Weight	compensation for Gibb's Phenomenon if rise- or fall-time is 0; activated=yes; ignored if rise and fall are non-0	None	no
Harmonics	number of harmonics	None	16
SaveCurrent	flag to save branch current; yes or no	None	yes
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None

Range of Usage

Delay 0; Rise 0; Fall 0; Rise + Fall < $T_0/2$

Notes/Equations

1. This time-periodic square-wave voltage source can be used in all simulations. However, the Vf_Square source is short circuited for AC simulation. The time-periodic signal is converted to discrete frequency components that are harmonically related and represented using the signal's equivalent Fourier series.
2. The source produces a voltage between -Vpeak+Vdc and Vpeak+Vdc with respect to pin 1.
3. Rise-time (Rise) or fall-time (Fall) is defined from Vdc to Vpeak or -Vpeak. If either rise-time or fall-time is zero, the discontinuity in the pulse gives rise to Gibb's Phenomenon when the pulse is synthesized from its Fourier components. The ripple effect at the discontinuity can be smoothed by specifying Weight=yes, which scales the Fourier coefficients of the source by Lanczos factors or weights.
4. The number of terms in the Fourier series used to represent this source in the

frequency domain is equivalent to the order chosen for the harmonic balance simulation.

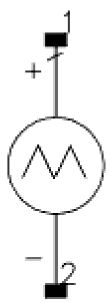
5. A similar time-periodic signal can be synthesized by connecting in series a number of sinusoidal steady-state sources at harmonically related frequencies with amplitudes and phases of the corresponding Fourier coefficients.
6. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

Vf_Triangle (Voltage Source, Fourier Series Expansion of Period Triangle Wave)

Symbol



Parameters

Name	Description	Units	Default
Vpeak	peak amplitude of wave	V	1
Vdc	DC offset	V	0
Freq	frequency	GHz	1
Delay	time delay	nsec	0
Harmonics	number of harmonics	None	16
SaveCurrent	flag to save branch current; yes or no	None	yes
FundIndex	Fundamental Frequency Index (Can Be Used Instead of Specifying "Freq")	None	None

Range of Usage

Delay ≥ 0

Notes/Equations

1. This is a time-periodic triangle-wave voltage source that can be used in all simulations. However, the Vf_Triangle source is short circuited for AC simulation. The time-periodic signal is converted to discrete frequency components that are harmonically related and represented using the signal's equivalent Fourier series.
2. The source produces a positive voltage with respect to pin 1.
3. The number of terms in the Fourier series used to represent this source in the frequency domain is equivalent to the order chosen for the harmonic balance simulation.
4. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_HB_Dataset (Voltage Source, HB Dataset Variable)

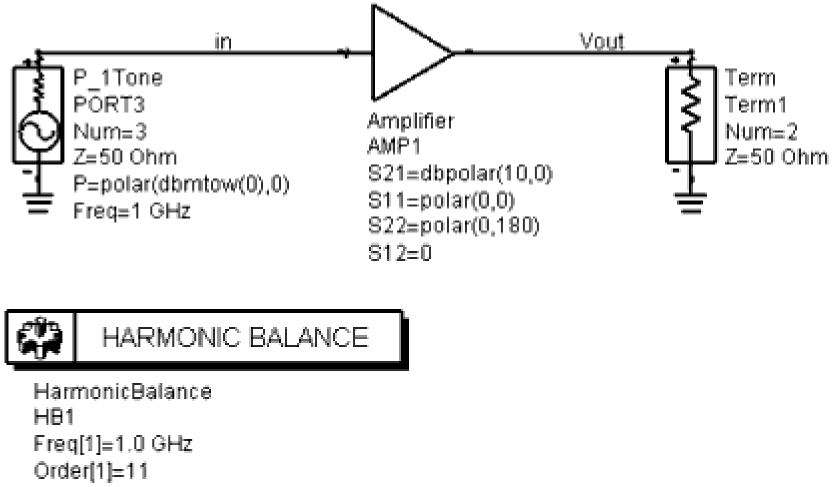
Symbol

Parameters

Name	Description	Units	Default
Dataset	Dataset name	None	None
Variable	Dataset variable	None	None
Vdc	DC voltage	V	0
Vac	AC voltage, use polar() for phase	V	polar (1,0)
SaveCurrent	flag to save branch current; yes or no	None	yes

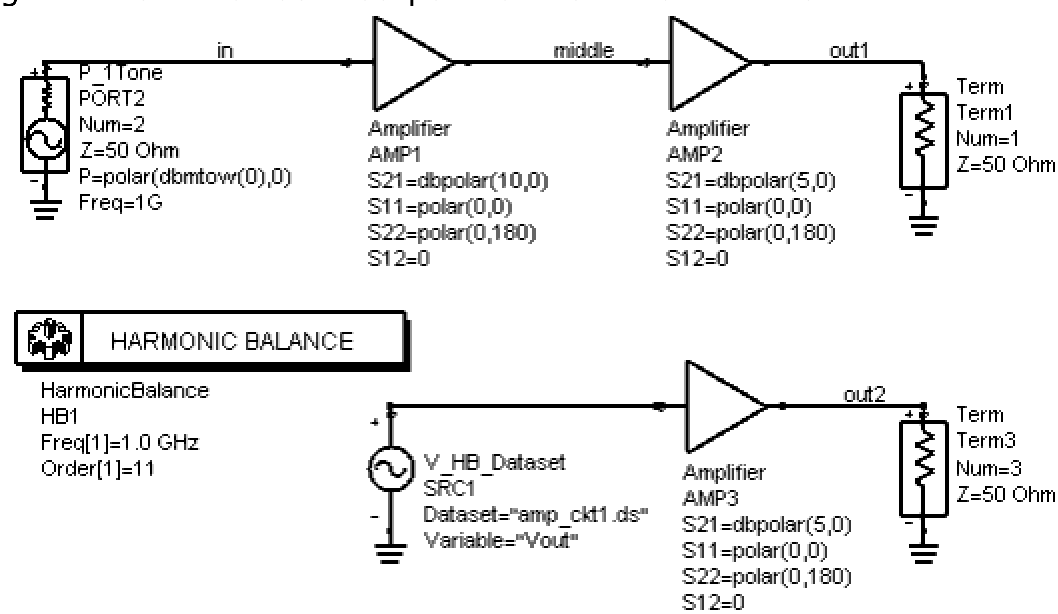
Notes/Equations

1. This data-based, frequency domain waveform voltage source is defined by a frequency-domain dataset variable. The dataset variable must have frequency as its independent swept axis.
2. The dataset filename and dataset variable must be enclosed in double quotes.
3. When performing a Harmonic Balance simulation with V_HB_Dataset, set the frequency on the HB simulation controller to the same frequency (from the earlier HB simulation controller) that was used to generate the dataset and the variable.
4. This source does not handle datasets that contain results from multiple simulations (such as those with more than one simulation controller). This does not mean that the dataset cannot have more than one variable. The dataset may contain several variables; however, they must be from the same simulation with a single simulation controller.
5. This source makes it possible to use a dataset variable from one Harmonic Balance simulation in another Harmonic Balance simulation.
   In the following simple example, the output from a single stage amplifier is used as the input for another single stage amplifier using the V_HB_Dataset source.
   From the schematic of the Single Stage Amplifier, a dataset named *amp_ckt1.ds* is generated and includes the nodal voltage variable *Vout*. The circuit in *amp_ckt1* contains an amplifier with a gain of 10 dB.



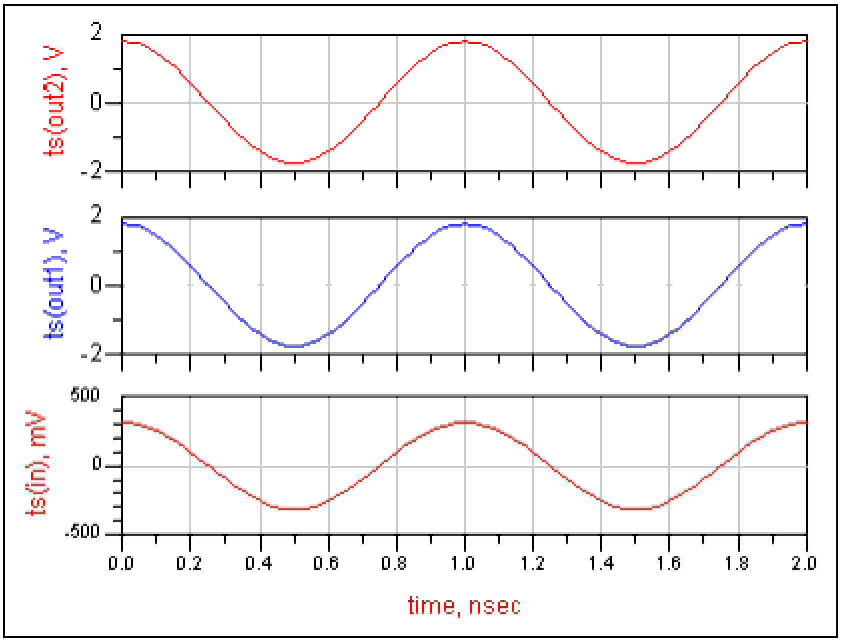
Single Stage Amplifier

The schematic of the Single Stage Amplifier using V_HB_Dataset Source (*both_amps*) contains the V_HB_Dataset source with the variable *Vout* from the dataset *amp_ckt1.ds* as the input to an amplifier with a gain of 5 dB. This is equivalent to having two amplifiers cascaded in series, the first with a gain of 10 dB; the second with a gain of 5 dB. Both circuits are shown, and the results from each are also given. Note that both output waveforms are the same.



Single Stage Amplifier using V_HB_Dataset Source

Simulation results are shown in the following image (the output spectrum and waveform are shown for the swept values of the amplifier gain).



Simulation Results

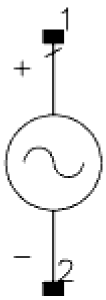
6. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_nHarm (Voltage Source, Fundamental Frequency with N-Harmonics)

Symbol



Parameters

Name	Description	Units	Default
Freq	fundamental frequency	GHz	1
PhaseNoise	List of frequency, phase noise data pairs	None	None
V	N-th harmonic amplitude (use "Add" for more harmonics), use polar() for phase	V	polar(1,0)
Vdc	DC voltage	V	0
Vac	AC voltage, use polar() for phase	V	polar(1,0)
SaveCurrent	flag to save branch current; yes or no	None	yes
Other	output string to netlist	None	None

Notes/Equations

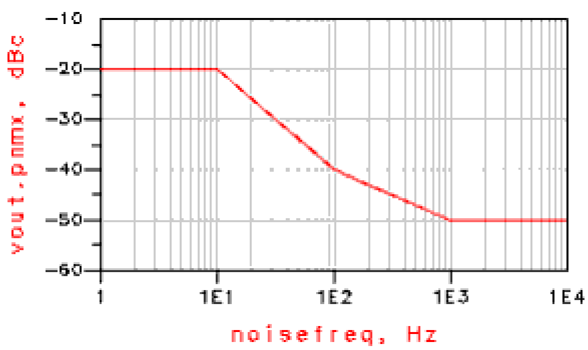
1. This voltage source has a fundamental freq. component and N ($1 \le N < \infty$) harmonics of the fundamental freq. The phase of each harmonic is specified by a complex V, such as V=polar(IV, 45). This source is used in all simulations. The phase of the source is specified by a complex value V, such as V=polar(1V, 45).
   For ac simulation, only Vac is used and all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and circuit envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source voltage is set to 0 for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated.
   This source can also be used in transient analysis to generate an arbitrary waveform at the specified carrier frequency. When this source represents a real-only, baseband voltage (that is, transient or the baseband part of an envelope signal), then only the real part of the signal is generated. Otherwise, the full complex value of V is used to define both the amplitude and phase relationships.
2. For time-domain analyses, transient and envelope, the voltage parameter may be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the voltage parameter is a function of frequency, since this

is not fully supported in all analysis modes.

3. A dc term can be defined for this device. Also, as with the other voltage sources, a SaveCurrent parameter is available to disable the storing of the voltage source current to the dataset.
4. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. In S-parameter analysis, this component is treated as an ideal short circuit.
6. The phase noise is specified using the list function:
   `list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
   It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
   The following image shows the phase noise results for the sample data list given above.

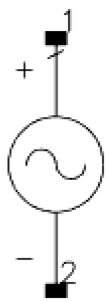


Phase Noise Results

   Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
   This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
   Noise is not generated by this source during Circuit Envelope or transient analysis.
7. The phase noise is only specified for the fundamental. Phase noise is generated by the rest of the specified harmonics using the fundamental phase noise specification plus 20*log10(N) dB, where N is the harmonic number.
8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_nTone (Voltage Source, N Frequencies and Amplitudes)

Symbol



Parameters

Name	Description	Units	Default
Freq	N-th frequency tone (use "Add" for more tones)	GHz	1
PhaseNoise	List of frequency, phase noise data pairs (repeatable)		None
V	Corresponding N-th tone amplitude, (use "Add" for more amplitudes), use polar() for phase	V	polar(1,0)
Vdc	DC voltage	V	0
Vac	AC voltage, use polar() for phase	V	polar(1,0)
SaveCurrent	flag to save branch current; yes or no	None	yes
Other	output string to netlist	None	None

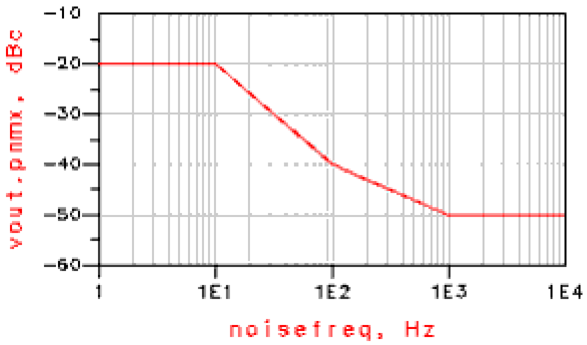
Notes/Equations

1. This voltage source can have an arbitrary number ($1 \leq N < \infty$) of harmonically independent tones and can be used in all simulations. The phase of each tone is specified by a complex V value such as V = polar(1V, 45).
   For ac simulation, only Vac is used and all other parameters are ignored. When frequency conversion ac analysis is performed, the Freq parameter is used to set the frequency of the source. For harmonic balance and circuit envelope, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough, a warning is generated and the source voltage is set to 0 for that analysis. In the envelope analysis, the frequency difference can be up to 0.5/timestep and the given frequency is still properly generated. For ac analysis, the Freq parameter is ignored.
2. For time-domain analyses, transient and envelope, the voltage parameter may be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the voltage parameter is a function of frequency, since this

is not fully supported in all analysis modes.
3. A dc term can be defined for this device. Also, as with the other voltage sources, a SaveCurrent parameter is available to disable the storing of the voltage source current to the dataset.
4. *DC Operating Point Information* lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. In S-parameter analysis, this component is treated as an ideal short circuit.
6. The phase noise is specified using the list function:
`list(10Hz, -20dB, 100Hz,-40dB, 1kHz,-50dB)`
It consists of pairs of offset frequencies in Hertz and phase noise values in dBc/Hz. When evaluated using offset frequencies that are smaller or larger than those given in the list, the phase noise corresponding to the smallest or largest frequency is used; the data are not extrapolated. No noise is generated if the phase noise is less than -300 dBc/Hz. Any data pair that contains a frequency <= 0 Hz is ignored.
The following image shows the phase noise results for the sample data list given above.

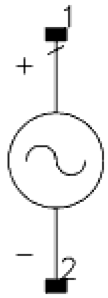


Phase Noise Results

Noise is generated by this source in AC, S-parameter and HB analyses. The noise on either side of the carrier is correlated to produce pure phase noise with no amplitude noise. For example, with a carrier frequency of 1 MHz, the noise at 0.99 MHz and 1.01 MHz is correlated and has a value that depends on the phase noise at 10 kHz and the magnitude of the carrier signal.
This source generates broadband noise. Noise will be generated at any offset frequency from the carrier. If the offset frequency is larger than the last one in the phase noise list, that value will be used. The phase noise is not extrapolated and does not stop for large offsets.
Noise is not generated by this source during Circuit Envelope or transient analysis.
7. Phase noise can be specified for each of the independent tones. If the phase noise is not specified for one of the tones, then that tone generates no phase noise but the other tones do.
8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).

V_SpectrumDataset (Voltage Source, Frequency Spectrum Defined in Dataset)

Symbol



Parameters

Name	Description	Units	Default
Dataset	Dataset name	None	None
Expression	Dataset variable or expression	None	None
Freq	fundamental frequency	GHz	1
Vdc	DC voltage	V	0
SaveCurrent	flag to save branch current: yes or no	None	yes

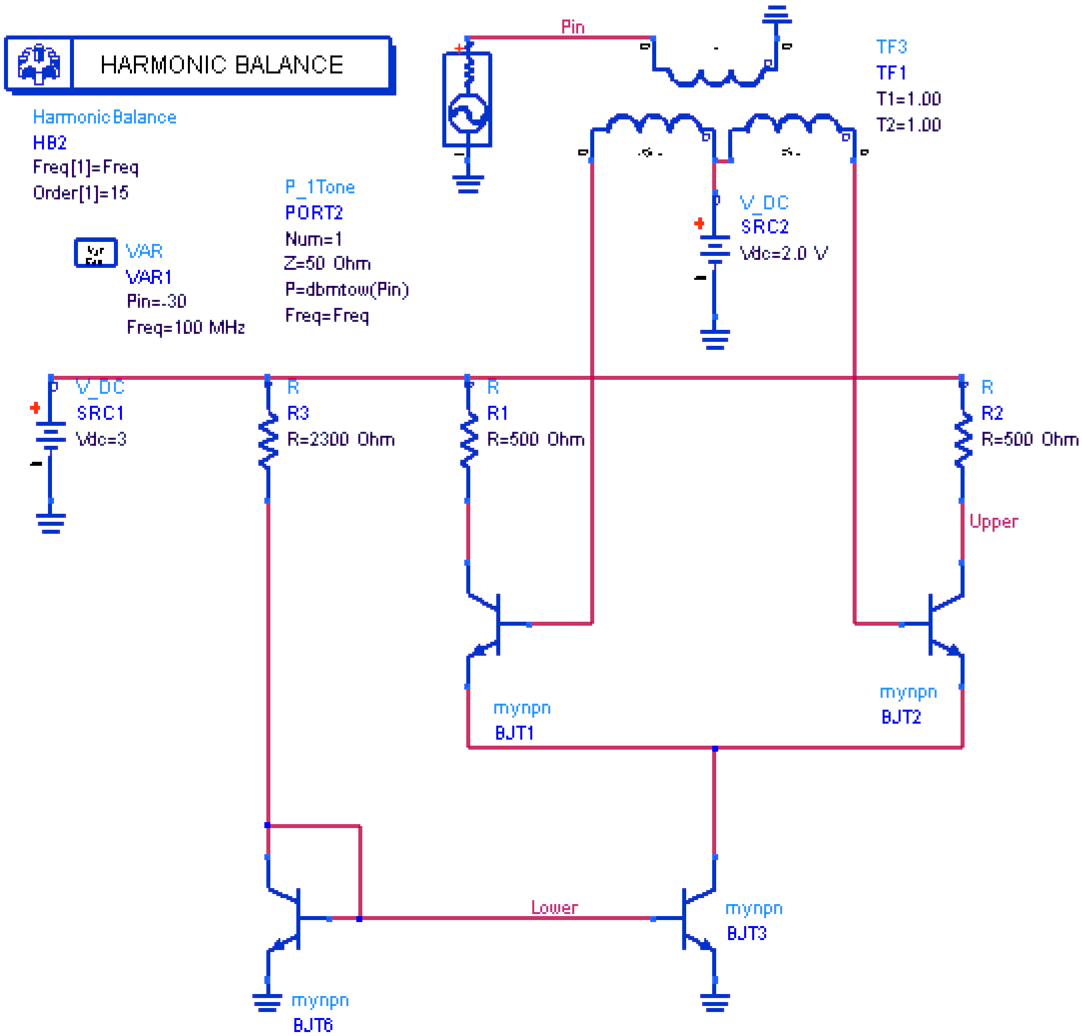
Notes/Equations

1. Each dataset-based source has these fields:
   - A field Dataset, for the name of the dataset.
   - A field Expression, for an expression or a dataset variable. The values of this expression will be used as the harmonics for this source.
   - A field Freq for the fundamental frequency of this source.
2. The frequency of the fundamental is specified on this source. It is not affected by the actual value of the fundamental associated with the harmonic data in a dataset.
3. Expression must evaluate to a one-dimensional array with two or more entries. The entries in this array are interpreted as dc, fundamental, second harmonic, third harmonic, and so on. There cannot be gaps in the list of harmonics; if the list of harmonics includes the 6th harmonic, harmonics 0-5 must be present.
4. Because no interpolation or extrapolation is done by the system, the harmonic data must be single-dimensional. While multi-dimensional data is handled for dataset variables, it is not handled for this source. This source does not support multi-tone harmonic balance simulations, (e.g., when Freq[1], Freq[2], etc. are given on the HB controller). It does however, support a swept harmonic balance simulation in which there is only one tone, (e.g., Freq[1]). For datasets generated from a multitone harmonic balance simulation, please refer to *V_HB_Dataset (Voltage Source, HB Dataset Variable)* (ccsrc).
5. The harmonic values must be numeric and can be given as real (integer) or complex values. If given as real values, they will be converted to complex (zero imaginary part) before being used in a simulation.
   The designer must ensure the rationality of the expression that is used. If an

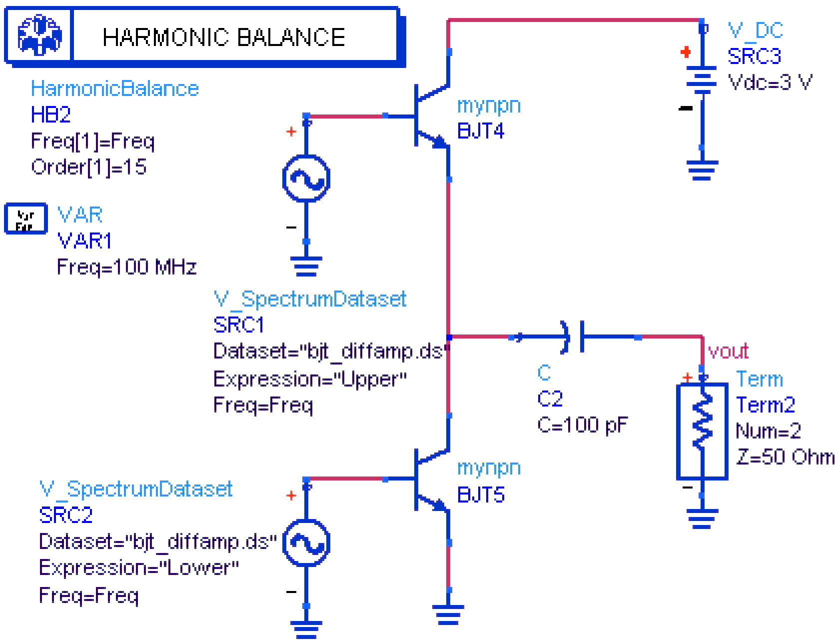
6. expression is used that actually evaluates to a value of resistance, the system has no way of detecting this, and will treat these resistance values as harmonics in a harmonic balance simulation.
   The independent data extracted from the design system expression will be ignored; only the dependent data will be used, and it will be treated as harmonics. The independent data is ignored so that the source can be frequency shifted (the fundamental value can be changed to something other than that associated with the harmonics in a dataset).
7. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

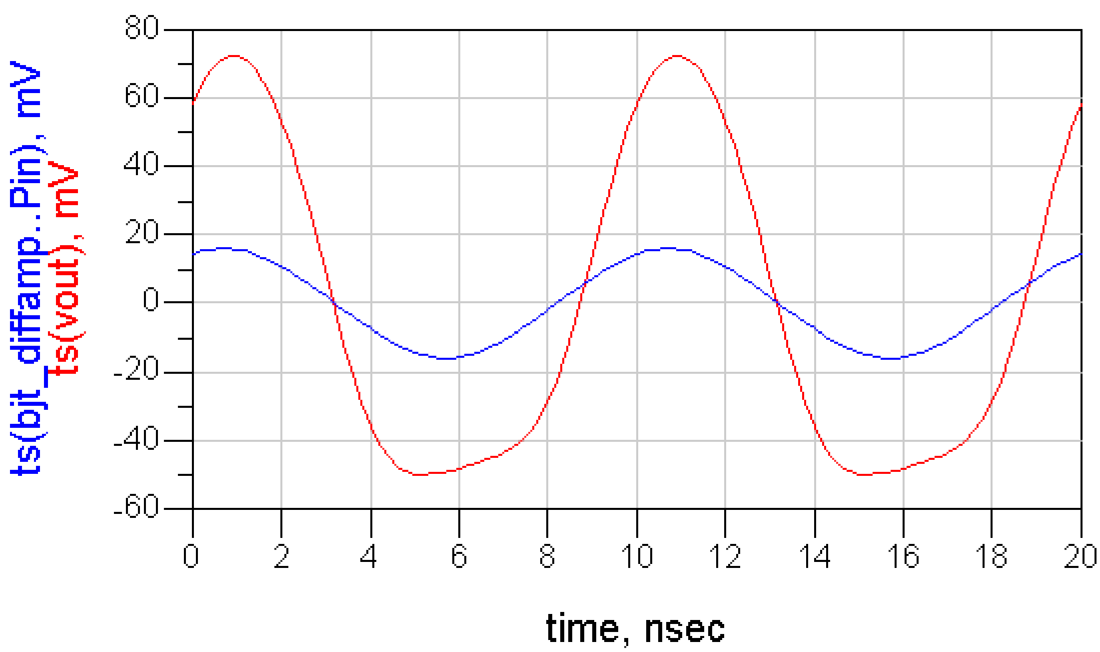
8. For general information regarding frequency domain sources, refer to the *Introduction* (ccsrc).
9. The example of the differential amplifier is given below, it is desired to design the emitter-follower in order to convert the output from high-impedance differential to lower impedance single ended. This can be done using the two outputs (Upper and Lower) from the first stage of the differential amplifier as Expressions on the V_SpectrumDataset and as inputs to the emitter-follower. (For this example, the name of the design is bjt_diffamp, thus, the dataset which is referred to, is bjt_diffamp.ds)



Use the output from the first stage of the differential amplifier as inputs to the final stage to complete the amplifier. This can be done with the V_SpectrumDataset.

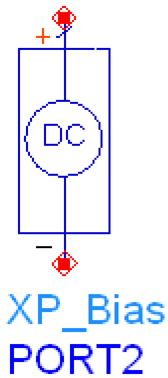


This plot shows the results of the output stage compared to the input source from the first stage of the differential amplifier. Additionally, one could sweep the input power, or the another parameter such as the output capacitor in the final stage to see how the differential amplifier will behave as the power is increased, or to fine tune the emitter follower stage.



XP_Bias (Bias Source for X-Parameter Generator)

Symbol



Parameters

Name	Description	Units	Default
Port number (or Num)	port number	None	lowest available
Port name (or PortName)	Port name	None	None
DC Bias type (or DC_mode)	DC bias type: None, Voltage, Current	None	Voltage
DC Sweep type (or DC_swpType)	DC bias sweep type: Single point, Use sweep	None	point
DC Single point (or DC_value)	DC bias single value	V or A	3 V
DC Start (or DC_start)	DC bias sweep start value	V or A	None
DC Stop (or DC_stop)	DC bias sweep stop value	V or A	None
DC Num. of pts (or DC_numPts)	DC bias sweep number of points	None	None

Notes/Equations

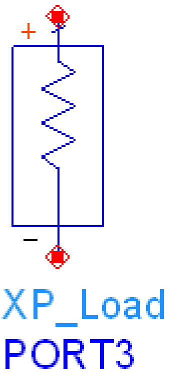
1. This component is designed for the X-Parameter Generator to establish DC biasing conditions. For more information, refer to *X-Parameter Generator Basics* (xparam).
2. This component must not interact with external sweeps. Therefore, all the values (point, start, stop, num. of pts) must not be defined via external variables.
3. This component can also be used in simulations other than X-parameter generation and will behave as:
    - An ideal voltage source if *Voltage* is selected.

- An ideal current source if *Current* is selected.
- An open circuit if DC bias type is set to *None*.

4. Any sweep defined in this component is ignored in simulations other than X-parameter generation and a single value (either point or start) is used.
5. Port numbers do not have to be consecutive. However, the highest port number will establish the total number of ports for the simulation component using the generated X-parameters. Thus the highest port number should not exceed the largest number of ports available in those components. Otherwise the data will not be available for simulation using those components. For more information, refer to *XnP Components (X1P - X10P)* (ccsim).

XP_Load (Port Load for X-Parameter Generator)

Symbol



Parameters

Name	Description	Units	Default
Port number (or Num)	port number	None	lowest available
Port name (or PortName)	port name	None	None
Reference impedance (or Z0)	Source impedance and reference impedance	Ohm	50+j*0
DC Bias type (or DC_mode)	DC bias type: None, Voltage, Current	None	None
DC Sweep type (or DC_swpType)	DC bias sweep type: Single point, Use sweep	None	point
DC Single point (or DC_value)	DC bias single value	V or A	None
DC Start (or DC_start)	DC bias sweep start value	V or A	None
DC Stop (or DC_stop)	DC bias sweep stop value	V or A	None
DC Num. of pts (or DC_numPts)	DC bias sweep number of points	None	None
Load Load type (or Load_mode)	Load type: Impedance, Gamma (reflection coefficient)	None	Impedance
Load Frequency harmonic indices	Frequency harmonic indices - comma separated list of harmonic/mixing indices	None	1

(or LS_freqHarms)			
Load Format (or LS_format)	Load data format: Mag/Phase, Real/Imag	None	Mag/Phase
Load Impedance or Gamma Sweep type (or LS_swpType)	Load sweep type: Single point, Use sweep	None	Sweep
Load Impedance or Gamma Single point Mag and Phase (or LS_value)	Load single value	Ohm or none	50 Ohm /0 degrees
Load Impedance or Gamma Use sweep Mag and Phase Start (or LS_start)	Load sweep start value	Ohm or none	50 Ohm /0 degrees
Load Impedance or Gamma Use sweep Mag and Phase Stop (or LS_stop)	Load sweep stop value. If this value is not set then the Start value is treated as a Single Point	Ohm or none	None
Load Impedance or Gamma Use sweep Mag and Phase Num. of pts (or LS_numPts)	Load sweep number of points. This value must be set if the Stop value is specified.	None	None

Notes/Equations

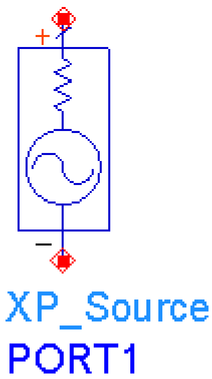
1. This component is designed for the X-Parameter Generator to establish the load or a load sweep for the large signal operating conditions. For more information, refer to *X-Parameter Generator Basics* (xparam).
2. This component represents the load specified in the *Load* tab at the frequency defined in the field *Frequency harmonic indices*. At all other frequencies, this component represents the load specified in the field *Reference impedance*.
3. If *Use sweep* is selected, then the X-parameter generation is performed for each value of the specified 2-dimensional sweep.
4. This component must not interact with external sweeps. Therefore, all the values (point, start, stop, num. of pts) must not be defined via external variables.
5. Reference impedance establishes the reference impedance for the incident and reflected waves for this port. It also establishes the value of the load at any frequency different from the frequency specified by *Frequency harmonic indices*.
6. Port numbers do not have to be consecutive. However, the highest port number will establish the total number of ports for the simulation component using the generated X-parameters. Thus the highest port number should not exceed the largest number

of ports available in those components. Otherwise the data will not be available for simulation using those components. For more information, refer *XnP Components (X1P - X10P)* (ccsim).

7. This component can also be used in simulations other than X-parameter generation. In Harmonic Balance simulations this component will represent the load specified in the Load tab at the frequency defined in the field *Frequency harmonic indices* relative to those defined in the Harmonic Balance controller. At all other frequencies and other simulation types this component represents the load specified in the field *Reference impedance*. Any sweep defined in this component is ignored and a single value (either point or start) is used.
8. At DC, this component behaves as an ideal voltage source if DC bias type *Voltage* is selected, or as an ideal current source if DC bias type *Current* is selected. If DC bias type is set to *None* then, at DC, the component becomes a resistance with the value equal to the real part of the *Reference impedance*.

XP_Source (Source for X-Parameter Generator)

Symbol



Parameters

Name	Description	Units	Default
Port number (or Num)	port number	None	lowest available
Port name (or PortName)	port name	None	None
Reference impedance (or Z0)	Source impedance and reference impedance	Ohm	50+j*0
DC Bias type (or DC_mode)	DC bias type: None, Voltage, Current	None	None
DC Sweep type (or DC_swpType)	DC bias sweep type: Single point, Use sweep	None	point
DC Single point (or DC_value)	DC bias single value	V or A	None
DC Start (or DC_start)	DC bias sweep start value	V or A	None
DC Stop (or DC_stop)	DC bias sweep stop value	V or A	None
DC Num. of pts (or DC_numPts)	DC bias sweep number of points	None	None
Power source Frequency harmonic indices (or LS_freqHarms)	Frequency harmonic indices - comma separated list of harmonic/mixing indices	None	1
Power source Power level Sweep type	Large signal sweep type: Single point, Use sweep	None	sweep

(or LS_swpType)			
LS_format (*Display* tab only)	Large signal format: Mag/Phase (not editable)	None	Mag/Phase
Power source Power level Single point Mag and Phase (or LS_value)	Large signal single value	W dBm dBW /degree	-20 dBm /0 degrees
Power source Power level Use sweep Mag and Phase Start (or LS_start)	Large signal sweep start value	W dBm dBW /degree	-20 dBm /0 degrees
Power source Power level Use sweep Mag and Phase Stop (or LS_stop)	Large signal sweep stop value. If this value is not set then the Start value is treated as a Single Point	W dBm dBW /degree	-20 dBm /0 degrees
Power source Power level Use sweep Mag and Phase Num. of pts (or LS_numPts)	Large signal sweep number of points. This value must be set if the Stop value is specified.	None	None

Notes/Equations

1. This component is designed for the X-Parameter Generator to establish power and DC sweeps for the large signal operating conditions. For more information, refer to *X-Parameter Generator Basics* (xparam).
2. This component must not interact with external sweeps. Therefore, all the values (point, start, stop, num of pts) must not be defined via external variables.
3. In X-parameter generation, the power sweep is logarithmic if the power unit is dBm or dBW. Otherwise, the sweep is linear. Logarithmic sweeps place most of the sweep points at lower power levels while linear sweeps can provide a good coverage at higher power levels. If desired, more than one sweep can be defined and different sweeps are allowed to be of different types. Since the type of the sweep is determined from the units, mixing Watt and dB units within the same sweep is not allowed.
4. This component can also be used in simulations other than X-parameter generation and, in general, will behave like a P_nTone component with the following exceptions:
   - Source frequencies are set relative to those defined in the Harmonic Balance controllers.
   - The AC power (parameter Pac of the P_nTone component) is zero.
   - All the sweeps defined in this component are ignored and a single value (either point or start) is used.
   - The DC source behavior may be different.
5. Port numbers do not have to be consecutive. However, the highest port number will establish the total number of ports for the simulation component using the generated X-parameters. Thus the highest port number should not exceed the largest number of ports available in those components. Otherwise the data will not be available for simulation using those components. For more information, refer to *XnP Components (X1P - X10P)* (ccsim).

6. Reference impedance establishes both the RF source impedance and the reference impedance for the incident and reflected waves for this port.
7. At DC, this component behaves as an ideal voltage source if DC bias type *Voltage* is selected, or as an ideal current source if DC bias type *Current* is selected. If DC bias type is set to *None* then, at DC, the component becomes a resistance with the value equal to the real part of the *Reference impedance*.

Sources, Modulated

Introduction

Note
Refer to the *Simulator Expressions* (expsim) for predefined functions that can be used to build more complicated expressions.

- *PtRF 3GPP Uplink (Pwr Src, RF Carrier Modulated by 3GPP Uplink Signal)* (ccsrc)
- *PtRF_CDMA2K_REV (Pwr Src, RF Carrier Modulated by CDMA2K Reverse Link Signal)* (ccsrc)
- *PtRF_CDMA_ESG_FWD (Pwr Src, RF Carrier Modulated by ESG Fwd Link CDMA Signal)* (ccsrc)
- *PtRF_CDMA_ESG_REV (Pwr Src, RF Carrier Modulated by ESG Rev. Link CDMA Signal)* (ccsrc)
- *PtRF_CDMA_IS95_FWD (Pwr Src, RF Carrier Modulated by IS95 Fwd Link CDMA Signal)* (ccsrc)
- *PtRF_CDMA_IS95_REV (Pwr Src, RF Carrier Modulated by IS95 Rev. Link CDMA Signal)* (ccsrc)
- *PtRF DECT (Pwr Src, RF Carrier Modulated by DECT Signal)* (ccsrc)
- *PtRF EDGE Uplink (Pwr Src, RF Carrier Modulated by EDGE Uplink Signal)* (ccsrc)
- *PtRF GSM (Pwr Src, RF Carrier Modulated by GSM Signal)* (ccsrc)
- *PtRF NADC (Pwr Src, RF Carrier Modulated by NADC Signal)* (ccsrc)
- *PtRF PHS (Pwr Src, RF Carrier Modulated by PHS Signal)* (ccsrc)
- *PtRF Pulse (Pwr Src, RF Pulse Train)* (ccsrc)
- *PtRF Step (Pwr Src, RF Step)* (ccsrc)
- *VtRF Pulse (Voltage Source, RF Pulse)* (ccsrc)
- *VtRF SStudio (Signal Studio File Based Source)* (ccsrc)
- *VtRF Step (Voltage Source, RF Step)* (ccsrc)

PtRF_3GPP_Uplink (Pwr Src, RF Carrier Modulated by 3GPP Uplink Signal)

Symbol

Parameters

Name	Description	Units	Default
Freq	Carrier frequency	MHz	1950
Power	Output power at RF output	dBm	0
R	Output impedance of RF output (not used)	Ohm	(50)
Num	Port number	Integer	1

Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a user equipment 3GPP (WCDMA) signal. It also contains framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The stored data file is generated by the 3GPP Design Library. The pulse-shaping filter is a root raised-cosine filter with roll-off α=0.22, according to 3GPP specifications.
3. The data file contains 1 frame (10 μ) of 3GPP data (38400 chips at 1/3.84 μ per chip).
4. It is recommended that simulation timestep be set to (1/3.84/4 msec), that is, taking four samples per chip. For other timestep values the source interpolates between data samples and results in different or lower fidelity signal spectrum.
5. Recommended controller setups for Envelope simulation are:
    - Envelope item
      Freq[1] = RFfreq
      Order[1] = 1
      StatusLevel=2
      Stop=tstop

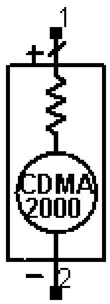
Step=tstep
Other=SaveToDataset=yes

- VAR item
  chip_rate=3.84 MHz
  RFfreq = 1.95 GHz
  Pavs = 0_dBm
  sam_per_chip = 4
  tstep = 1 / chip_rate / sam_per_chip
  numChips = 256
  tstop = numChips / chip_rate
- PtRF_3GPP_Uplink item
  Freq = RFfreq
  Power = dbmtow(Pavs)
  (R = 50 Ohm)

6. For an overview of 3GPP (WCDMA) systems, refer to *About 3GPP W-CDMA Design Library* (wcdma3g).

PtRF_CDMA2K_REV (Pwr Src, RF Carrier Modulated by CDMA2K Reverse Link Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	carrier frequency	MHz	825
Power	RF output power	dBm	0
Z	RF output impedance (not used)	Ohm	(50)
Num	Port number	Integer	1

Notes/Equations

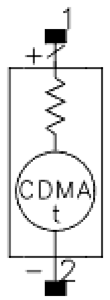
1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a mobile station CDMA2000 signal. It also contains framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The stored data file is generated by the CDMA2000 Design Library. The bandlimiting filter coefficients come from IS-2000 specifications.
3. The data file contains 1 frame (20 μ) of CDMA2000 data (24576 chips at 1/1.2288 msec per chip).
4. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
5. It is recommended that simulation timestep be set to (1/1.2288/4 μ), that is, taking four samples per chip. For other timestep values the source interpolates between data samples and results in different or lower fidelity signal spectrum.
6. Recommended controller setups for Envelope simulation are:
   - Envelope item
     Freq[1] = RFfreq
     Order[1] = 1
     StatusLevel=2
     Stop=tstop
     Step=tstep
     Other=SaveToDataset=yes

- VAR item
  chip_rate=1.2288 MHz
  RFfreq = 825 MHz
  Pavs = 0_dBm
  sam_per_chip = 4
  tstep = 1 / chip_rate / sam_per_chip
  numChips = 256
  tstop = numChips / chip_rate
- PtRF_CDMA2K_REV item
  F0 = RFfreq
  Power = dbmtow(Pavs)
  (R = 50 Ohm)

7. For an overview of CDMA2000 systems, refer to the *cdma2000-Compliant Design Library* (cdma2k).

PtRF_CDMA_ESG_FWD (Pwr Src, RF Carrier Modulated by ESG Fwd Link CDMA Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	Carrier frequency	MHz	1900
Power	RF output power	dBm	0
Z	RF output impedance	Ohm	50
Num	Port number	Integer	1

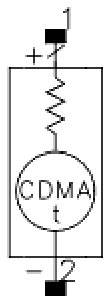
Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a base station CDMA signal. It does not contain any framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The stored data file is generated by the Agilent ESG series of signal generators. This source has lower adjacent channel power than that of PtRF_CDMA_IS95_FWD.
3. An identical source called IS95FwdLinkSrc that you can modify is located in the *examples/Tutorial/ModSources_wrk* directory.
4. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
5. It is recommended that simulation timestep is equal to (0.25/1.2288 MHz), i.e, taking four samples per bit. Using other timestep values causes the source to interpolate between data samples and thus result in a distorted spectrum.
6. Recommended controller setups for Envelope simulation are:
    - Envelope item
      Freq[1] = RFfreq
      Order[1] = 1
      StatusLevel=2
      Stop=tstop
      Step=tstep
      Other=SaveToDataset=yes

- VAR item
  bit_rate=1.2288 MHz
  RFfreq = 1.9 GHz
  Pavs = 0_dBm
  sam_per_bit = 4
  tstep = 1 / bit_rate / sam_per_bit
  numSymbols = 256
  tstop = num Symbols/ bit_rate / 2
- PtRF_CDMA_ESG_FWD item
  F0=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

PtRF_CDMA_ESG_REV (Pwr Src, RF Carrier Modulated by ESG Rev. Link CDMA Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	carrier frequency	MHz	1900
Power	RF output power	dBm	0
Z	RF output impedance	Ohm	50
Num	Port number	Integer	1

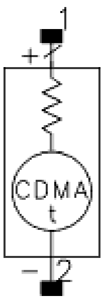
Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a handset CDMA signal. It does not contain any framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The stored data file is generated by the Agilent ESG series of signal generators.This source has lower adjacent channel power than that of PtRF_CDMA_IS95_REV.
3. An identical source called IS95RevLinkSrc2 that you can modify is located in the *examples/Tutorial/ModSources_wrk* directory.
4. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
5. It is recommended that simulation timestep is set equal to (0.25/1.2288 MHz), i.e, taking four samples per bit. Using other timestep values, the source interpolates between data samples and results in a distorted spectrum.
6. Recommended controller setups for Envelope simulation are:
    - Envelope item
      Freq[1] = RFfreq
      Order[1] = 1
      StatusLevel=2
      Stop=tstop
      Step=tstep
      Other=SaveToDataset=yes

- VAR item
  bit_rate=1.2288 MHz
  RFfreq = 1.9 GHz
  Pavs = 0_dBm
  sam_per_bit = 4
  tstep = 1 / bit_rate / sam_per_bit
  numSymbols = 256
  tstop = num Symbols/ bit_rate / 2
- PtRF_CDMA_ESG_REV item
  F0=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

PtRF_CDMA_IS95_FWD (Pwr Src, RF Carrier Modulated by IS95 Fwd Link CDMA Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	carrier frequency	MHz	1900
Power	RF output power	dBm	0
Z	RF output impedance	Ohm	50
Num	Port number	Integer	1

Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a base station CDMA signal. It does not contain any framing characteristics.
2. The bandlimiting filter coefficients come from IS-95 specifications. This source has higher adjacent channel power than that of PtRF_CDMA_ESG_FWD.
3. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
4. It is recommended that simulation timestep is set equal to (0.25/1.2288 MHz), i.e, taking four samples per bit. Using other timestep values makes the source interpolate between data samples and will result in a distorted spectrum.
5. Recommended controller setups for Envelope simulation are:
   - Envelope item
     Freq[1] = RFfreq
     Order[1] = 1
     StatusLevel=2
     Stop=tstop
     Step=tstep
     Other=SaveToDataset=yes
   - VAR item
     bit_rate=1.2288 MHz
     RFfreq = 1.9 GHz
     Pavs = 0_dBm

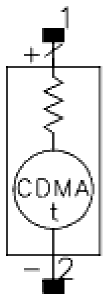
sam_per_bit = 4
tstep = 1 / bit_rate / sam_per_bit
numSymbols = 256
tstop = num Symbols/ bit_rate / 2

- PtRF_CDMA_!S95_FWD item
  F0=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

6. There is a limitation for ACPR test using PtRF_CDMA_IS95_FWD source. This source uses an IS95 filter specified by the IS95 Standard that does not provide an adequate spectrum for ACPR testing. If ACPR testing is required, use the PtRF_CDMA_ESG_FWD Source component. The PtRF_CDMA_ESG_FWD Source component includes an ESG filter designed by Agilent Technologies that provides a good spectrum for ACPR testing.

PtRF_CDMA_IS95_REV (Pwr Src, RF Carrier Modulated by IS95 Rev. Link CDMA Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	carrier frequency	MHz	1900
Power	RF output power	dBm	0
Z	RF output impedance	Ohm	50
Num	Port number	Integer	1

Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a handset CDMA signal. It does not contain any framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The bandlimiting filter coefficients come from IS-95 specifications. This source has higher adjacent channel power than that of PtRF_CDMA_ESG_REV.
3. An identical source called IS95RevLinkSrc that you can modify is located in the *examples/Tutorial/ModSources_wrk*. directory.
4. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
5. It is recommended that simulation timestep is equal to (0.25/1.2288 MHz), i.e, taking four samples per bit. Using other timestep values makes the source to interpolate between data samples and result in distorted spectrum.
6. Recommended controller setups for Envelope simulation are:
   - Envelope item
     Freq[1] = RFfreq
     Order[1] = 1
     StatusLevel=2
     Stop=tstop
     Step=tstep
     Other=SaveToDataset=yes
   - VAR item
     bit_rate=1.2288 MHz

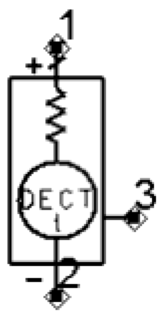
RFfreq = 1.9 GHz
Pavs = 0_dBm
sam_per_bit = 4
tstep = 1 / bit_rate / sam_per_bit
numSymbols = 256
tstop = num Symbols/ bit_rate / 2

- PtRF_CDMA_!S95_FWD item
  F0=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

7. There is a limitation for ACPR test using PtRF_CDMA_IS95_REV source. This source uses an IS95 filter specified by the IS95 Standard that does not provide an adequate spectrum for ACPR testing. If ACPR testing is required, use the PtRF_CDMA_ESG_REV Source component. The PtRF_CDMA_ESG_REV Source component includes an ESG filter designed by Agilent Technologies that provides a good spectrum for ACPR testing.

PtRF_DECT (Pwr Src, RF Carrier Modulated by DECT Signal)

Symbol



Parameters

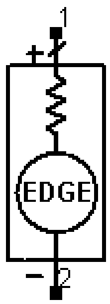
Name	Description	Units	Default
F0	carrier frequency	MHz	1897.344
Power	RF output power	dBm	0
Z	RF output impedance	Ohm	50
Num	Port number	Integer	1

Notes/Equations

1. This model generates a digitally modulated RF signal that has the modulation characteristics of a DECT signal. Bit time is 0.868 μ. NRZ data is Gaussian-filtered with BT=0.5.
2. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
3. The third terminal is the digital (-1/1 volt) bit sequence.

PtRF_EDGE_Uplink (Pwr Src, RF Carrier Modulated by EDGE Uplink Signal)

Symbol



Parameters

Name	Description	Units	Default
Freq	Carrier frequency	MHz	890.2
Power	Output power at RF output	dBm	0
R	Output impedance of RF output (not used)	Ohm	(50)
Num	Port number	Integer	1

Notes/Equations

1. This model generates a digitally-modulated RF signal that has the modulation characteristics of a mobile station EDGE signal. It also contains framing characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The stored data file is generated by the EDGE Design Library.
3. The data file contains 1 TDMA frame ((120/26) μ) of EDGE data (1250 symbols at 48/13 μ per symbol). One EDGE frame contains 8 time slots with each time slot containing 156.25 symbols. The EDGE frame generated by this source contains data (normal burst with 8PSK modulation) in the second time slot, all other seven time slots are idle (no signal). This frame represents one active user in the EDGE uplink.
4. It is recommended that simulation timestep be set to ((6/1625/8) μ), that is, taking eight samples per symbol. For other timestep values, the source interpolates between data samples and results in a different or lower fidelity signal spectrum.
5. Recommended controller setups for Envelope simulation are:
    - Envelope item
      Freq[1] = RFfreq
      Order[1] = 1
      StatusLevel=2
      Stop=tstop
      Step=tstep
    - VAR item
      sym_rate = 1625 kHz / 6
      RFfreq = 890.2 MHz

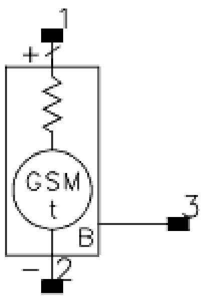
Pavs = 0_dBm
sam_per_sym = 8
tstep = 1 / sym_rate / sam_per_sym
numSymbols = 256
tstop = numSymbols / sym_rate

- PtRF_EDGE_Uplink item
  Freq = RFfreq
  Power = dbmtow(Pavs)
  (R = 50 Ohm)

6. For an overview of EDGE systems, refer to the *EDGE Design Library* (edge)

PtRF_GSM (Pwr Src, RF Carrier Modulated by GSM Signal)

Symbol



Parameters

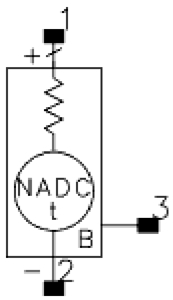
Name	Description	Units	Default
F0	carrier frequency	GHz	1
Power	RF output power	dBm	0
Rout	RF output resistance	Ohm	50
DataRate	digital modulation data rate	kHz	270.833
InitBits	initial state of PRBS data generator	None	"001101010010"
Num	Port number	Integer	1

Notes/Equations

1. This model generates a continuously digitally modulated RF signal that has the modulation characteristics of a transmitted GSM signal. It does not contain GSM framing or pulse modulation characteristics. It consists of a pseudorandom data generator (PRBS) feeding a Gaussian filter with a bandwidth time product of 0.3 that then FM modulates a voltage source to generate the RF output waveform. The baseband digital waveform is also output from this source.
2. The user can define the carrier frequency, power and output resistance of the RF output. The data rate can also be set, along with the initial seed value of the PRBS generator. The PRBS generator has 17 stages, with maximal length taps at bits 17 and 3. The baseband digital output is a −1V to +1V digital bit stream with a 1-ohm output impedance.
3. The RF output resistance, Rout, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
4. There is a time delay of 2.5-bit periods plus one analysis timestep between the digital output and the modulated RF output. The RF output can be floated with any common mode voltage on its two outputs, whereas the baseband output is always referenced to ground.

PtRF_NADC (Pwr Src, RF Carrier Modulated by NADC Signal)

Symbol



Parameters

Name	Description	Units	Default
F0	carrier frequency	MHz	870.03
Power	RF output power	dBm	0
Z	Output Impedance of RF Output, use 1+j*0 for complex	Ohm	50
LinMod	additional linear modulation	None	1.0
Toffset	time offset into data array	sec	0
Num	Port number	Integer	1

Notes/Equations

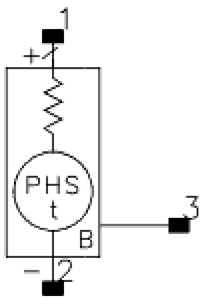
1. This model generates a continuously digitally modulated RF signal that has the modulation characteristics of a transmitted NADC signal. It does not contain framing or pulse modulation characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The user can define the carrier frequency, power and output impedance of the RF output.
3. Additional amplitude or phase modulation can be added by using LinMod to define an additional time varying modulation function. And, Toffset can be set to delay into the pseudorandom sequence to vary the effective starting point of the digital modulation sequence.
   The −1V to +1V baseband digital data stream is also available as an output at the third terminal and has a 1-ohm source resistance.
4. This 48.6 Kbps data stream was generated by using a PRBS source to modulate an RF source using the pi/4DQPSK modulator and filtering the signal with a root raised-cosine filter amplifier with a rolloff factor of 0.35. The filter uses an impulse response equal to 40 symbol periods and a Hanning window. The data sequence is 1024 PRBS symbols in addition to 46 zero-padding symbols. This pattern repeats if necessary, depending on the analysis stop time.
5. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF

output power.

6. The data is stored at 10 samples per symbol. If the analysis timestep is a multiple of this value, then there is no interpolation error. With other timestep values, spurious spectra may appear, but are more than 80dB below the main signal. Cubic interpolation is used on the RF output to minimize this error. Linear interpolation is used on the baseband, digital output to maintain its digital nature.

PtRF_PHS (Pwr Src, RF Carrier Modulated by PHS Signal)

Symbol



Parameters

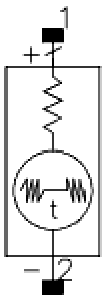
Name	Description	Units	Default
F0	carrier frequency	MHz	1895
Power	RF output power	dBm	0
Z	Output Impedance of RF Output, use 1+j*0 for complex	Ohm	50
LinMod	additional linear modulation	None	1.0
Toffset	time offset into data array	sec	0
Num	Port number	Integer	1

Notes/Equations

1. This model generates a continuously digitally modulated RF signal that has the modulation characteristics of a transmitted PHS signal. It does not contain framing or pulse modulation characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.
2. The user can define the carrier frequency, power and output impedance of the RF output.
3. The RF output resistance, Z, is expected to be a real resistance greater than zero. Use of a complex impedance, though allowed, might not result in the specified RF output power.
4. Additional amplitude or phase modulation can be added using LinMod to define an additional time-varying modulation function. And, Toffset can be set to delay into the pseudorandom sequence, to vary the effective starting point of the digital modulation sequence.
   The −1V to +1V baseband digital data stream is also available as an output at the third terminal and has a 1-ohm source resistance.

PtRF_Pulse (Pwr Src, RF Pulse Train)

Symbol



Parameters

Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
P	carrier power during pulse	dBm	0
Freq	RF carrier frequency	GHz	1
OffRatio	Linear amplitude ratio of OFF to ON portions of pulse	None	0
Delay	delay time before first pulse	nsec	0
Rise	rise time of pulse	nsec	1
Fall	fall time of pulse	nsec	1
Width	width of constant portion of pulse	nsec	3
Period	pulse repetition period	nsec	100
Chirp	linear frequency modulation during pulse	Hz	0
Phase0	initial phase of pulse carrier	deg	0
Noise	Enable/disable port thermal noise: YES, NO	None	yes
Pac	AC power, use 1+j*0 for complex	dBm	0
Vdc	open circuit dc voltage		None

Notes/Equations

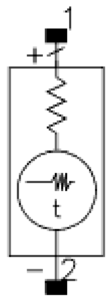
1. This RF pulse power source creates a pulse modulated RF carrier with optional frequency chirping. The carrier frequency at the start of the pulse is defined by the Freq parameter. For envelope simulation, Freq identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source output is set to zero for that analysis.
2. The pulse amplitude characteristics are defined using the Gaussian-shaped erf_pulse function, so the pulse parameters have the same definition as in the VTPulse model with Edge=erf. OffRatio defines the low state of the pulse relative to the high state, defined by P; P may be complex (such as P=polar(dBmtoW(0),45), and time-varying to provide additional amplitude and phase modulation. When this source represents a baseband signal (transient or the baseband part of an envelope signal), then only the real part of the signal is output.
3. The additional frequency chirp is referenced to the frequency value at the Delay time

point where the pulse first starts turning on. The chirp rate is calculated by dividing the Chirp parameter by the sum of Width, Rise and Fall time. The Chirp value then represents the amount of frequency shift over the full, extended pulse width. If OffRatio is not 0, this same chirp rate will continue until the next pulse starts, when it is reset to the Freq value.

4. This source applies to Circuit Envelope and transient simulation. In harmonic balance, the RF component of the source is turned off and the source is electrically equivalent to a DC supply of Vdc Volts in series with a Z Ohm resistor.

PtRF_Step (Pwr Src, RF Step)

Symbol



Parameters

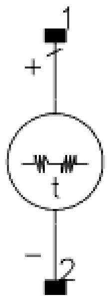
Name	Description	Units	Default
Num	port number	Integer	1
Z	Source impedance, use 1+j*0 for complex	Ohm	50
P	steady state power	dBm	0
Freq	RF frequency	GHz	1
Delay	time delay before step	nsec	0
Rise	rise time of step	nsec	0
Noise	Enable/disable port thermal noise: YES, NO	None	yes
Pac	AC power, use polar() for phase	dBm	0
Vdc	open circuit dc voltage		None

Notes/Equations

1. This RF step power source creates an RF carrier that is turned on after the start of the time-domain simulation. The carrier frequency is defined by Freq. For envelope simulations, Freq identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source output is set to zero for that analysis.
2. The carrier is turned on at the time specified by Delay. The turn-on duration is defined by Rise and uses the Gaussian-shaped rise time defined by the erf_pulse() function.
3. The P parameter can be complex and a function of time and will provide amplitude-only modulation with logarithmic scaling. Refer to the VtRF_Step source if linear or other modulation is desired. When this source represents a baseband signal (transient or the baseband part of an envelope signal), then only the real part of the signal is output.

VtRF_Pulse (Voltage Source, RF Pulse)

Symbol



Parameters

Name	Description	Units	Default
Freq	RF carrier frequency	GHz	1
Vpeak	voltage envelope of pulse	None	dbmtov(0,50)
OffRatio	Linear amplitude ratio of OFF to ON portions of pulse	None	0
Delay	time delay before first pulse	nsec	0
Rise	rise time of pulse	nsec	1
Fall	fall time of pulse	nsec	1
Width	width of constant portion of pulse	nsec	3
Period	pulse repetition period	nsec	100
Chirp	linear frequency modulation during pulse	Hz	0
Phase0	initial phase of pulse carrier	deg	0
Vdc	DC voltage		None
Vac	AC voltage	V	1
SaveCurrent	Flag to save branch current: YES, NO	None	yes

Notes/Equations

1. This RF pulse voltage source creates a pulse modulated RF carrier with optional frequency chirping. The carrier frequency at the start of the pulse is defined by the Freq parameter. For envelope simulation, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source output is set to zero for that analysis.
2. The pulse amplitude characteristics are defined using the Gaussian-shaped erf_pulse function, so the parameters have the same definition as in the VPulse with Edge=erf. OffRatio defines the low state of the pulse relative to the high state, defined by Vpeak. The Vpeak parameter can be complex and time-varying to provide additional amplitude and phase modulation. When this source represents a baseband signal (transient or the baseband part of an envelope signal), only the real part of the signal is output.
3. The additional frequency chirp is referenced to the frequency value at the Delay time point where the pulse first starts turning on. The chirp rate is calculated by dividing the Chirp parameter by the sum of the Width, Rise and Fall time. The Chirp value

then represents the amount of frequency shift over the full, extended pulse width. If the OffRatio is not zero, this same chirp rate will continue until the next pulse starts, when it is reset to the Freq parameter value.

4. This source output in harmonic balance analyses is only the value at time=0. Additional source parameters that are available can be found in the perform/edit component dialog box.

VtRF_SStudio (Signal Studio File Based Source)

Symbol

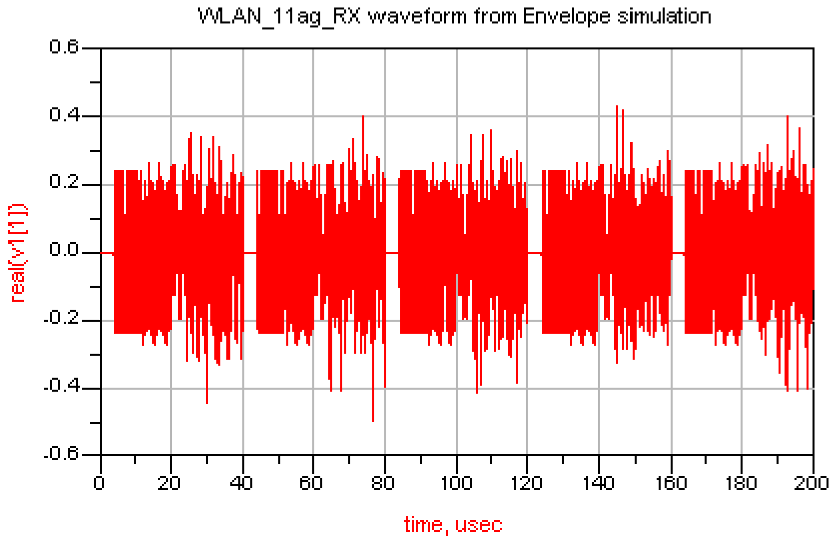
Parameters

Name	Description	Units	Default
File	Name for Signal Studio waveform file (*.wfm)	None	None
Freq	Carrier frequency	GHz	1
VoltageScale	Scaling factor for I and Q voltage axes	None	1
SaveCurrent	Flag to save branch current: YES, NO	None	yes

Notes/Equations

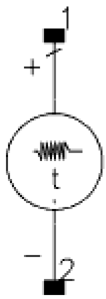
1. VtRF_SStudio can be used to generate modulated signals based on waveform (*.wfm) files exported from any standard Signal Studio package. WFM files are used to capture a wide range of application-specific test signals at baseband RF and microwave frequencies using Agilent MXG, ESG, and PSG signal generators. For more information on Signal Studio, refer to http://www.agilent.com/find/SignalStudio .
2. Waveform files may or may-not be associated with a specific Signal Studio license. VtRF_SStudio checks for availability of appropriate license prior to file reading. A license free template file is available from the dialog box under the File parameter for trial purposes.
3. Waveform files are captured in binary format and contain information regarding the modulating waveform such as in-phase (I) and quadrature (Q) voltages at a certain number of evenly spaced out time points. The sampling interval of this modulating signal is captured to the header of the file as is the carrier frequency that was used to generate the waveform in Signal Studio. Upon successfully reading the supplied waveform file, VtRF_SStudio issues a standard message regarding statistics such as carrier frequency (which may be zero if the signal was extracted at baseband), sampling interval and number of data points.
4. VtRF_SStudio uses the value of Freq defined on the component instance to generate its modulated signal without relying on the carrier frequency mentioned in the waveform file. This component is designed for use in Circuit Envelope simulation. The user is urged to pay attention to differences between the sampling interval of the file and the time step may have been set for the Envelope controller to judge effects of data interpolation on output signal quality.
5. The component issues a warning message if more than 10 million time points on the waveform file and restricts the waveform accordingly.

6. If stop time of the Envelope simulation exceeds the minimum of 10 million and the number of data points on file, then file values are repeated from the beginning to continue producing identical frames of the signal. Effectively no extrapolation technique is associated with this component.
7. The VoltageScale parameter is a numeric multiplier applied to both the I and Q waveforms. It is made available for simple scaling of the modulating waveform.
8. The following figure demonstrates the modulated waveform generated from the template file WLAN_11ag_RX.wfm under Circuit Envelope simulation set for 200 ms with time step of 25 nsec. In this case each time point during simulation corresponds to each time point of the data file. The fundamental frequency was set to the exact carrier tone of 2.4 GHz for this WLAN protocol.



VtRF_Step (Voltage Source, RF Step)

Symbol



Parameters

Name	Description	Units	Default
Freq	RF frequency	GHz	1
V	voltage envelope of step	None	polar(1,90)
Delay	time delay before step	nsec	0
Rise	rise time of step	nsec	0
Vdc	DC voltage		None
Vac	AC voltage	V	1
SaveCurrent	Flag to save branch current: YES, NO	None	yes

Notes/Equations

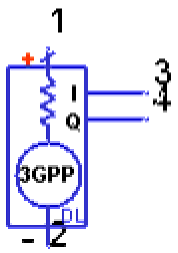
1. This RF step voltage source creates an RF carrier that is turned on after the start of the time-domain simulation. The carrier frequency is defined by the Freq parameter. For envelope analyses, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source voltage is set to 0 for that analysis.
2. The carrier is turned on at the time specified by the Delay parameter. The turn-on duration is defined by the Rise parameter and uses the Gaussian-shaped rise time defined by the (erf_pulse() function).
3. The voltage parameter can be a complex value to define both the amplitude and phase of the carrier. It can also be a time-varying expression to put additional amplitude or phase modulation on the carrier. When this source represents a baseband signal (transient or the baseband part of an envelope signal), then only the real part of the signal is output.

Sources, Modulated-DSP-Based

- *3GPPFDD DnLink (3GPP FDD Downlink Signal Source)* (ccsrc)
- *3GPPFDD UpLink (3GPP FDD Uplink Signal Source)* (ccsrc)
- *TDSCDMA DnLink (TDSCDMA Downlink Signal Source)* (ccsrc)
- *TDSCDMA UpLink (TDSCDMA Uplink Signal Source)* (ccsrc)
- *WLAN 802 11a (WLAN 80211a Signal Source)* (ccsrc)
- *WLAN 802 11b (WLAN 80211b Signal Source)* (ccsrc)

3GPPFDD_DnLink (3GPP FDD Downlink Signal Source)

Symbol



Parameters

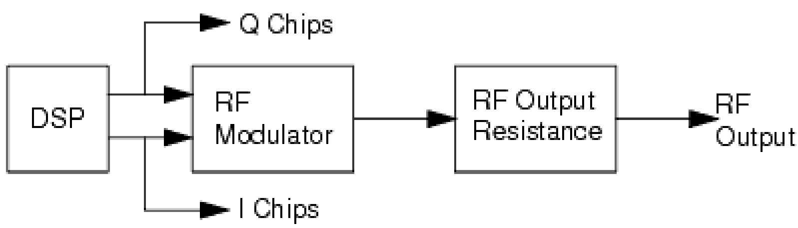
Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/3.84 MHz/SamplesPerChip			string	
FCarrier	Carrier frequency	2140 MHz		Hz	real	(0, ∞)
Power	Power	dbmtow(43.0)		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
SamplesPerChip	Samples per chip	8	S		int	[2, 32]
RRC_FilterLength	RRC filter length (chips)	16			int	[2, 128]
SpecVersion	Specification version: Version 03_00, Version 12_00, Version 03_02	Version 12_00			enum	
SourceType	Source type: TestModel1_16DPCHs, TestModel1_32DPCHs, TestModel1_64DPCHs, TestModel2, TestModel3_16DPCHs, TestModel3_32DPCHs, TestModel4	TestModel1_16DPCHs			enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed
3	I	I symbols	real
4	Q	Q symbols	real

Notes/Equations

1. This 3GPP FDD signal source generates a downlink RF signal of 3GPP FDD test models. The RF signal has a chip rate of 3.84 MHz. The downlink is from the base station to the user equipment.
   To use this source, RF carrier frequency (FCarrier) and power (Power) must be set. RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   3GPP FDD signal characteristics can be specified by setting the RRC_FilterLength, SpecVersion, and SourceType parameters.
   The maximum Circuit Envelope simulation time allowed is 1/3.84 MHz/SamplesPerChip. If the actual Circuit Envelope simulation time step is greater than this maximum allowed, the simulation will stop and display an error message.
2. An example (3GPPFDD_DnLink_test) demonstrating the use of this signal source is available under /examples/WCDMA3G/RF_Verification_wrk.
3. This signal source includes a DSP section, RF modulator, and RF output resistance as illustrated in the following image.

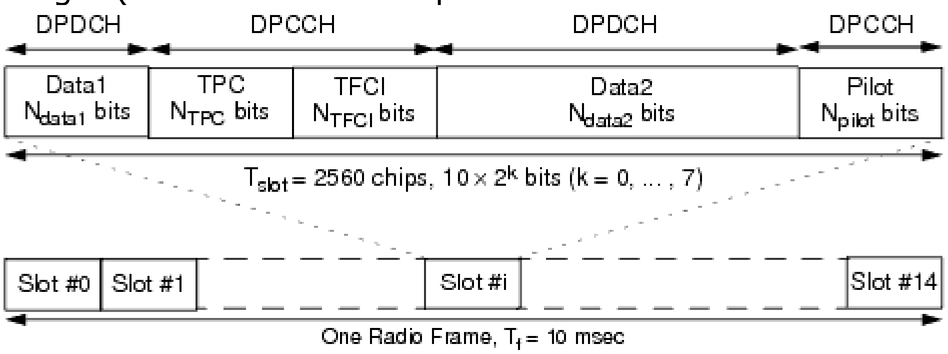
   

   Signal Source Block Diagram

   The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
   The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).
   The I and Q outputs are baseband outputs with zero source resistance and contain the unfiltered I and Q chips available at the RF modulator input. Because the I and Q outputs are from the inputs to the RF modulator, the RF output signal has a time delay relative to the I and Q chips. This RF time delay (RF_Delay) is related to the RRC_FilterLength parameter value.
   RF_Delay = RRC_FilterLength/(3.84e6)/2 sec
4. This 3GPP FDD downlink signal source model is compatible with Agilent E4438C ESG Vector Signal Generator, Option 400 (3GPP W-CDMA Firmware Option for the E4438C

ESG Vector Signal Generator).
Details regarding Agilent E4438C ESG for 3GPP FDD are included at
http://www.agilent.com/find/esg

5. Regarding the 3GPP downlink signal frame structure, one frame has a time duration of 10 msec and consists of 15 slots. Each slot contains 2560 chips. Each chip is an RF signal symbol.
There is only one type of downlink dedicated physical channel, the downlink Dedicated Physical Channel (downlink DPCH).
Within one downlink DPCH, dedicated data generated at Layer 2 and above, i.e. the dedicated transport channel (DCH), is transmitted in time-multiplex with control information generated at Layer 1. The Layer 1 control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, and an optional transport-format combination indicator (TFCI). The TFCI informs the receiver about the instantaneous transport format combination of the transport channels mapped to the simultaneously transmitted downlink DPCH radio frame.
The downlink DPCH can therefore be seen as a time multiplex of a downlink DPDCH (Data1 and Data2) and a downlink DPCCH (TPC, TFCI, and Pilot).
The frame and slot structure of the downlink DPCH is illustrated in the following image. (The various tables provide more information about each field.)



3GPP FDD Downlink Frame and Slot Structure

6. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO disables the Temp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power delivered into a matched load of resistance R.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage.
     Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set MirrorSpectrum to YES.
   - GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and

IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor based on the Power and R parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).

- SamplesPerChip is used to set the number of samples in a chip.
  The default value is set to 8 to display settings according to the 3GPP standard. It can be set to a larger value for a simulation frequency bandwidth wider than 8 × 3.84 MHz. It can be set to a smaller value for faster simulation; however, this will result in lower signal fidelity. If SamplesPerChip = 8, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 8 (e.g., simulation RF bandwidth = 8 × 3.84 MHz).
- RRC_FilterLength is used to set root raised-cosine (RRC) filter length in number of chips.
  The default value is set to 16 to transmit a 3GPP FDD downlink signal in time and frequency domains based on the 3GPP standard defined in [4]. It can be set to a smaller value for faster simulation times; however, this will result in lower signal fidelity.
- SpecVersion is used to specify the 3GPP specification versions (2000-03, 2000-12 and 2002-03).
- SourceType is used to specify the type of baseband signal that can be generated by this source based on the test model as defined in [5].
  TestModel1_16DPCHs, TestModel1_32DPCHs, TestModel1_64DPCHs The following table lists the active channels of Test Model 1, which tests spectrum emission mask, ACLR, spurious emissions, transmit intermodulation, and base station maximum output power.

Test Model 1 Active Channels

Type	Number of Channels	Fraction of Power(%)	Level Setting (dB)	Channelization Code	Timing Offset (x256Tchip)
PCCPCH+SCH	1	10	-10	1	0
Primary CPICH	1	10	-10	0	0
PICH	1	1.6	-18	16	120
SCCPCH containing PCH (SF=256) †	1	1.6	-18	3	0
DPCH (SF=128) ††	16/32/64	76.8 total	see Reference 5	see Reference 5	see Reference 5

† SCCPCH containing PCH is not included in versions 2000-03 and 2000-12 (Reference 5).

†† Refer to DPCH Structure for Test Model 1 and Test Model 2 for DPCH structure.

TestModel2. The following table lists the active channels in Test Model 2, which tests output power dynamics.

Test Model 2 Active Channels

Type	Number of Channels	Fraction of Power(%)	Level Setting (dB)	Channelization Code	Timing Offset (x256Tchip)
PCCPCH+SCH	1	10	-10	1	0
Primary CPICH	1	10	-10	0	0
PICH	1	5	-13	16	120
SCCPCH containing PCH (SF=256) †	1	5	-13	3	0
DPCH (SF=128) ††	3	2x10, 1x50	2x-10, 1x-3	24, 72, 120	1, 7, 2

† SCCPCH containing PCH is not included in versions 2000-03 and 2000-12 (Reference 5).

†† Refer to DPCH Structure for Test Model 1 and Test Model 2 for DPCH structure.

TestModel3_16DPCHs, TestModel3_32DPCHs. The following table lists the active channels of Test Model 3, which tests peak code domain error.

Test Model 3 Active Channels

Type	Number of Channels	Fraction of Power(%) 16/32	Level Setting (dB)	Channelization Code	Timing Offset (x256Tchip)
PCCPCH+SCH	1	12.6/7.9	-9 / -11	1	0
Primary CPICH	1	12.6/7.9	-9 / -11	0	0
PICH	1	5/1.6	-13/-18	16	120
SCCPCH containing PCH (SF=256) †	1	5/1.6	-13/-18	3	0
DPCH (SF=256) ††	16/32	63,7/80,4 total	see Reference 5	see Reference 5	see Reference 5

† SCCPCH containing PCH is not included in versions 2000-03 and 2000-12 [5].
†† Refer to DPCH Structure for Test Model 3 for DPCH structure.

TestModel4. The following table lists the active channels of Test Model 4, which tests EVM.

Test Model 4 Active Channels

Type	Number of Channels	Fraction of Power(%) 16/32	Level Setting (dB)	Channelization Code	Timing Offset (x256Tchip)
PCCPCH+SCH when Primary CPICH is disabled	1	50 to 1.6	-3 to -18	1	0
PCCPCH+SCH when Primary CPICH is enabled	1	25 to 0.8	-6 to -21	1	0
Primary CPICH†	1	25 to 0.8	-6 to -21	0	0
SCCPCH containing PCH (SF=256) †	1	5/1.6	-13/-18	3	0
DPCH (SF=256) ††	16/32	63,7/80,4 total	see Reference 5	see Reference 5	see Reference 5

† Primary CPICH is optional; it is not included in versions 2000-03 and 2000-12 (Reference 5).

DPCH Structure for Test Model 1 and Test Model 2

Slot Format No.	Channel Bit Rate (kbps)	Channel Symbol Rate (kbps)	SF	Bits / Slot	DPDCH Bits / Slot		DPCCH Bits / Slot		
					NData1	NData2	NTFCI	NTPC	Npilot
10	60	30	128	40	6	24	0	2	8

DPCH Structure for Test Model 3

Slot Format No.	Channel Bit Rate (kbps)	Channel Symbol Rate (kbps)	SF	Bits / Slot	DPDCH Bits / Slot		DPCCH Bits / Slot		
					NData1	NData2	NTFCI	NTPC	Npilot
6	30	15	256	20	2	8	0	2	8

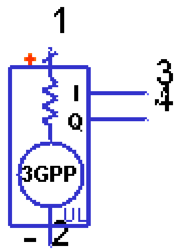
7. Use with Circuit Analyses
   The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
   Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

1. 3GPP Technical Specification TS 25.211, "Physical channels and mapping of transport channels onto physical channels (FDD)" Release 1999.
   http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25211-3a0.zip
2. 3GPP Technical Specification TS 25.212, "Multiplexing and Channel Coding (FDD)" Release 1999.
   http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25212-390.zip
3. 3GPP Technical Specification TS 25.213, "Spreading and modulation (FDD)" Release 1999.
   http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25213-370.zip
4. 3GPP Technical Specification TS 25.104, "UTRA (BS) FDD; Radio transmission and Reception" Release 1999.
   http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25104-3a0.zip
5. 3GPP Technical Specification TS 25.141, "Base station conformance testing (FDD)" Release 1999.
   http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25141-390.zip

3GPPFDD_UpLink (3GPP FDD Uplink Signal Source)

Symbol



Parameters

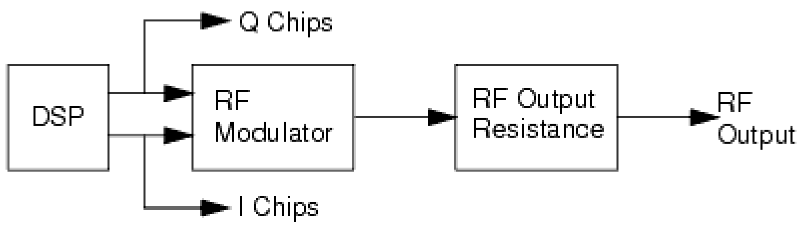
Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/3.84 MHz/SamplesPerChip			string	
FCarrier	Carrier frequency	1950 MHz		Hz	real	(0, ∞)
Power	Power	dbmtow(24.0)		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I (dB)	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
SamplesPerChip	Samples per chip	8	S		int	[2, 32]
RRC_FilterLength	RRC filter length (chips)	16			int	[2, 128]
SpecVersion	Specification version: Version 03_00, Version 12_00, Version 03_02	Version 12_00			enum	
SourceType	Source type: UL_12_2, UL_768	UL_12_2			enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed
3	I	I symbols	real
4	Q	Q symbols	real

Notes/Equations

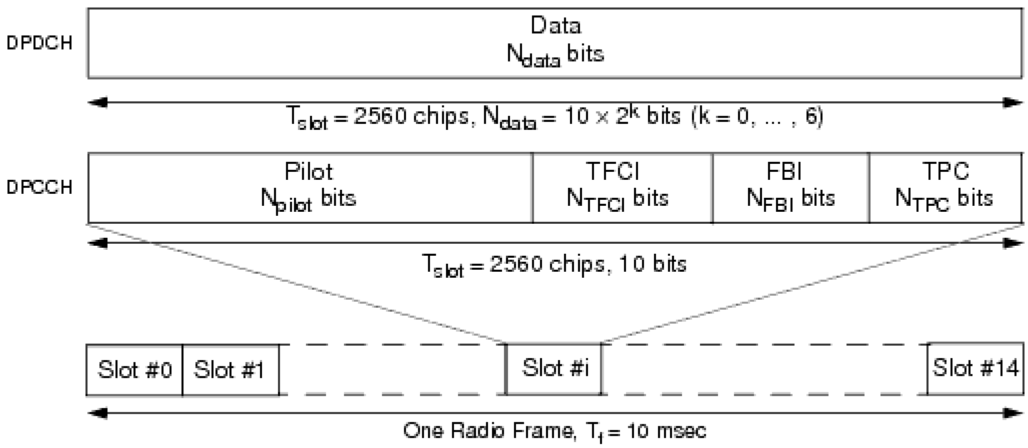
1. This 3GPP FDD uplink signal source generates a 12.2 and 768 kbps uplink RF signal with one dedicated transport channel (DTCH) and one dedicated control channel (DCCH). The RF signal has a chip rate of 3.84 MHz. The uplink is from the user equipment to the base station.
   To use this source, RF carrier frequency (FCarrier) and power (Power) must be set. RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   3GPP FDD signal characteristics can be specified by setting the RRC_FilterLength, SpecVersion, and SourceType parameters.
   The maximum Circuit Envelope simulation time allowed is 1/3.84 MHz/SamplesPerChip. If the actual simulation Circuit Envelope simulation time step is greater than this maximum allowed, the simulation will stop and display an error message.
2. An example (3GPPFDD_UpLink_test) demonstrating the use of this signal source is available under /examples/WCDMA3G/RF_Verification_wrk.
3. This signal source includes a DSP block, an RF modulator, and RF output resistance as illustrated in the following image.

   Signal Source Block Diagram

   The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
   The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).
   The I and Q outputs are baseband outputs with zero source resistance and contain the unfiltered I and Q chips available at the RF modulator input. Because the I And Q outputs are from the RF modulator inputs, the RF output signal has a time delay relative to the I and Q chips. This RF time delay (RF_Delay) is related to the RRC_FilterLength parameter value.
   RF_Delay = RRC_FilterLength/(3.84e6)/2 sec.
4. This 3GPP FDD downlink signal source model is compatible with Agilent E4438C ESG Vector Signal Generator, Option 400 (3GPP W-CDMA Firmware Option for the E4438C ESG Vector Signal Generator).
   Details regarding Agilent E4438C ESG for 3GPP FDD are included at the website http://www.agilent.com/find/esg
5. Regarding the 3GPP uplink signal frame structure, one frame has a time duration of 10 msec and consists of 15 slots. Each slot corresponds to one power control period

and contains 2560 chips.
There are two types of uplink dedicated physical channels - uplink Dedicated Physical Data Channel (uplink DPDCH) and uplink Dedicated Physical Control Channel (uplink DPCCH). These channels are I/Q code multiplexed within each radio frame.
Uplink DPDCH is used to carry the DCH transport channel. There may be zero, one, or several uplink DPDCHs on each radio link.
Uplink DPCCH is used to carry control information generated at Layer 1. The Layer 1 control information consists of known pilot bits to support channel estimation for coherent detection, transmit power-control (TPC) commands, feedback information (FBI), and an optional transport-format combination indicator (TFCI). The TFCI informs the receiver about the instantaneous transport format combination of the transport channels mapped to the simultaneously transmitted uplink DPDCH radio frame. There is only one uplink DPCCH on each radio link.
The frame structure of the uplink dedicated physical channels is illustrated in the following image. (The various tables provide more information about each field.).



12.2 kbps Uplink Channel Frame Structure

6. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO disables the Temp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power delivered into a matched load of resistance R.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage.
     Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set MirrorSpectrum to YES.
   - GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.

The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

where *A* is a scaling factor based on the Power and R parameters specified by the user, *V* I(*t*) is the in-phase RF envelope, *V* Q(*t*) is the quadrature phase RF envelope, *g* is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal *V* RF(*t*) is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).

- SamplesPerChip is used to set the number of samples in a chip.
  The default value is set to 8 to display settings according to the 3GPP standard. It can be set to a larger value for a simulation frequency bandwidth wider than 8 × 3.84 MHz. It can be set to a smaller value for faster simulation times; however, this will result in lower signal fidelity. If SamplesPerChip = 8, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 8 (e.g., simulation RF bandwidth = 8 × 3.84 MHz).
- RRC_FilterLength is used to set root raised-cosine (RRC) filter length in chips. The default value is set to 16 to transmit a 3GPP FDD uplink signal in time and frequency domains based on the 3GPP standard [4]. It can be set to a smaller value for faster simulation times; however, this will result in lower signal fidelity.
- SpecVersion is used to specify the 3GPP specification versions (2000-03, 2000-12 and 2002-03).
- SourceType is used to specify the type of baseband signal. Reference measurement channels (RMC) 12.2 and 768 kbps as defined in [4] and [5] are available.
  Basic parameters of 12.2 kbps RMC (SourceType = UL_12_2) are listed in the "Uplink 12.2 kbps Reference Measurement Channel" tables.
  Basic parameters of 768 kbps RMC (SourceType = UL_768) are listed in the "Uplink 768 kbps Reference Measurement Channel" tables.

Uplink 12.2 kbps Reference Measurement Channel, Physical Parameters

Parameter	Unit	Level
Information bit rate	kbps	12.2
DPDCH	kbps	60
DPCCH	kbps	15
DPCCH Slot Format		0
DPCCH/DPDCH power ratio	dB	-5.46
TFCI		On
Repetition	%	23

Uplink 12.2 kbps Reference Measurement Channel, DPDCH Fields

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame	Bits/Slot	Ndata
60	60	64	600	40	40

Uplink 12.2 kbps Reference Measurement Channel, DPCCH Fields

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame	Bits/ Slot	Npilot	NTPC	NTFCI	NFBI
15	15	256	150	10	6	2	2	0

Uplink 12.2 kbps Reference Measurement Channel, Transport Channel Parameters

Parameter	DTCH	DCCH
Transport Channel Number	1	2
Transport Block Size	244	100
Transport Block Set Size	244	100
Transmission Time Interval	20 ms	40 ms
Type of Error Protection	Convolution Coding	Convolution Coding
Coding Rate	1/3	1/3
Rate Matching attribute	256	256
Size of CRC	16	12

Uplink 768 kbps Reference Measurement Channel, Physical Parameters

Parameter	Unit	Level
Information bit rate	kbps	2*384
DPDCH1	kbps	960
DPDCH2	kbps	960
DPCCH	kbps	15
DPCCH Slot Format		0
DPCCH/DPDCH power ratio	dB	-11.48
TFCI		On
Puncturing	%	18

Uplink 768 kbps Reference Measurement Channel, Transport Channel Parameters

Parameter	DTCH	DCCH
Transport Channel Number	1	2
Transport Block Size	3840	100
Transport Block Set Size	7680	100
Transmission Time Interval	10 ms	40 ms
Type of Error Protection	Turbo Coding	Convolution Coding
Coding Rate	1/3	1/3
Rate Matching attribute	256	256
Size of CRC	16	12

Uplink 768 kbps Reference Measurement Channel, DPDCH Fields†

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame	Bits/Slot	Ndata
960	960	4	9600	640	640

† There are two DPDCHs in uplink 768 kbps RMC.

Uplink 768 kbps Reference Measurement Channel, DPCCH Fields

Channel Bit Rate (kbps)	Channel Symbol Rate (ksps)	SF	Bits/Frame	Bits/Slot	Npilot	NTPC	NTFCI	NFBI
15	15	256	150	10	6	2	2	0

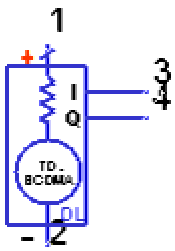
7. Use with Circuit Analyses
The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

1. 3GPP Technical Specification TS 25.211, "Physical channels and mapping of transport channels onto physical channels (FDD)" Release 1999.
http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25211-3a0.zip
2. 3GPP Technical Specification TS 25.212, "Multiplexing and Channel Coding (FDD)" Release 1999.
http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25212-390.zip
3. 3GPP Technical Specification TS 25.213, "Spreading and modulation (FDD)" Release 1999.
http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25213-370.zip
4. 3GPP Technical Specification TS 25.101, "UE Radio Transmission and Reception (FDD)" Release 1999.
http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25101-3a0.zip
5. 3GPP Technical Specification TS 25.104, "BS Radio transmission and (FDD)" Release 1999.
http://www.3gpp.org/ftp/Specs/2002-03/R1999/25_series/25104-3a0.zip

TDSCDMA_DnLink (TDSCDMA Downlink Signal Source)

Symbol



Parameters

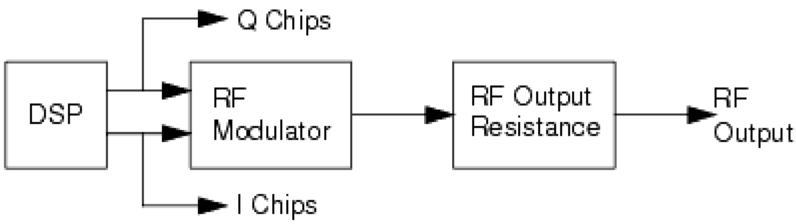
Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/1.28 MHz/SamplesPerChip			string	
FCarrier	Carrier frequency	1900 MHz		Hz	real	(0, ∞)
Power	Power	0.01		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
SamplesPerChip	Samples per chip	8	S		int	[2, 32]
RRC_FilterLength	RRC filter length (chips)	12			int	[2, 128]
ModPhase	Modulation phase quadruples: S1, S2	S1			enum	
MidambleAllocScheme	Midamble allocation scheme: UE_Specific, Common, Default	Common			enum	
BasicMidambleID	Basic midamble index	0			int	[0, 127]
MidambleID1	1st DPCH midamble index	1			int	[1, K]
MidambleID2	2nd DPCH midamble index	2			int	[1, K]
MaxMidambleShift	Max midamble shift	16	K		int	{2, 4, 6, 8, 10, 12, 14, 16}
SpreadCode1	1st DPCH spread code index	1			int	[1, 16]
SpreadCode2	2nd DPCH spread code index	2			int	[1, 16]
DwPCH_Gain	DwPCH gain	1			int	(0, ∞)
DownlinkPilotCode	Downlink pilot code index	0			int	[0, 31]
ActiveTimeslot	Slot index: TS0, TS2, TS3, TS4, TS5, TS6	TS6			enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed
3	I	I symbols	real
4	Q	Q symbols	real

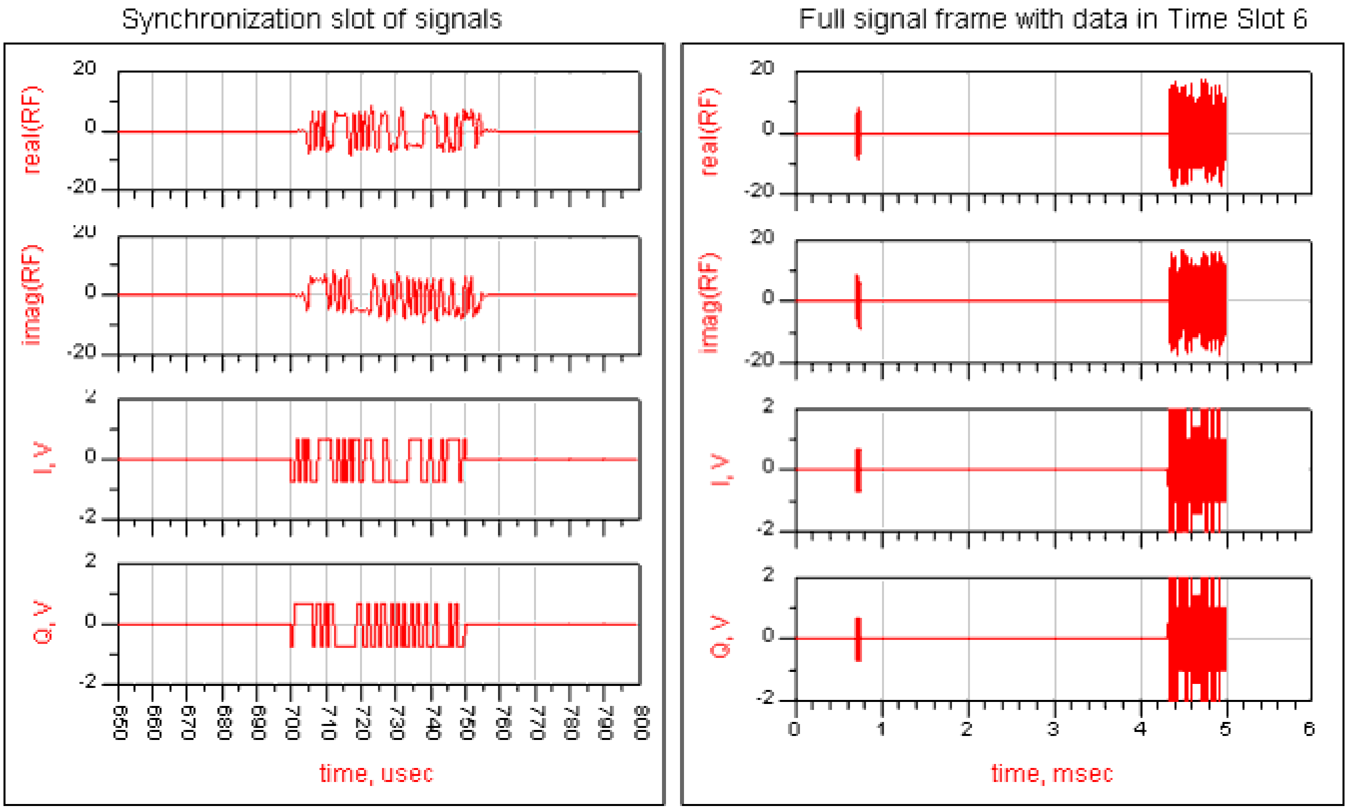
Notes/Equations

1. This TD-SCDMA signal source generates a 12.2 kbps downlink RF signal with two dedicated physical channels (DPCH) and one downlink pilot channel (DwPCH). The RF signal has a chip rate of 1.28 MHz. The downlink is from the base station to the user equipment.
   To use this source, RF carrier frequency (FCarrier) and power (Power) must be set. RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   TD-SCDMA signal characteristics can be specified by setting the RRC_FilterLength, ModPhase, MidambleAllocScheme, BasicMidambleID, MidambleID1, MidambleID2, MaxMidambleShift, SpreadCode1, SpreadCode2, DwPCH_Gain, DownlinkPilotCode, and ActiveTimeslot parameters.
   The maximum Circuit Envelope simulation time allowed is 1/1.28 MHz/SamplesPerChip. If the actual simulation Circuit Envelope simulation time step is greater than this maximum allowed, the simulation will stop and display an error message.
2. An example (TDSCDMA_DnLink_test) demonstrating the use of this signal source is available under /examples/TDSCDMA/RF_Verification_wrk.
3. This signal source includes a DSP section, RF modulator, and RF output resistance as illustrated in the following image.



Signal Source Block Diagram

   The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
   The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).
   The I and Q outputs are baseband outputs with zero source resistance and contain the unfiltered I and Q chips available at the RF modulator input. Because the I And Q outputs are from the inputs to the RF modulator, the RF output signal has a time delay relative to the I and Q chips. This RF time delay (RF_Delay) is related to parameter value for RRC_FilterLength.
   RF_Delay = RRC_FilterLength/(1.28e6)/2 sec.
4. The RF power delivered into a matched load with resistance R is the average power delivered in the subframe time slot specified by ActiveTimeslot (this is not the average frame power, which is less).
   The following image shows the RF envelope for an output RF signal with 30 dBm power delivered in time slot 6 (ActiveTimeSlot = TS6).



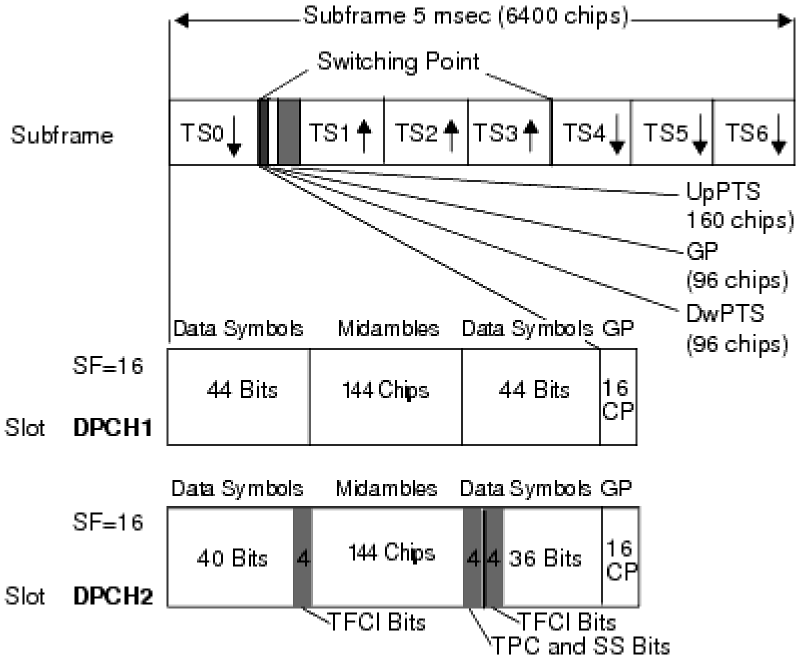
TD-SCDMA Downlink Source

5. This TD-SCDMA downlink signal source model is compatible with Agilent Signal Studio software option 411 for transmission test.
   Details regarding Signal Studio for TD-SCDMA are included at the website http://www.agilent.com/find/signalstudio

> **Note**
> There are two standards for TD-SCDMA systems: the international standard is called the 3GPP NTDD standard; the China national standard is called the TD-SCDMA TSM standard. This partially-coded TD-SCDMA signal source in ADS is based on the 3GPP NTDD standard. The Agilent TD-SCDMA signal studio signal source is based on the TD-SCDMA TSM standard. For TD-SCDMA transmission tests, this partially-coded TD-SCDMA signal source in ADS is compatible with the Agilent Signal Studio signal source.

6. Regarding the TD-SCDMA signal frame structure, one frame consists of two subframes. Each subframe consists of 7 time slots (TS), and one downlink pilot time slot (DwPTS), one guard period (GP) and one uplink pilot time slot (UpPTS). Each time slot can transmit DPCH signals. One subframe is composed of 6400 chips. Because the chip rate is 1.28 MHz, the subframe has a 5 msec duration. The subframe structure is illustrated in the following image.
   For example, two DPCH signals in DPCH1 and DPCH2 are transmitted in TS0 as illustrated in the following image. The first DPCH bits are modulated by QPSK and Spread by Walsh code of length 16 then transmitted in the slot. The DPCH1 signal is comprised of 88 coded information bits (88 × 16/2 chips) and 144 chips for midamble sequence plus 16 chips for GP. The DPCH2 signal, with the same modulation and spread scheme as DPCH1, is composed of 76 coded information bits (76 × 16/2 chips), 8 bits (8 × 16/2 chips) for transport format combination indicator (TFCI), 144 chips for midamble sequence, 4 bits (4 × 16/2 chips) for transmitter power control and synchronization shift (TPC and SS) plus 16 chips for GP. The total

chips for the subframe is composed of 7 time slots plus 96 chips for DwPTS, 96 chips for GP and 160 chips for UpPTS and summarized as (88 × 8+144+16) × 7+160+96 × 2=6400 chips.



Subframe Structure of 12.2 kbps DL Channel

7. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO, disables Temp and effectively sets it to -273.15oC (0 Kelvin); when set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power. The Power of the signal is defined as the average power delivered in the subframe time slot specified by ActiveTimeslot. Refer to the preceding note 4 for details.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage.
     Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
   - GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
     The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

     where *A* is a scaling factor based on the Power and R parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).

- SamplesPerChip sets the number of samples in a chip.
  The default value is set to 8 to display settings according to the 3GPP NTDD. It can be set to a larger value for a simulation frequency bandwidth wider than 8 × 1.28 MHz. It can be set to a smaller value for faster simulation; however, this will result in lower signal fidelity. If SamplesPerChip = 8, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 8 (e.g., simulation RF bandwidth = 8 × 1.28 MHz).
- RRC_FilterLength is used to set root raised-cosine (RRC) filter length in number of chips.
  The default value is set to 12 to transmit TD-SCDMA downlink signals in time and frequency domains based on the 3GPP NTDD standard [1] - [3]. It can be set to a smaller value for faster simulation; however, this will result in lower signal fidelity.
- ModPhase is used to select the phase quadruples of DwPTS for various phase rotation patterns. In Signal Studio, the Rotation Phase parameter is used to select the phase quadruples.
  There are two different phase quadruples, S1 and S2 specified by 3GPP NTDD standard [3], as described in the following table. A quadruple always starts with an even signal frame number.

Phase Modulation Sequences

Name	Phase Quadruple	Description
S1	135, 45, 225, 135	A P-CCPCH is present in the next 4 sub-frames
S2	315, 225, 315, 45	A P-CCPCH is not present in the next 4 sub-frames

- MidambleAllocScheme is used to select the midamble allocation scheme. There are three midamble allocation schemes based on the 3GPP NTDD standard [1], [2].
  UE specific midamble allocation a UE specific midamble for uplink and downlink is explicitly assigned by higher layers
  Default midamble allocation the midamble for uplink and downlink is assigned by layer 1 depending on associated channelization code.
  Common midamble allocation the midamble for downlink is allocated by layer 1 depending on the number of channelization codes currently present in the downlink time slot.
  To set MidambleAllocScheme parameter based on the 3GPP NTDD standard [1], related parameters must be set as stated here:
  if **MidambleAllocScheme=UE_Specific**, the BasicMidambleID,

MaxMidambleShift and MidambleID parameters are used to specify which midamble is exported.
if **MidambleAllocScheme=Common**, only the BasicMidambleID, MaxMidambleShift are used to specify which midamble is exported; the MidambleID parameter is ignored.
if **MidambleAllocScheme=Default**, only the BasicMidambleID, MaxMidambleShift are used to specify which midamble is exported, the MidambleID parameter is ignored.

- BasicMidambleID sets the basic midamble code ID. The basic midamble code is used for training sequences for uplink and downlink channel estimation, power measurements and maintaining uplink synchronization. There are 128 different sequences; BasicMidambleID can be set from 0 to 127.
  In Signal Studio, Basic Midamble ID code has the same meaning as this parameter.
- MaxMidambleShift is the maximum number of different midamble shifts in a cell that can be determined by maximum users in the cell for the current time slot.
- MidambleID1 and MidambleID2 set the indices of midambles for the first and second DPCH, respectively. Midambles of different users active in the same cell and the same time slot are cyclically shifted versions of one basic midamble code.
  Let P = 128, the length of basic midamble and K=MaxMidambleShift, then
  $W = \left\lfloor \frac{P}{K} \right\rfloor$ is the shift between midambles and
  $\lfloor x \rfloor$ denotes the largest number less or equal to x. The MidambleID range is from 1 to MaxMidambleShift.
  MidambleID and MaxMidambleShift together correspond to parameter of Midamble Offset in Signal Studio for Timeslot setup. Midamble Offset = MidambleID × W.
- SpreadCode1 and SpreadCode2 set spread code indices for the first and second DPCH, respectively. For this signal source, the spreading factor is 16.
  In Signal Studio, channelization code for time slot setup has the same meaning as SpreadCode1 and SpreadCode2.
- DwPCH_Gain sets the gain of DwPCH relative to DPCH.
  In Signal Studio, there are dialog boxes with dB unit for each DwPCH to set the gain of DwPCH relative to DPCH.
- DownlinkPilotCode sets the downlink pilot synchronization sequence (SYNC-DL). Downlink pilot synchronization is used for DL synchronization and cell initial search. There are 32 different SYNC-DL code groups, which are used to distinguish base stations.

  DwPTS has 64 chips of a complex SYNC_DL sequence $\underline{s} = (\underline{s}_1, \underline{s}_2, \ldots, \underline{s}_{64})$
  and 32 chips of guard period. To generate the complex SYNC_DL code, the basic SYNC_DL code $s = (s_1, s_2, \ldots, s_{64})$
  is used. There are 32 different basic SYNC_DL codes for the whole system. The relation between s and $\underline{s}$
  is given by:
  $\underline{s}_i = (j)^{i} s_i$ where $v_i \in \{1, -1\}, i = 1, \ldots, 64$

Therefore, the elements $\underline{s}_i$ of $\underline{s}$
are alternating real and imaginary.
In Signal Studio, SYNC Code is used to set the downlink pilot code.

- ActiveTimeslot is used to select which slot signal in the subframe will be transmitted.

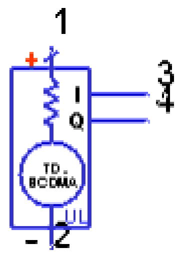
8. Use with Circuit Analyses
The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

1. 3GPP TS 25.221, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical channels and mapping of transport channels onto physical channels (TDD) (Release 4), version 4.5.0, Dec., 2001.
http://www.3gpp.org/ftp/specs/archive/25_series/25.211/
2. 3GPP TS 25.223, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Spreading and modulation (TDD) (Release 4), version 4.3.0, Dec., 2001.
http://www.3gpp.org/ftp/specs/archive/25_series/25.223/
3. 3GPP TS 25.105, *3rd Generation Partnership Project; Technical Specification Group Radio Access Network;* BS Radio transmission and Reception (TDD) *(Release 4)* , version 4.5.0, June 2002.
http://www.3gpp.org/ftp/Specs/2002-06/Rel-4/25_series/25105-450.zip

TDSCDMA_UpLink (TDSCDMA Uplink Signal Source)

Symbol



Parameters

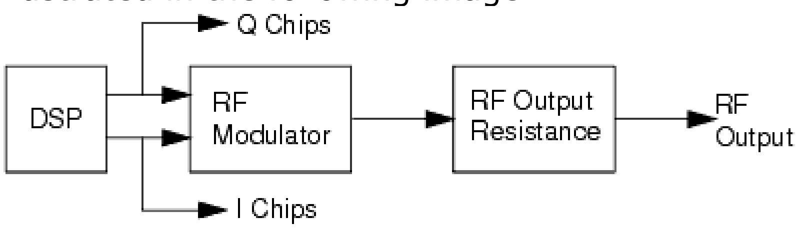
Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/1.28 MHz/SamplesPerChip			string	
FCarrier	Carrier frequency	1900 MHz		Hz	real	(0, ∞)
Power	Power	0.01		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
SamplesPerChip	Samples per chip	8	S		int	[2, 32]
RRC_FilterLength	RRC filter length (chips)	12			int	[2, 128]
MidambleAllocScheme	Midamble allocation scheme: UE_Specific, Common, Default	Common			enum	
BasicMidambleID	Basic midamble index	0			int	[0, 127]
MidambleID	Midamble index	1			int	[1, K]
MaxMidambleShift	Max midamble shift	16	K		int	{2, 4, 6, 8, 10, 12, 14, 16}
SpreadCode	Spread code index	1			int	[1, 8]
ActiveTimeslot	Slot index: TS1, TS2, TS3, TS4, TS5, TS6	TS2			enum	

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed
3	I	I symbols	real
4	Q	Q symbols	real

Notes/Equations

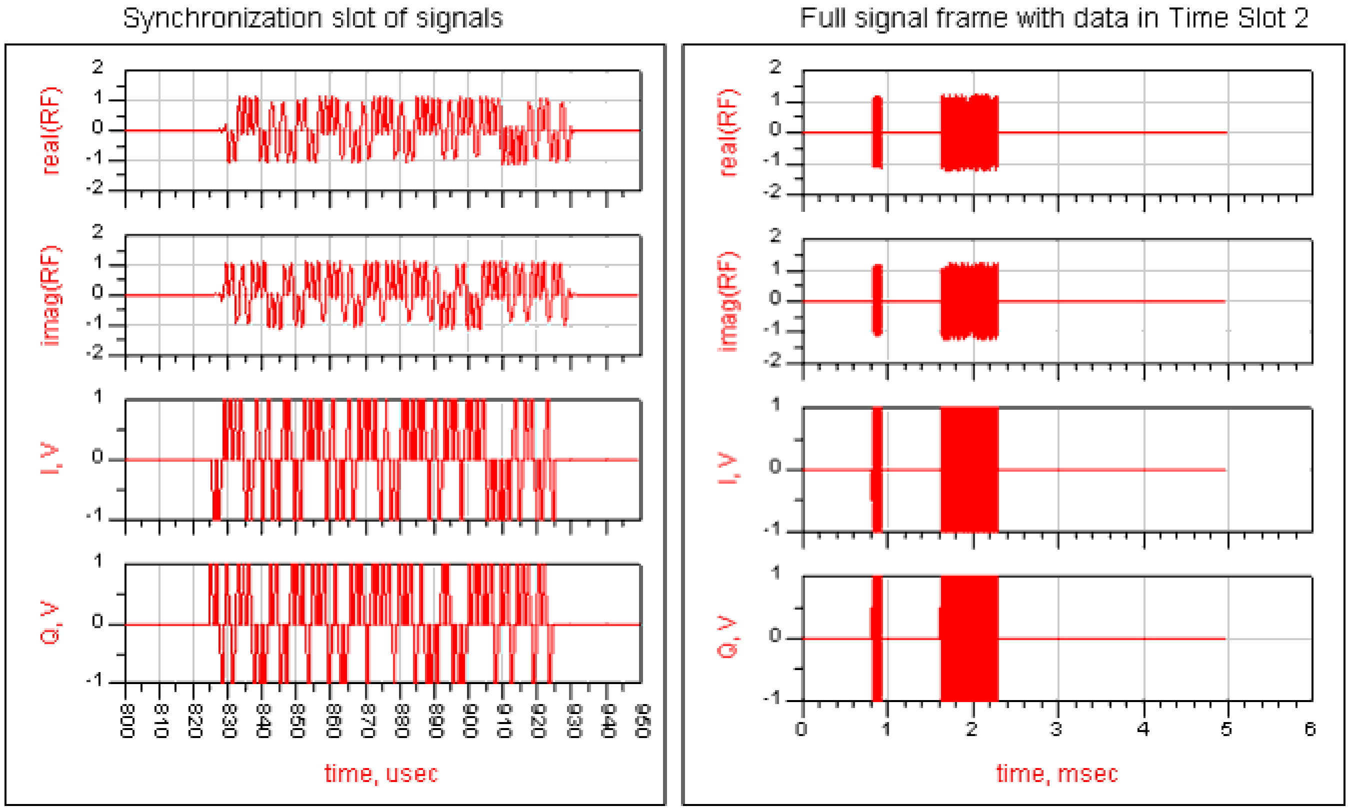
1. This TD-SCDMA signal source generates a 12.2 kbps uplink RF signal with one dedicated physical channel (DPCH) and one uplink pilot channel (UpPCH). The index of the basic synchronization code is set to 0 in the UpPCH. The RF signal has a chip rate of 1.28 MHz. The uplink is from the user equipment to the base station.
   To use this source, RF carrier frequency (FCarrier) and power (Power) must be set. RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   TD-SCDMA signal characteristics can be specified by setting the RRC_FilterLength, MidambleAllocScheme, BasicMidambleID, MidambleID, MaxMidambleShift, SpreadCode, and ActiveTimeslot parameters.
   The maximum Circuit Envelope simulation time allowed is 1/1.28 MHz/SamplesPerChip. If the Circuit Envelope simulation time step is greater than the maximum allowed, the simulation will stop and an error message will be displayed.
2. An example (TDSCDMA_UpLink_test) demonstrating the use of this signal source is available under /examples/TDSCDMA/RF_Verification_wrk.
3. This signal source includes a DSP section, RF modulator, and RF output resistance as illustrated in the following image.



Signal Source Block Diagram

The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).
The I and Q outputs are baseband outputs with zero source resistance and contain the unfiltered I and Q chips available at the RF modulator input. Because the I And Q outputs are from the inputs to the RF modulator, the RF output signal has a time delay relative to the I and Q chips. This RF time delay (RF_Delay) is related to parameter value for RRC_FilterLength.
RF_Delay = RRC_FilterLength/(1.28e6)/2sec.

4. The RF power delivered into a matched load with resistance R is the average power delivered in the subframe time slot specified by parameter ActiveTimeslot. This is not the average subframe power (which is less).
   The following image shows the RF envelope for one subframe with 10 dBm RF power delivered in time slot 2 (ActiveTimeslot = TS2).



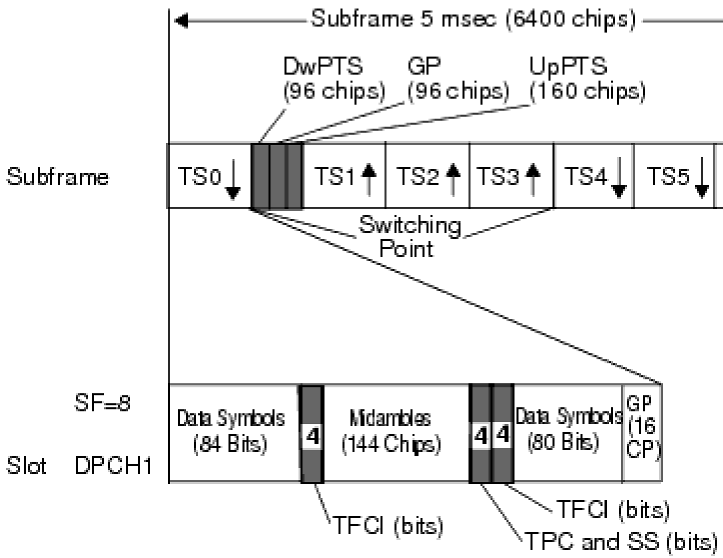
TD-SCDMA Uplink Source

5. This TD-SCDMA uplink signal source model is compatible with Agilent Signal Studio software option 411 for transmission test.
   Details regarding Signal Studio for TD-SCDMA are included at the website http://www.agilent.com/find/signalstudio

> **Note**
> There are two standards for TD-SCDMA systems: the international standard is called the 3GPP NTDD standard; the China national standard is called the TD-SCDMA TSM standard. This partially-coded TD-SCDMA signal source in ADS is based on the 3GPP NTDD standard. The Agilent TD-SCDMA signal studio signal source is based on the TD-SCDMA TSM standard. For TD-SCDMA transmission tests, this partially-coded TD-SCDMA signal source in ADS is compatible with the Agilent Signal Studio signal source.

6. Regarding the TD-SCDMA signal frame structure, one frame consists of two subframes. Each subframe consists of 7 time slots (TS), and one downlink pilot time slot (DwPTS), one guard period (GP) and one uplink pilot time slot (UpPTS). Each time slot can transmit DPCH signals. One subframe is composed of 6400 chips. Because the chip rate is 1.28 MHz, the subframe has a 5msec duration. The subframe structure is illustrated in the following image.
   For example, one DPCH signal is transmitted in TS2 as illustrated in the following image. The DPCH bits are modulated by QPSK and spread by Walsh code of length 8 then transmitted in the slot. The DPCH signal is composed of 164 coded information bits (164 × 8/2 chips), 8 bits (8 × 8/2 chips) for transport format combination

indicator (TFCI), 144 chips for midamble sequence, 2 bits (2 × 8/2 chips) for transmitter power control and 2 bits (2 × 8/2 chips) reserved (TPC and Reserved) plus 16 chips for GP. The total chips for the subframe is composed of 7 time slots plus 96 chips for DwPTS, 96 chips for GP and 160 chips for UpPTS and summarized as (164 × 4+8 × 4+144+2 × 4+2 × 4+16) × 7+160+96 × 2=6400 chips.



12.2 kbps Uplink Channel of Subframe Structure

7. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO disables the Temp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power. The Power of the signal is defined as the average power delivered in the subframe time slot specified by parameter ActiveTimeslot. See the preceding note 4 for details.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
   - GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here. The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

$$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

     where *A* is a scaling factor based on the Power and R parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, g is the gain imbalance

$$g = 10^{\frac{GainImbalance}{20}}$$

and, φ (in degrees) is the phase imbalance.
Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).

- SamplesPerChip sets the number of samples in a chip.
  The default value is set to 8 to display settings according to the 3GPP NTDD. It can be set to a larger value for a simulation frequency bandwidth wider than 8 × 1.28 MHz. It can be set to a smaller value for faster simulation; however, this will result in lower signal fidelity. If SamplesPerChip = 8, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 8 (e.g., simulation RF bandwidth = 8 × 3.84 MHz)
- RRC_FilterLength shows root raised-cosine (RRC) filter length in chips.
  The default value of this parameter is set to 12 to transmit TD-SCDMA downlink signals in time and frequency domains based on the 3GPP NTDD standard [1-3]. It can be set to a smaller value for faster simulation; however, this will result in lower signal fidelity.
- MidambleAllocScheme is used to select the midamble allocation scheme. There are three midamble allocation schemes based on the 3GPP NTDD standard [1,2].
  UE specific midamble allocation: a UE specific midamble for uplink and downlink is explicitly assigned by higher layers
  Default midamble allocation: the midamble for uplink and downlink is assigned by layer 1 depending on associated channelization code.
  Common midamble allocation: the midamble for downlink is allocated by layer 1 depending on the number of channelization codes currently present in the downlink time slot.
  To set the MidambleAllocScheme parameter based on the 3GPP NTDD standard [1], related parameters must be set as stated here:
  if **MidambleAllocScheme=UE_Specific**, the BasicMidambleID, MaxMidambleShift and MidambleID parameters are used to specify which midamble is exported.
  if **MidambleAllocScheme=Common**, only the BasicMidambleID, MaxMidambleShift are used to specify which midamble is exported; the MidambleID parameter is ignored.
  if **MidambleAllocScheme=Default**, only the BasicMidambleID, MaxMidambleShift are used to specify which midamble is exported, the MidambleID parameter is ignored.
- BasicMidambleID sets the basic midamble code ID. The basic midamble code is used for training sequences for uplink and downlink channel estimation, power measurements and maintaining uplink synchronization. There are 128 different sequences; BasicMidambleID can be set from 0 to 127. In Signal Studio, Basic Midamble ID code has the same meaning as this parameter.
- MaxMidambleShift is the maximum number of different midamble shifts in a cell that can be determined by maximum users in the cell for the current time slot.

- MidambleID sets the index of midambles for DPCH. Midambles of different users active in the same cell and the same time slot are cyclically shifted versions of one basic midamble code.
  Let P = 128, the length of basic midamble and K=MaxMidambleShift, then
  $W = \left\lfloor \frac{P}{K} \right\rfloor$ is the shift between midambles and
  $\lfloor x \rfloor$ denotes the largest number less than or equal to x. MidambleID range is from 1 to MaxMidambleShift.
  MidambleID and MaxMidambleShift together correspond to the Midamble Offset parameter in Signal Studio for Timeslot setup. Midamble Offset = MidambleID × W.
- SpreadCode sets the spread code index for the DPCH. For this signal source, the spreading factor is 8.
  In Signal Studio, Channelization code for Time slot setup has the same meaning of SpreadCode.
- ActiveTimeslot parameter is used to select which slot signal in the subframe will be transmitted.

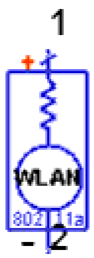
8. Use with Circuit Analyses
   The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
   Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

1. 3GPP TS 25.221, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Physical channels and mapping of transport channels onto physical channels (TDD) (Release 4), version 4.5.0, Dec., 2001.
   http://www.3gpp.org/ftp/specs/archive/25_series/25.211/
2. 3GPP TS 25.223, 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Spreading and modulation (TDD) (Release 4), version 4.3.0, Dec., 2001.
   http://www.3gpp.org/ftp/specs/archive/25_series/25.223/
3. 3GPP TS 25.102, *3rd Generation Partnership Project; Technical Specification Group Radio Access Network;* UE Radio transmission and Reception (TDD) *(Release 4)*, version 4.5.0, June 2002.
   http://www.3gpp.org/ftp/Specs/2002-06/Rel-4/25_series/25102-450.zip

WLAN_802_11a (WLAN 80211a Signal Source)

Symbol



Parameters

Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/Bandwidth/ 2^OversamplingOption			string	
FCarrier	Carrier frequency: CH1_2412.0M, CH3_2422.0M, CH5_2432.0M, CH6_2437.0M, CH7_2442.0M, CH9_2452.0M, CH11_2462.0M, CH13_2472.0M, CH36_5180.0M, CH40_5200.0M, CH44_5220.0M, CH48_5240.0M, CH52_5260.0M, CH56_5280.0M, CH60_5300.0M, CH64_5320.0M, CH149_5745.0M, CH153_5765.0M, CH157_5785.0M, CH161_5805.0M	CH1_2412.0M		Hz	real enum	(0, ∞)
Power	Power	0.04		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)

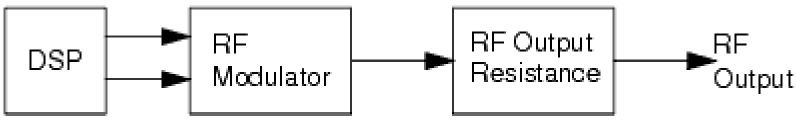
OversamplingOption	Oversampling ratio option: Option 0 for Ratio 1, Option 1 for Ratio 2, Option 2 for Ratio 4, Option 3 for Ratio 8, Option 4 for Ratio 16, Option 5 for Ratio 32	Option 2 for Ratio 4	S		enum	
DataRate	Data rate (Mbps): Mbps_6, Mbps_9, Mbps_12, Mbps_18, Mbps_24, Mbps_27, Mbps_36, Mbps_48, Mbps_54	Mbps_54	R		enum	
Bandwidth	Bandwidth	20 MHz	B	Hz	real	(0, ∞)
IdleInterval	Burst idle interval	4.0 usec	I	sec	real	[0, 1000usec]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	100	L		int	[1, 4095]
GuardInterval	Guard interval (frac FFT size)	0.25			real	[0, 1]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed

Notes/Equations

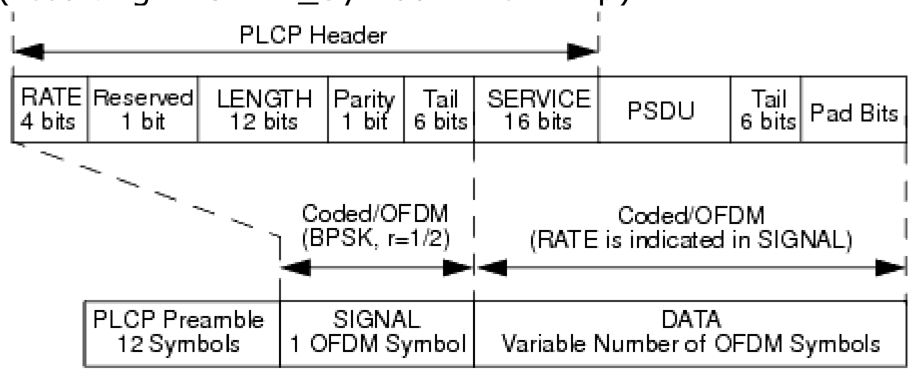
1. This WLAN signal source generates an IEEE 802.11a and 802.11g OFDM RF signal. To use this source, RF carrier frequency (FCarrier) and power (Power) must be set. RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   802.11a/g signal characteristics can be specified by setting the OversamplingOption, DataRate, Bandwidth, IdleInterval, DataType, DataLength, and GuardInterval parameters.
   The maximum Circuit Envelope simulation time allowed is 1/Bandwidth/Ratio where Ratio = $2^{OversamplingOption}$. If the actual simulation Circuit Envelope simulation time step is greater than this maximum allowed, the simulation will stop and display an error message.
2. An example (WLAN_802_11a_test) demonstrating the use of this signal source is available under /examples/WLAN/RF_Verification_wrk.
3. This signal source includes a DSP section, RF modulator, and RF output resistance as illustrated in the following image.



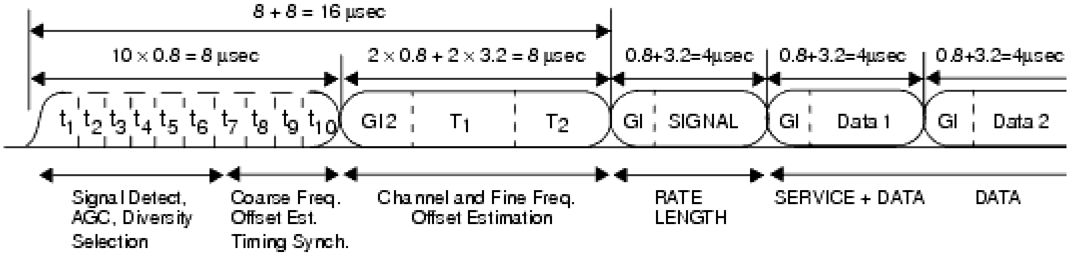
Signal Source Block Diagram

The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).

4. This WLAN 802.11a signal source model is compatible with the Agilent Signal Studio Software for 802.11 WLAN Agilent E4438C ESG Vector Signal Generator Option 417 for transmitter test.
   Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio
5. Regarding the WLAN 802.11a/g signal burst structure, one burst consists of four parts. Each burst is separated by an IdleInterval and is composed of the Short Preamble, Long Preamble, SIGNAL and DATA fields.
   - The Short Preamble field consists of 10 short preambles (8 μ).
   - The Long Preamble field consists of 2 long preambles (8 μ). The two preamble fields combined compose the PLCP Preamble that has a constant time duration (16 μ) for all source parameter settings.
   - The SIGNAL field includes 802.11a/g bursts of information (such as data rate, payload data, and length).
   - The DATA field contains the payload data.
     Channel coding, interleaving, mapping and IFFT processes are also included in SIGNAL and DATA parts generation. The SIGNAL field and each individual Data field (part of the overall DATA field) have a time duration defined as the OFDM_SymbolTime and includes a GuardInterval. OFDM_SymbolTime depends on the Bandwidth (=64/Bandwidth).
     The burst structure is illustrated in the following images. In these figures, PLCP means *physical layer convergence procedure*, PSDU means *PLCP service data units*, GI means *guard interval*; GI is set to 0.25 and Bandwidth is set to 20 MHz (resulting in OFDM_SymbolTime = 4 μ).



802.11a/g Burst Format



OFDM Training Structure

6. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO disables the Temp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power. The Power of the signal is defined as the average burst power and excludes the idle interval time intervals.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage.
     Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set this parameter to YES.
   - The GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
     The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:

     $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$

     where *A* is a scaling factor based on the Power and R parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance

     $$g = 10^{\frac{GainImbalance}{20}}$$

     and, φ (in degrees) is the phase imbalance.
     Next, the signal *V* RF(*t*) is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).
   - Bandwidth is used to determine the actual bandwidth of WLAN system and also is used to calculate the sampling rate and time step per sample. The default value is 20 MHz, which is defined in 802.11a/g specification. Bandwidth can be set to 40 MHz in order to double the rate for the 802.11a/g turbo mode.

- OversamplingOption sets the oversampling ratio of 802.11a/g RF signal source. Options from 0 to 5 result in oversampling ratio 2, 4, 8, 16, 32 where oversampling ratio = $2^{OversamplingOption}$. If OversamplingOption = 2, the oversampling ratio = 2^2 = 4 and the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=20 MHz, the simulation RF bandwidth = 20 MHz × 4 = 80 MHz).
- DataRate specifies the data rate: 6, 9, 12, 18, 24, 27, 36, 48 and 54 Mbps are available in this source. All data rates except 27 Mbps are defined in the 802.11a/g specification; 27 Mbps is from HIPERLAN/2 [2].
  The following table lists key parameters of 802.11a/g.

Rate-Dependent Values

Data Rate (Mbps)	Modulation	Coding Rate (R)	Coded Bits per Subcarrier	Coded Bits per OFDM Symbol	Data Bits per OFDM Symbol
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
27	16-QAM	9/16	4	192	108
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

7. IdleInterval specifies the idle interval between two consecutive bursts when generating a 802.11a signal source.
   - For DataType:
     if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153.
     if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151.
     if FIX4 is selected, a zero-stream is generated.
     if x_1_x_0 is selected (where x equals 4, 8, 16, 32, or 64) a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
   - DataLength is used to set the number of data bytes in a frame (or burst). There are 8 bits per byte.
   - GuardInterval is used to set cyclic prefix in an OFDM symbol. The value range of GuardInterval is [0.0,1.0]. The cyclic prefix is a fractional ratio of the IFFT length. 802.11a/g defines GuardInterval=1/4 (0.8 μ) and HIPERLAN/2 defines two GuardIntervals (1/8 and 1/4).
8. Use with Circuit Analyses
   The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
   Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

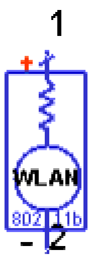
1. IEEE Standard 802.11a-1999, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band," 1999. http://standards.ieee.org/getieee802/download/802.11a-1999.pdf
2. ETSI TS 101 475 v1.1.1, "Broadband Radio Access Networks (BRAN); HIPERLAN Type 2; Physical (PHY) layer," November 2000.
3. IEEE P802.11G-2003, "Part II: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications Amendment 4: Further Higher Data Rate Extension in the 2.4 GHz Band," April 2003. http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
4. CCITT, Recommendation O.151(10/92).
5. CCITT, Recommendation O.153(10/92).

WLAN Links

- European Radiocommunications Office: http://www.ero.dk .
- U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome .
- IEEE 802.11b Compliance Organization: http://www.wi-fi.org .
- IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html .

WLAN_802_11b (WLAN 80211b Signal Source)

Symbol



Parameters

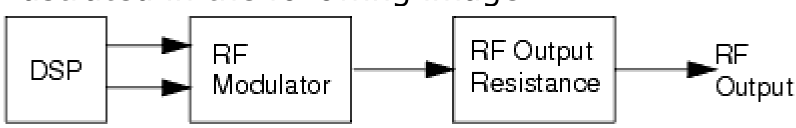
Name	Description	Default	Sym	Unit	Type	Range
Num	Port number for S-parameter and HB noise figure analysis	1			int	[1, ∞)
R	Source resistance	50 Ohm		Ohm	real	(0, ∞)
Temp	Temperature			Celsius	real	[-273.15, ∞)
Noise	Enable thermal noise? NO, YES	YES			enum	
MaxTimeStep	Expression showing how TStep is related to the other source parameters	1/11 MHz/OversamplingRatio			string	
FCarrier	Carrier frequency: CH1_2412.0M, CH3_2422.0M, CH5_2432.0M, CH6_2437.0M, CH7_2442.0M, CH9_2452.0M, CH11_2462.0M, CH13_2472.0M	CH1_2412.0M		Hz	real enum	
Power	Power	0.04		W	real	[0, ∞)
MirrorSpectrum	Mirror spectrum about carrier? NO, YES	NO			enum	
GainImbalance	Gain imbalance, Q vs I	0.0		dB	real	(-∞, ∞)
PhaseImbalance	Phase imbalance, Q vs I	0.0		deg	real	(-∞, ∞)
I_OriginOffset	I origin offset (percent)	0.0			real	(-∞, ∞)
Q_OriginOffset	Q origin offset (percent)	0.0			real	(-∞, ∞)
IQ_Rotation	IQ rotation	0.0		deg	real	(-∞, ∞)
OversamplingRatio	Oversampling ratio	2	S		int	[2, 9]
DataRate	Data rate (Mbps): Mbps_1, Mbps_2, Mbps_5.5, Mbps_11	Mbps_11	R		enum	
Modulation	Modulation format: CCK, PBCC	CCK			enum	
PreambleFormat	Preamble/header format: Long, Short	Long	H		enum	
ClkLockedFlag	Lock header clock? NO, YES	YES			enum	
PwrRamp	RF power ramp shape: None, Linear, Cosine	None	P		enum	
IdleInterval	Burst idle interval	10.0 usec	I	sec	real	[0, 1000usec]
FilterType	Shaping filter type: NoneFilter, Gaussian, Root Cosine, Ideal Lowpass	Gaussian			enum	
RRC_Alpha	RRC roll-off factor	0.2			real	(0.0, 1.0]
GaussianFilter_bT	Gaussian filter bT coefficient	0.3			real	(0.0, 1.0]
FilterLength	Filter length (chips)	6			int	[1, 200]
DataType	Payload data type: PN9, PN15, FIX4, _4_1_4_0, _8_1_8_0, _16_1_16_0, _32_1_32_0, _64_1_64_0	PN9			enum	
DataLength	Data length (bytes per burst)	100	L		int	[1, 2312]

Pin Outputs

Pin	Name	Description	Signal Type
1	RF	RF output	timed
2	Minus	Ground	timed

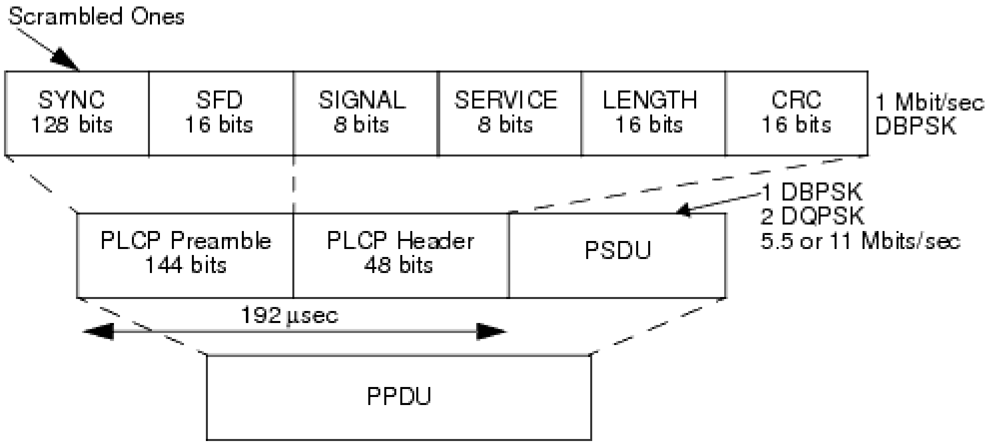
Notes/Equations

1. This WLAN signal source generates an IEEE 802.11b and 802.11g DSSS/CCK/PBCC RF signal.
   To use this source, RF carrier frequency (FCarrier) and power (Power) must be set.
   RF impairments can be introduced by setting the R, Temp, Noise, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters.
   802.11b/g signal characteristics an be specified by setting the OversamplingRatio, DataRate, Modulation, PreambleFormat, ClkLockedFlag, PwrRamp, IdleInterval, FilterType, RRC_Alpha, GaussianFilter_bT, FilterLength, DataType, and DataLength parameters.
   The maximum Circuit Envelope simulation time allowed is 1/11 MHz/OversamplingRatio. If the actual simulation Circuit Envelope simulation time step is greater than the maximum allowed, the simulation will stop and an error message will be displayed.
2. An example (WLAN_802_11b_test) demonstrating the use of this signal source is available under /examples/WLAN/RF_Verification_wrk.
3. This signal source includes a DSP section, RF modulator, and RF output resistance as illustrated in the following image.

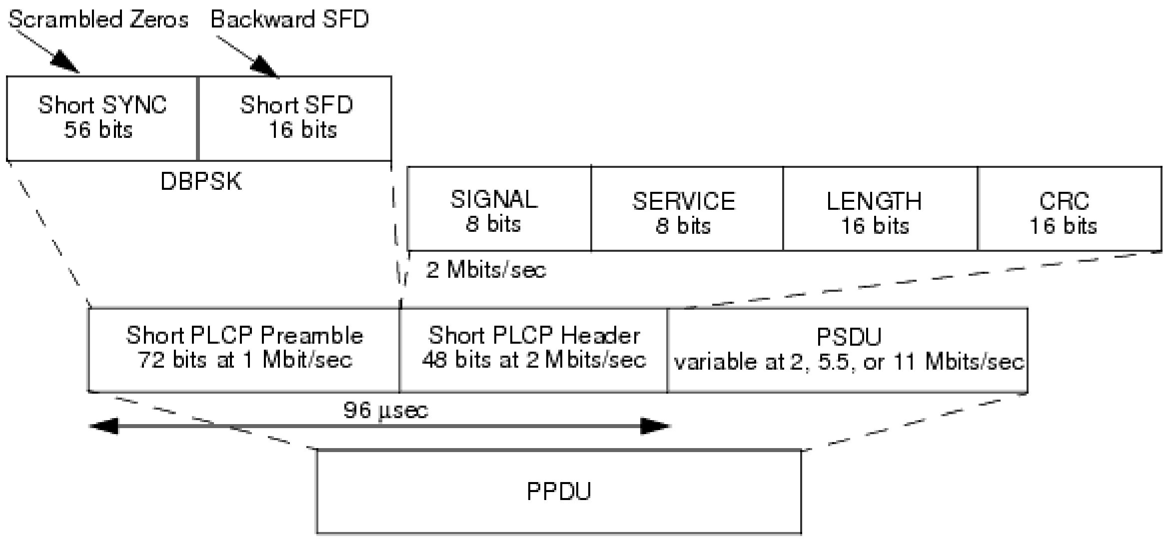
   

   Signal Source Block Diagram

   The R, Temp and Noise parameters are used by the RF output resistance. The FCarrier, Power, MirrorSpectrum, GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation parameters are used by the RF modulator. The remaining signal source parameters are used by the DSP block.
   The RF output from the signal source is at the frequency specified (FCarrier), with the specified source resistance (R) and with power (Power) delivered into a matched load of resistance R. The RF signal has additive Gaussian noise power set by the resistor temperature (Temp) (when Noise=yes).
4. This WLAN 802.11b signal source model is compatible with the Agilent Signal Studio Software for 802.11 WLAN Agilent E4438C ESG Vector Signal Generator Option 417 for transmitter test.
   Details regarding Signal Studio for WLAN 802.11 are included at the website http://www.agilent.com/find/signalstudio .
5. The 802.11b baseband signal source frame structure is illustrated in the following images. Each frame is separated by an IdleInterval; one 802.11b frame consists of PLCP Preamble, PLCP Header and Data (PSDU) parts. (PPDU means *physical layer protocol data units*; SFD means *start frame delimiter*; CRC means *cyclic redundancy code*; PLCP means *physical layer convergence procedure*; PSDU means *PLCP service data units*.)



Long PLCP frame format



Short PLCP Frame Format

6. Parameter Details
   - Num defines the circuit port number for S-parameter and Harmonic Balance noise figure analysis only (it is not used for other circuit analysis).
   - R is the RF output source resistance.
   - Temp is the RF output source resistance temperature in Celsius and sets the noise density in the RF output signal to (k(Temp+273.15)) Watts/Hz, where k is Boltzmann's constant.
   - Noise, when set to NO disables the Temp and effectively sets it to -273.15oC (0 Kelvin). When set to YES, the noise density due to Temp is enabled.
   - FCarrier is the RF output signal frequency.
   - Power is the RF output signal power. The Power of the signal is defined as the average frame power and excludes the idle interval time intervals.
   - MirrorSpectrum is used to mirror the RF_out signal spectrum about the carrier. This is equivalent to conjugating the complex RF envelope voltage. Depending on the configuration and number of mixers in an RF transmitter, the RF output signal from hardware RF generators can be inverted. If such an RF signal is desired, set MirrorSpectrum to YES.

- GainImbalance, PhaseImbalance, I_OriginOffset, Q_OriginOffset, and IQ_Rotation are used to add certain impairments to the ideal output RF signal. Impairments are added in the order described here.
  The unimpaired RF I and Q envelope voltages have gain and phase imbalance applied. The RF is given by:
  $$V_{RF}(t) = A\left(V_I(t)\cos(\omega_c t) - gV_Q(t)\sin\left(\omega_c t + \frac{\phi\pi}{180}\right)\right)$$
  where *A* is a scaling factor based on the Power and R parameters specified by the user, $V_I(t)$ is the in-phase RF envelope, $V_Q(t)$ is the quadrature phase RF envelope, *g* is the gain imbalance
  $$g = 10^{\frac{GainImbalance}{20}}$$
  and, φ (in degrees) is the phase imbalance.
  Next, the signal $V_{RF}(t)$ is rotated by IQ_Rotation degrees. The I_OriginOffset and Q_OriginOffset are then applied to the rotated signal. Note that the amounts specified are percentages with respect to the output rms voltage. The output rms voltage is given by sqrt(2 R Power).
- OversamplingRatio sets the oversampling ratio of 802.11b RF signal source. There are eight oversampling ratios (2, 3, 4, 5, 6, 7, 8, 9) supported by this source. If OversamplingRatio = 4, the simulation RF bandwidth is larger than the signal bandwidth by a factor of 4 (e.g. for Bandwidth=11 MHz, the simulation RF bandwidth = 11 MHz × 4 = 44 MHz).
- DataRate specifies the data rate; 1, 2, 5.5, and 11 Mbps can be implemented in this source. All data rates are defined in 802.11b specification.
  Modulation is defined as CCK or PBCC, which are two modulation formats in 802.11b. This DataRate parameter is useless for 1 Mbps and 2 Mbps data rates. For 5.5 Mbps and 11 Mbps data rates, the two different modulation formats available are CCK and PBCC.
- PreambleFormat is used to set the format of the framed signal preamble/header sections; refer to the preceding images of Long PLCP frame format and Short PLCP Frame Format.
- ClkLockedFlag is used to toggle the clock locked flag in the header. This is Bit 2 in the Service field of the PPDU frame. This bit is used to indicate to the receiver if the carrier and the symbol clock use the same local oscillator. If ClkLockedFlag=YES, this bit is set to 1; if ClkLockedFlag=NO, this bit is set to 0.
- PwrRamp is used to select shape of the RF burst in framed mode. Selects the power up/down ramp type as none, linear, or cosine. Cosine ramp gives least amount of out-of-channel interference. None starts transmitting the signal at full power, and is the simplest power ramp to implement. The linear ramp shapes the burst in a linear fashion. The length (in microseconds) of the power up/down ramp is set to 2 μ when PwrRamp is not none.
- IdleInterval sets an idle duration time between two consecutive bursts when generating the 802.11b signal source.
- FilterType can be used to specify that a baseband filter is applied to reduce the transmitted bandwidth, thereby increasing spectral efficiency. The 802.11b specification does not indicate the type of filter to be used, but the transmitted signal must meet the spectral mask requirements. Four options for baseband

filtering are available:
None (no filter)
Gaussian The Gaussian filter does not have zero ISI. Wireless system architects must determine how much of the ISI can be tolerated in a system and combine that with noise and interference. The Gaussian filter is Gaussian-shaped in time and frequency domains, and it does not ring as root cosine filters do.
The effects of this filter in the time domain are relatively short and each symbol interacts significantly (or causes ISI) with only the preceding and succeeding symbols. This reduces the tendency for particular sequences of symbols to interact which makes amplifiers easier to build and more efficient.
Root Cosine (also referred to as square root raised-cosine) These filters have the property that their impulse response rings at the symbol rate. Adjacent symbols do not interfere with each other at the symbol times because the response equals zero at all symbol times except the center (desired) one.
Root cosine filters heavily filter the signal without blurring the symbols together at the symbol times. This is important for transmitting information without errors caused by ISI. Note that ISI exists at all times except at the symbol (decision) times.
Ideal Low Pass In the frequency domain, this filter appears as a lowpass, rectangular filter with very steep cut-off characteristics. The passband is set to equal the symbol rate of the signal. Due to a finite number of coefficients, the filter has a predefined length and is not truly *ideal*. The resulting ripple in the cut-off band is effectively minimized with a Hamming window. A symbol length of 32 or greater is recommended for this filter.

- RRC_Alpha is used to set the sharpness of a root cosine filter when FilterType=Root Cosine.
- GaussianFilter_bT is the Gaussian filter coefficient. B is the 3 dB bandwidth of the filter; T is the duration of the symbol period. BT determines the extent of the filtering of the signal. Common values for BT are 0.3 to 0.5.
- FilterLength is used to set the number of symbol periods to be used in the calculation of the symbol.
- For DataType:
  if PN9 is selected, a 511-bit pseudo-random test pattern is generated according to CCITT Recommendation O.153
  if PN15 is selected, a 32767-bit pseudo-random test pattern is generated according to CCITT Recommendation O.151
  if FIX4 is selected, a zero-stream is generated
  if x_1_x_0 is selected, where x equals 4, 8, 16, 32, or 64, a periodic bit stream is generated, with the period being 2 x. In one period, the first x bits are 1s and the second x bits are 0s.
- DataLength is used to set the number of data bytes in a frame.

7. Use with Circuit Analyses
   The full features of this model are used with Circuit Envelope simulations; for other circuit simulations, it defaults to a simpler model.
   Signal output noise is based on Temp and Noise parameters and included in the RF output I and Q waveforms for Circuit Envelope (Env) analysis.

References

1. IEEE Standard 802.11b-1999, "Part 11: Wireless LAN Medium Access Control (MAC)

and Physical Layer (PHY) specifications: High-speed Physical Layer Extension in the 2.4 GHz Band," 1999. http://standards.ieee.org/getieee802/download/802.11b-1999.pdf
2. IEEE P802.11g/D8.2, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: Further Higher Data Rate Extension in the 2.4 GHz Band," April 2003. http://ieeexplore.ieee.org/servlet/opac?punumber=4040922
3. CCITT, Recommendation O.151(10/92).
4. CCITT, Recommendation O.153(10/92).

WLAN Links

- European Radiocommunications Office: http://www.ero.dk .
- U.S. Frequency Allocations Chart: http://www.ntia.doc.gov/osmhome .
- IEEE 802.11b Compliance Organization: http://www.wi-fi.org .
- IEEE 802.11 Working Group: http://grouper.ieee.org/groups/802/11/index.html .

Sources, Noise

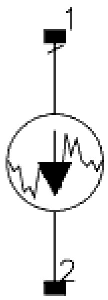
Introduction

> **Note**
> Refer to the *Simulator Expressions* (expsim) for predefined functions that can be used to build more complicated expressions.

- *I Noise (Noise Current Source)* (ccsrc)
- *I NoiseBD (Bias-Dependent Noise Current Source)* (ccsrc)
- *NoiseCorr (Noise Source Correlation)* (ccsrc)
- *Noisy2Port (Linear Noisy 2 Port Network)* (ccsrc)
- *V Noise (Noise Voltage Source)* (ccsrc)
- *V NoiseBD (Bias-dependent Noise Voltage Source)* (ccsrc)

I_Noise (Noise Current Source)

Symbol



Parameters

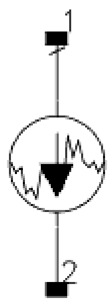
Name	Description	Units	Default
I_Noise	Noise current magnitude, per sqrt(Hz)	pA	1

Notes/Equations

1. I_Noise is the rms noise current. For simulations other than noise analysis, it will be replaced by an open circuit.

I_NoiseBD (Bias-Dependent Noise Current Source)

Symbol



Parameters

Name	Description	Units	Default
K	multiplicative constant	None	None
Ie	DC bias current exponent	None	None
A0	additive constant in the denominator	None	None
A1	multiplication factor for the frequency	None	None
Fe	frequency exponent	None	None
Elem	ID of an element such as R, FET, BJT	None	None
Pin	element pin number or name	None	None

Range of Usage

A0 and A1 cannot be simultaneously set to zero.

Notes/Equations

1. For simulations other than noise analysis, I_NoiseBD is treated as an open circuit.
2. The values and the units of K, Ie, A0, A1, and Fe should be such that the strength of the noise source as calculated from the following expression results in amperes^2/Hz. The noise spectral density of this source is given by

$$<i^2> = \frac{K \times Idc^{Ie}}{A0 + A1 \times f^{Fe}}$$

where *Idc* is the dc bias current in amperes and *f* is the simulation frequency in hertz. The dc current is that flowing into the Pin of Elem. Depending on the values of K, Ie, A0, A1, and Fe this source can be used as a flicker, burst, shot or thermal noise source. This can be explained by comparing the noise spectral density with the spectral density of a flicker, burst, shot and thermal noise source, given:
Flicker noise:

$$<i^2> = \frac{Kf \times Idc^{Af}}{f^{Ffe}}$$

Burst noise:

$$<i^2> = \frac{Kb \times Idc^{Ab}}{1 + \left(\frac{f}{Fb}\right)^2}$$

Shot noise: $<i^2> = 2 \times q \times Idc$

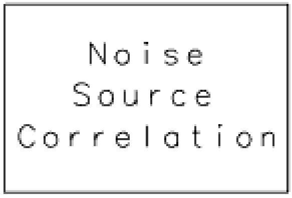
Thermal noise: $<i^2> = 4 \times k \times T \times g$

Parameter	Flicker	Burst	Shot	Thermal
K	Kf	Kb	2×q	4×k×T×g
Ie	Af	Ab	1.0	0.0
A0	0.0	1.0	1.0	1.0
A1	1.0	(1/Fb)2	0.0	0.0
Fe	Ffe	2.0	0.0	0.0

3. This component has no default artwork associated with it.

NoiseCorr (Noise Source Correlation)

Symbol



Parameters

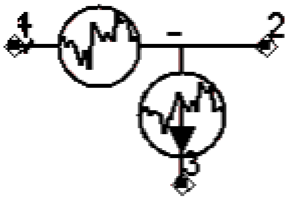
Name	Description	Units	Default
CorrCoeff	correlation coefficient	None	0.5
Source1	source 1 name	None	None
Source2	source 2 name	None	None

Notes/Equations

1. This source is used in noise analysis; it is not supported for Envelope or Transient noise analysis-a warning message will be issued when used in these analyses.
2. The sources that are correlated can be current or voltage sources.
   The correlation coefficient is defined in this equation:
   $$CorrCoeff = \frac{\langle n_1, n_2^* \rangle}{\sqrt{|n_1|^2 |n_2|^2}}$$
   where
   CorrCoeff is the correlation coefficient between the sources
   n1 and n2 are rms values of the noise generated by each source.

Noisy2Port (Linear Noisy 2 Port Network)

Symbol



Parameters

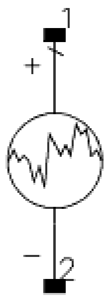
Name	Description	Units	Default
NFmin	minimum noise figure	None	1 dB
Rn	noise resistance	Ohm	50
Sopt	optimum match for minimum noise figure	None	0.0

Notes/Equations

1. Noisy2Port is a noisy 2-port. It is characterized by the minimum noise figure NFmin (real), the noise resistance Rn (real), and the optimal reflection coefficient for minimum noise figure Sopt (complex). The reference impedance for Sopt is Rref=50 Ohms (real). If connected to a source with the admittance Ys (complex), the noise figure NF of a 2-port is determined by:
$$Yopt = \frac{1}{Rref} \times \frac{1 - Sopt}{1 + Sopt}$$
$$Fmin = 10^{NFmin/10}$$
$$F = Fmin + \frac{Rn}{Real[Ys]} \times |Ys - Yopt|^2$$
$$NF = 10 \times \log(F)$$
2. Noisy2Port is used for noise analysis only. For other simulations, the voltage source is replaced by a short circuit and current source is replaced by an open circuit.
3. If NFmin, Rn, and Sopt, are used to characterize noise, the following relation must be satisfied for a realistic model:
$$\frac{Rn}{Rref} \geq \frac{To(Fmin - 1)|1 + Sopt|^2}{T * 4} \frac{(1 - |S_{11}|^2)}{|1 - Sopt\ S_{11}|^2}$$
where, T0 is the standard IEEE noise temperature (290 Kelvin) and
T is the ambient temperature.
Since the reflection coefficient, S11, for the network in which Noisy2Port is embedded is not known, it is not possible to check. Instead, if the noise parameters NFmin, Rn, and Sopt describe a system that requires negative noise because Rn is too small, the negative part of the noise will be set to zero and a warning message will be issued.
4. Sopt is always with respect to a reference impedance of Rref=50 ohms. The reference impedance is not changeable.

V_Noise (Noise Voltage Source)

Symbol



Parameters

Name	Description	Units	Default
V_Noise	Noise voltage amplitude, per sqrt(Hz)	uV	1
SaveCurrent	Flag to save branch current: YES, NO	None	yes

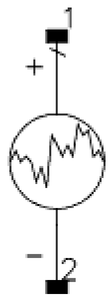
Notes/Equations

1. This source is the rms noise voltage. For simulations other than noise analysis, it will be replaced by a short circuit.
2. Setting V_Noise=1mV specifies a spectral noise density in units of $\frac{volts}{\sqrt{Hz}}$
RMS noise voltage calculated by
$\sqrt{mean(Vsource^2)}$
where Vsource is the random noise voltage at each timestep is
$1\mu V\sqrt{\frac{1}{Step}}$
Therefore, rms noise voltage is
$1\mu V\sqrt{\frac{1}{0.1msec}} = 100\mu V$
For baseband envelope, noise is distributed in a bandwidth out to 0.5/Step, rms noise voltage of the baseband envelope is
$1\mu V\sqrt{\frac{0.5}{0.1msec}} = 70.7\mu V$
3. Where V_Noise information refers to step, it is referring to the Circuit Envelope timestep only. The transient noise analysis gives the exact answer only when fixed timestep is used and the noise bandwidth is equal to 1/(2 × timestep). The answer is slightly less when other timesteps or the variable timestep algorithm is used. For those cases, a special algorithm is used to keep the noise from changing as the timestep changes.
The noise bandwidth is used to define a sampling timestep:
step = 1/(2 × NoiseBandwidth)
A random value with the proper Gaussian distribution is generated at each

time=i × step, where i is an integer from 1 to infinity. When the simulator wants to get the random value of the source in variable timestep mode, it gets the two random values (fully uncorrelated) on either side of the current time and performs linear interpolation.

V_NoiseBD (Bias-dependent Noise Voltage Source)

Symbol



Parameters

Name	Description	Units	Default
K	multiplicative constant	None	None
Ie	dc bias current exponent	None	None
A0	additive constant in the denominator	None	None
A1	multiplication factor for the frequency	None	None
Fe	frequency exponent	None	None
Elem	ID of an element	None	None
Pin	element pin number or name	None	None

Range of Usage

A0 and A1 cannot be simultaneously set to zero.

Notes/Equations

1. For simulations other than noise analysis, V_NoiseBD is treated as a short circuit.
2. The values and the units of K, Ie, A0, A1, and Fe should be such that the strength of the noise source as calculated from the following expression results in volts^2/Hz.
   The noise spectral density of this source is given by:
   $$\langle v^2 \rangle = \frac{K \times Idc^{Ie}}{A0 + A1 \times f^{Fe}}$$
   where *Idc* is the dc bias current in amperes and *f* is the simulation frequency in hertz. The dc current is that flowing into the Pin of Elem. Depending on the values of K, Ie, A0, A1, and Fe this source can be used as a flicker, burst, shot or thermal noise source. This can be explained by comparing the noise spectral density with the spectral density of a flicker, burst, shot and thermal noise source.
   Flicker noise:
   $$\langle v^2 \rangle = \frac{Kf \times Idc^{Af}}{f^{Ffe}}$$
   Burst noise:

$$<v^2> = \frac{Kb \times Idc^{Ab}}{1 + \left(\frac{f}{Fb}\right)^2}$$

Shot noise: $<v^2> = 2 \times q \times Idc$

Thermal noise: $<v^2> = 4 \times k \times T \times g$

The following table summarizes the values to which the parameters must be set to realize the types of noise sources.

Parameter	**Flicker**	**Burst**	**Shot**	**Thermal**
K	Kf	Kb	2×q	4×k×T×g
Ie	Af	Ab	1.0	0.0
A0	0.0	1.0	1.0	1.0
A1	1.0	$(1/Fb)^2$	0.0	0.0
Fe	Ffe	2.0	0.0	0.0

3. When using V_NoiseBD, the parameter K should be properly scaled such that it yields Thevenin equivalent of the above current sources.
4. This component has no default artwork associated with it.

Sources, Time Domain

Introduction

Independent sources that do not fit in the frequency-domain category are placed in the time-domain sources category.

Vt prefixes are transient voltage sources; It prefixes are transient current sources; Pt prefixes are transient power sources.

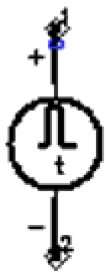
When time domain sources are used in S-parameter simulation, voltage sources are treated as short circuits, current sources are treated as open sources, and power sources are treated as impedances.

Time-domain sources are generally not used for frequency-domain simulation such as ac and harmonic balance.

> **Note**
> Refer to the *Simulator Expressions* (expsim) for predefined functions that can be used to build more complicated expressions.

- *ClockWjitter (Voltage Source - Clock with Jitter)* (ccsrc)
- *ItDataset (Current Source, Time Domain Waveform Defined in Dataset)* (ccsrc)
- *ItExp (Current Source, Exponential Decay)* (ccsrc)
- *ItPulse (Current Source, Pulse with Linear, Cosine, or Error Function Edge Shape)* (ccsrc)
- *ItPWL (Current Source, Piecewise Linear)* (ccsrc)
- *ItSFFM (Current Source, Decaying Single-Frequency FM Wave)* (ccsrc)
- *ItSine (Current Source, Decaying Sine Wave)* (ccsrc)
- *ItStep (Current Source, Step)* (ccsrc)
- *ItUserDef (Current Source, User-Defined)* (ccsrc)
- *PRBSsrc (Pseudo-Random Bit Sequence Source)* (ccsrc)
- *V DC (DC Voltage Source, Time Domain)* (ccsrc)
- *VtBitSeq (Voltage Source, Pseudo Random Pulse Train Defined at Continuous Time by Bit Sequence)* (ccsrc)
- *VtDataset (Voltage Source, Time Domain Waveform Defined in Dataset)* (ccsrc)
- *VtExp (Voltage Source, Exponential Decay)* (ccsrc)
- *VtImpulseDT (Voltage Source, Impulse Train Defined at Discrete Time Steps)* (ccsrc)
- *VtLFSR_DT (Voltage Source, Pseudo-Random Pulse Train Defined at Discrete Time Steps)* (ccsrc)
- *VtOneShot (Voltage Source, Retriggerable Pulse Train)* (ccsrc)
- *VtPRBS (Time-domain Pseudo-Random Bit Sequence Voltage Source)* (ccsrc)
- *VtPulse (Voltage Source, Pulse with Linear, Cosine, or Error Function Edge Shape)* (ccsrc)
- *VtPulseDT (Voltage Source, Pulse Train Defined at Discrete Time Steps)* (ccsrc)
- *VtPWL (Voltage Source, Piecewise Linear)* (ccsrc)
- *VtRetrig (Voltage Source, Retriggerable, User-Defined Waveform)* (ccsrc)
- *VtSFFM (Voltage Source, Single Frequency FM, SFFM Wave)* (ccsrc)
- *VtSine (Voltage Source, Decaying Sine Wave)* (ccsrc)
- *VtStep (Voltage Source, Step)* (ccsrc)
- *VtUserDef (Voltage Source, User-Defined)* (ccsrc)

ClockWjitter (Voltage Source - Clock with Jitter)



Parameters

Name	Description	Units	Default
Low	low-level voltage	V	0
High	high-level voltage	V	1
Rout	output resistance	Ohm	1
Delay	time delay	nsec	0
Rise	rise time	nsec	1
Fall	fall time	nsec	1
Width	pulse width	nsec	3
Period	pulse period	nsec	10
Jitter	jitter	nsec	0

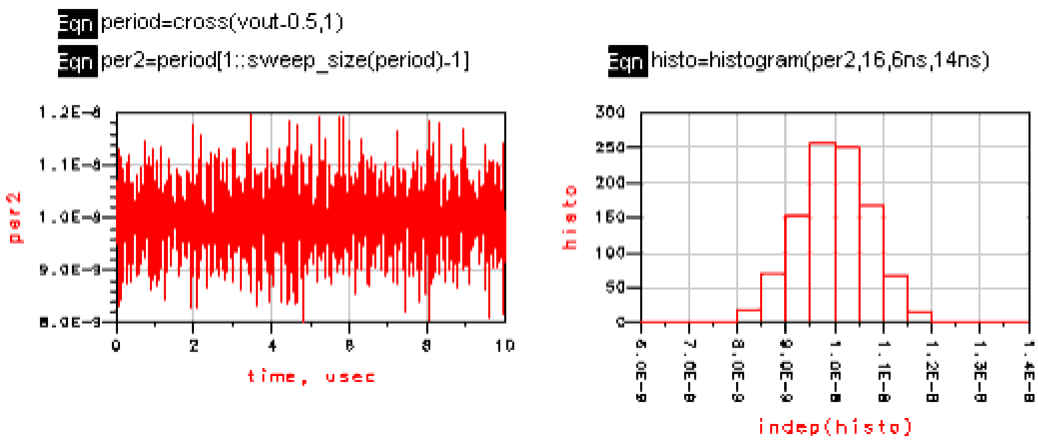
Range of Usage

Delay ≥ 0, Rise ≥ 0, Fall ≥ 0
Width > 0
Width + Rise + Fall ≤ Period

Notes/Equations

1. This source is a voltage source in series with a resistor Rout. If Rout is very small, it behaves like an ideal voltage source.
2. Jitter is specified in seconds. It models the timing jitter of a clock signal. The period of the pulse varies from nominal with a Gaussian distribution, where σ = Jitter. It exhibits a maximum deviation of ±3 σ. The pulse width is not affected by the jitter.
3. A transient simulation example is shown in the following image:

Transient Simulation Setup

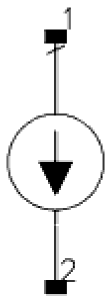


Simulation Results

4. For general information regarding time domain sources, refer to the *Introduction.* (ccsrc)

ItDataset (Current Source, Time Domain Waveform Defined in Dataset)

Symbol



Parameters

Name	Description	Units	Default
Dataset	dataset name	None	None
Expression	dataset variable or expression	None	None
Freq	carrier frequency	GHz	0
Gain	gain to apply to dataset values; can be complex and time varying	None	1.0
Tmax	maximum dataset time to use		None
Toffset	initial dataset time offset		None
Tscale	time speed-up scaling factor	None	None
Idc	DC offset current	mA	0
Interpolation	interpolation mode: Linear, Cubic Spline, Cubic, Value Lookup, Ceiling Value Lookup, Floor Value Lookup, and Value	None	Linear

Notes/Equations

1. This data-based, time-domain waveform current source is defined by a time domain dataset variable. The dataset variable must have time as its independent swept axis. This source can be used in transient or envelope simulation.
2. Set the Expression parameter to the dependent variable name of the dataset. If the dataset has *time & current* for example, this must be set to *current* .
3. The carrier frequency defined by the Freq parameter is independent of the dataset. For envelope simulation, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source current is set to zero for that analysis.
4. If Tmax is not given, the simulation Tstop must not exceed the time range of the stored variable. The output current at a given time is the interpolated dataset variable value at that time multiplied by the Gain parameter, evaluated at that time value. The dataset interpolation, if needed, is performed using linear or spline interpolation of the real and imaginary values. The Gain parameter can be complex and time varying. When this source represents a baseband signal (transient or the baseband part of an envelope signal), then only the real part of the signal is generated. For non-baseband signals this output current is the complex envelope at

the specified carrier frequency. The dataset variable and Gain parameter may be real, even for non-baseband signals, in which case they are simply defining the amplitude modulation of the carrier.

If Tmax is given, this source also allows the time axis to be scaled and will re-cycle through the dataset as many times as is necessary. This allows a single waveform that was captured, either by measurements or by simulation, and stored into a dataset to be used in different simulations with different time scales, and be translated to different carrier frequencies and converted into an indefinitely long, periodic waveform.

The Tmax parameter is the maximum dataset time value to use from the dataset. If time values greater than this are requested by the simulation, it will cycle back to dataset time=0.

The Toffset parameter is the dataset time value that this source initially starts at when simulation time=0. This allows different instances of this source to effectively create different waveforms by starting at different points in the dataset. Toffset won't be considered unless Tmax is set.

The Tscale parameter is the scaling applied to the simulator time to get the dataset time. Tscale >1 speeds up the waveform, increasing the apparent frequency and bandwidth of the stored waveform.

The relationship between the dataset time, Tds, and the actual simulation time, *time*, is

$$Tds = time, \quad \text{Tmax} = 0$$

$$Tds = (Toffset + rem(Tscale \times time, Tmax), \quad \text{Tmax != 0})$$

with the modulo remainder function

$$rem(x, y) = \left(x - int(\frac{x}{y}) \times y\right)$$

It is possible to use a negative Tscale factor to time-reverse a waveform, although Toffset must be set to greater than Tscale × Tstop, to avoid using a negative number in the rem( ) function.

5. The interpolation modes are: Linear, Cubic Spline, Cubic, Value Lookup, Ceiling Value Lookup, Floor Value Lookup, and Value. Consider an arbitrary set of time-current data pairs, namely I_0 at t=0, I_1 at $t=t_1$, I_2 at $t=t_2$, ... , I_n at $t=t_n$.

   Using the Value Lookup interpolation mode, the interpolated current will be determined as follows:

$$\text{Value Lookup}\begin{cases} i_0 & 0 < t < \frac{t_1}{2} \\ \frac{i_0 + i_1}{2} & t = \frac{t_1}{2} \\ i_1 & \frac{t_1}{2} < t < \frac{t_1 + t_2}{2} \\ \frac{i_1 + i_2}{2} & t = \frac{t_1 + t_2}{2} \\ i_2 & \frac{t_1 + t_2}{2} < t < \frac{t_2 + t_3}{2} \\ \frac{i_2 + i_3}{2} & t = \frac{t_2 + t_3}{2} \\ i_{n-1} & \frac{t_{n-2} + t_{n-1}}{2} < t < \frac{t_n + t_{n-1}}{2} \\ \frac{i_{n-1} + i_n}{2} & t = \frac{t_n + t_{n-1}}{2} \end{cases}$$

Using the Ceiling Value Lookup interpolation mode, the interpolated current will be determined as follows:

$$\text{Ceiling Value Lookup}\begin{cases} i_0 & t = 0 \\ i_1 & 0 < t \le t_1 \\ i_2 & t_1 < t \le t_2 \\ i_n & t_{n-1} < t \le t_n \end{cases}$$

Using the Floor Value Lookup interpolation mode, the interpolated current will be determined as follows:

$$\text{Floor Value Lookup}\begin{cases} i_0 & 0 \le t < t_1 \\ i_1 & t_1 \le t < t_2 \\ i_2 & t_2 \le t < t_3 \\ i_n & t_{n-1} \le t < t_n \end{cases}$$

The Value interpolation mode is to be used when the mode is variable or unknown. The entered parameter for Value interpolation mode should be a string (or integer) from the following set:
"linear" (0)
"spline" (1)
"cubic" (2)
"index_lookup" (3)
"value_lookup" (4)
"ceil_value_lookup" (5)
"floor_value_lookup" (6)
Refer to the DataAccessComponent documentation for additional information about the interpolation modes available for ItDataset.

6. The following table lists the DC operating point parameters that can be sent to the

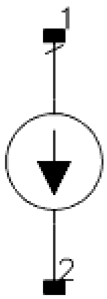
dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItExp (Current Source, Exponential Decay)

Symbol



Parameters

Name	Description	Units	Default
I_Low	initial current	mA	0
I_High	pulse current	mA	1
Delay1	rise delay time	nsec	0
Tau1	rise time constant	nsec	1
Delay2	fall delay time	nsec	1
Tau2	fall time constant	nsec	1

Range of Usage

Delay1 ≥ 0
Tau1 ≥ 0
Delay2 ≥ 0
Tau2 ≥ 0

Notes/Equations

1. If Tau1 or Tau2 = 0, it is replaced by MaxTimeStep from the transient simulation, or by Step from the envelope simulation.
   In SPICE, the equivalent to this source is a current source with the exponential waveform argument EXP and its parameters.
2. The current is given by:
   $I = I\_Low \quad 0 \le t \le Delay1$

   $$I = I\_Low + (I\_High - I\_Low) \times \left[1 - e^{\frac{-(t - Delay1)}{Tau1}}\right] \quad Delay1 < t \le Delay2$$

   $$I = I\_Low + (I\_High - I\_Low) \times \left[1 - e^{\frac{-(t - Delay1)}{Tau1}}\right]$$

   $$+ (I\_High - I\_Low) \times \left[1 - e^{\frac{-(t - Delay2)}{Tau2}}\right] \quad Delay2 < t$$

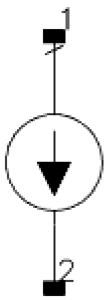
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItPulse (Current Source, Pulse with Linear, Cosine, or Error Function Edge Shape)

Symbol



Parameters

Name	Description	Units	Default
I_Low	initial current	mA	0
I_High	pulse current	mA	1
Delay	time delay	nsec	0
Edge	rise and fall edge type: linear, cosine, erf	None	linear
Rise	rise time	nsec	1
Fall	fall time	nsec	1
Width	pulse width	nsec	3
Period	pulse period	nsec	10

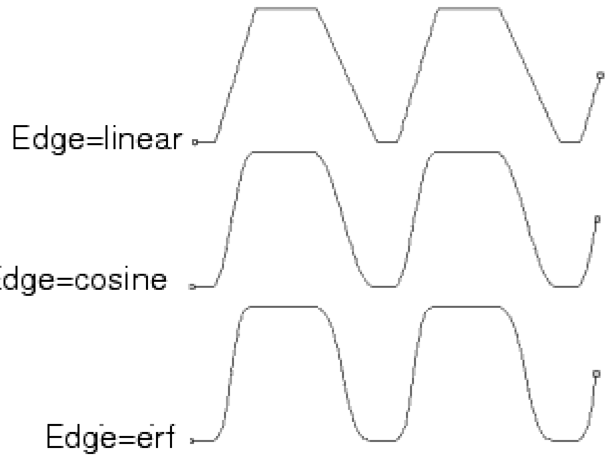
Notes/Equations

1. ItPulse is a time-periodic pulse-train current source for use with transient or envelope simulations; it is treated as an open circuit in all other simulations.
2. If Rise or Fall=0, it is replaced by MaxTimeStep from the transient simulation, or Step from the envelope simulation.
3. If Edge=linear, the rising and falling edge is a linear ramp. In SPICE, the equivalent to this source is a current or voltage source with the pulse waveform argument PULSE and its parameters.
   The intermediate points are determined by linear interpolation. Values greater than those specified are set by the parameter Period.

Time	Value
0	low
Delay	low
Delay + Rise	high
Delay + Rise + Width	high
Delay + Rise + Width + Fall	low
Period	low

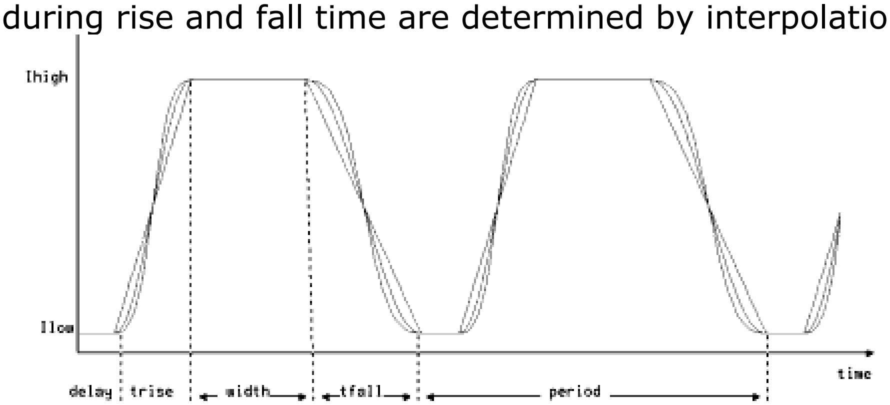
   If Edge=erf, instead of the rise and fall portions being linear ramps, this source generates a pulse based on the error function, giving a different shape to the rising

and falling edges. By not having abrupt changes in slope, the pulse shape is more realistic and its frequency spectrum decreases more rapidly.
For the error function pulse, the rise and fall time define the total transition period and the maximum slope is greater than (*I_High - I_Low*)/*Rise*, as seen in the following image.



ItPulse Waveforms with Different Edges

This source uses *1-erfc (x)*, (-2 < *x* < 2) to generate the transition region and has a peak slope that is approximately 2.25 times the linear rise time. Due to the faster slope, the 3db bandwidth of the output pulse are larger for a given rise time.
The shape of the waveform is shown in the following image; the intermediate points during rise and fall time are determined by interpolation.



Error Function Edge Shape

If Edge=cosine, this source generates cosine-shaped rising and falling edges. By not having abrupt changes in slope, the pulse shape is more realistic and its frequency spectrum decreases more rapidly.
For the cosine pulse, the rise and fall time define the total transition period and the maximum slope is greater than (*I_High-I_Low*)/*Rise*, as seen in the preceding image of the ItPulse Waveforms with Different Edges.

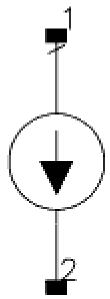
4. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItPWL (Current Source, Piecewise Linear)

Symbol



Parameters

Name	Description	Units	Default
I_Tran	pwl(time, time-current pairs), or pwlr(time, Ncycles, time-current pairs)	None	pwl(time, 0ns,0mA, 10ns,1mA, 20ns,0mA)

Notes/Equations

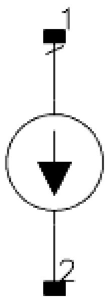
1. The piecewise linear current versus time data are specified with a pwl( ) function. The syntax for pwl is pwl(time, T_i, I_i, ...). Each pair of values (T_i, I_i) specifies that at time = T_i the current is I_i. The value of the source at intermediate values of time is determined by using linear interpolation on the input values.
   In SPICE, the equivalent to this source is a current source with the piecewise linear waveform argument PWL and its parameters.
2. If the piecewise linear waveform needs to be repeated for several cycles, a pwlr( ) function can be used. The syntax for pwlr( ) is pwlr(time, N_{cycles}, T_i, I_i, ...) where Ncycles is the number of cycles to be repeated.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItSFFM (Current Source, Decaying Single-Frequency FM Wave)

Symbol



Parameters

Name	Description	Units	Default
Idc	initial current offset	mA	0
Amplitude	Amplitude of sinusoidal wave	mA	1
CarrierFreq	carrier frequency	GHz	1
ModIndex	modulation index	None	0.5
SignalFreq	signal frequency	MHz	1

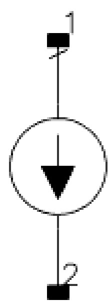
Notes/Equations

1. In SPICE, the equivalent to this source is a current source with the single-frequency FM source waveform argument SFFM and its parameters.
2. The shape of the waveform is described in the following equation.
   Idc + Amplitude × (sin(2πCarrierFreq × time) + ModIndex sin(2πSignalFreq × time))
   $Iac + A \times \sin(2\pi f_c t + \alpha \times \sin 2\pi f_s t$
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

ItSine (Current Source, Decaying Sine Wave)

Symbol



Parameters

Name	Description	Units	Default
Idc	initial current offset	mA	0
Amplitude	Amplitude of sinusoidal wave	mA	1
Freq	Frequency of sinusoidal wave	GHz	1
Delay	time delay	nsec	0
Damping	damping factor	None	0
Phase	phase value	deg	0

Range of Usage

Freq > 0
Delay ≥ 0

Notes/Equations

1. ItSine defines an ac sinusoidal current source, at a specified frequency and phase, including its turn-on characteristics for use with transient analysis. In SPICE, the equivalent to this source is a current source with the sinusoidal waveform argument SIN and its parameters.
2. ItSine has a value of [Idc + Amplitude × sin(phase)] from t=0, until t=Delay. It then becomes an exponentially damped sine wave described by

$$I = Idc + Amplitude \times \sin\left[2\pi\left(Freq(t - Delay) + \frac{Phase}{360}\right)\right]$$
$$\times e^{-(t - Delay) \times Damping}$$

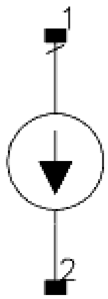
where t is time.
3. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItStep (Current Source, Step)

Symbol



Parameters

Name	Description	Units	Default
I_Low	initial current	mA	0
I_High	pulse current	mA	1
Delay	time delay	nsec	0
Rise	rise time	nsec	1

Notes/Equations

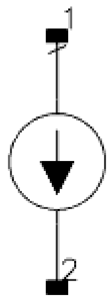
1. In SPICE, the equivalent to this source is a current or voltage source with the step waveform argument STEP and its parameters.
2. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

3. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

ItUserDef (Current Source, User-Defined)

Symbol



Parameters

Name	Description	Units	Default
I_Tran	transient current	None	damped_sin(time)
Idc	DC current	None	
Iac	AC current	mA	1

Notes/Equations

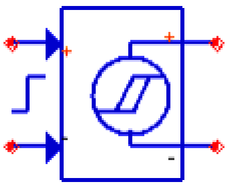
1. Typically, I_Tran is assigned an equation. This equation can be defined as a function of time by using the program reserved variable time in it. As the value of time is swept in transient or envelope simulation, the amplitude of the current source will take on the value of the equation.
2. Note that a variable or equation is unitless. However, the value of I_Tran as given by the result of a variable or equation will be assumed to be in amperes. The value of *time* will be the current simulation time in seconds.
3. There are several built-in functions that implement the standard SPICE sources, such as pwl and pulse. For a transient analysis, the ItUserDef source current is the sum of the value specified in the Idc and I_Tran parameters.
   Example
   `it = pwl (time, 0, 0, 1, 10ns, 1, 15ns, 0) + damped_sin (time)`
4. The Iac parameter is used in AC simulations and does not affect transient simulation. An example for specifying magnitude and phase would be Iac=polar(2,45), where 2 is the magnitude and 45 is the phase. For more parameter options (such as frequency) on an AC source, use the I_AC component on the Sources-Freq Domain palette.
5. The following table lists the DC operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

PRBSsrc (Pseudo-Random Bit Sequence Source)

Symbol



Parameters

Name	Description	Units	Range of Usage	Default
Mode	Source of digital input		[Enumerated, see Note 2]	[Maximal Length LFSR]
RegisterLength	Length of internal LFSR to be used for maximal length sequence		[2, 32]	8
Taps	User-defined taps for internal LFSR for generic binary sequence		String of [2, 32] bits	"10001110"
Seed	User-defined seed for internal LFSR for generic binary sequence		String of [2, 32] bits	"10101010"
BitSequence	Parametric bit sequence		String of bits	"10101010"
BitFile	ASCII file containing bit sequence		[See Note 3]	""
VtriggerThreshold	Threshold voltage for detecting external trigger	V	(-inf, inf)	0.5 V
Vlow	Lowest voltage of dynamic range	V	(-inf, inf)	0.0 V
Vhigh	Highest voltage of dynamic range	V	(-inf, inf)	1.0 V
Rout	Output resistance	Ohm	[0, inf]	50 Ohm
DeEmphasisMode	De-emphasis specification unit		[Enumerated, see Note 6]	[Percent reduction]
DeEmphasis	De-emphasized dynamic range relative to peak dynamic range		[0, 99.999%]	0.0
EmphasisSpan	Rational multiple of bit interval used for emphasis		[0, 32] †	0.0
EdgeShape	Analytical edge shape during level transitions		[Enumerated, see Note 7]	[Linear transition]
BitRate	Clock rate of generated bit stream	Hz	[0, inf) †	1 GHz
RiseTime	Duration of transition from any relatively lower to higher level	sec	[0, inf) †	10 psec
FallTime	Duration of transition from any relatively higher to lower level	sec	[0, inf) †	10 psec
TransitReference	Transition reference as a percentage of relative dynamic range		[Enumerated, see Note 9]	[0% - 100%]
RJrms	Standard deviation of Random Jitter	sec	[0, inf) †	0.0 sec
RJbw	Bandwidth for measurement of Random Jitter	Hz	[0, inf) †	1 THz
PJwave	Wave shape of Periodic Jitter		[Enumerated, see Note 10]	[Sinusoid]
PJamp[]	Amplitude of mode p of Periodic Jitter, p = {1,2,3}	sec	[0, inf) †	0.0 sec
PJfreq[]	Frequency of mode p of Periodic Jitter, p = {1,2,3}	Hz	[0, inf)	100 MHz

† Refer to Note 11 for explanation of how all user values for timing parameters are used to determine feasibility of operation.

Notes / Equations

1. The Pseudo-Random Bit Sequence source (PRBSsrc) is capable of generating waveforms distorted along amplitude and time axes, to represent realistic binary signals at an arbitrary point in a communication system. It is assumed that the user is sufficiently knowledegable about the transmission conditions present at the point of

interest to describe distortions of the waveform using various amplitude and timing parameters of this source.

2. Digital information may be supplied independently to a PRBSsrc instance in one of four possible Modes. Regardless of *Mode* or length of digital information supplied, the data is repeated as often as necessary to complete time domain simulation. These five modes and information entry points for each are described in the following table.

Mode	**Active Parameters**	**Comment**
Maximal Length LFSR	RegisterLength	Maximal length pseudo random sequence for an x-bit register is 2^x-1 bits long. The Taps and Seed settings are automatically generated within the source for any value of register length between 2 and 32 bits.
User Defined LFSR	Taps	Uses the shorter of these two bit strings to estimate LFSR length.
Explicit Bit Sequence	BitSequence	Arbitrary number of bits may be specified by manually editing the bit string. Internally up to 2^{32}-1 bits are supported before the bit sequence is repeated.
Bit File	BitFile	File(s) should be in ASCII format with '!' character used to mark comment lines. See Note 3 for details.
External Trigger	VtriggerThreshold	Ensure that trigger waveform traverses voltage specified here for proper operation. Trigger ports are assumed to be open circuited.

3. When specifying digital information in the ASCII file format, ensure that comment lines are preceded by the '!' character. Valid binary data is read from uncommented lines or sections of lines until a comment or end of line character is encountered. If multiple bit files need to be accessed in succession, do the following:
   1. Place all files in the data subdirectory of current ADS workspace. In this example, we use 3 separate files listed below. Note that no format-specific extention is required
   2. Using the keyword "dscrdata" for discrete data, create an ASCII database file e.g. PRBS.files in the data subdirectory as shown.

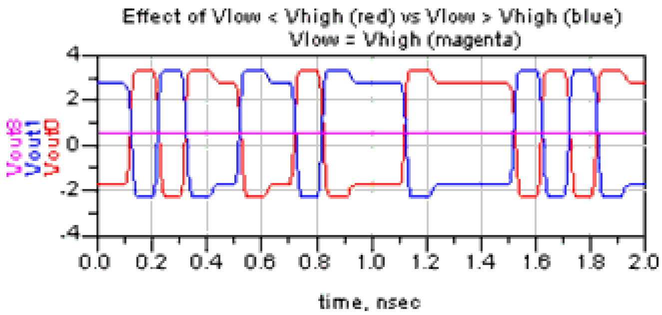
1.
```
BEGIN dscrdata
% Filenumber Filename
1 prbs1.txt
2 myprbs.file
3 your_arbitrary_bitfile.ext
END dscrdata
```

- Place a DataAccessComponent (DAC) on the schematic. Ensure that its File = "PRBS.files" Type = Discrete, InterpMode = Index Lookup, iVar = 1, iVal = fileIndex. Ignore settings of all other parameters such as *ExtrapMode* or *InterpDom*.
- Introduce a VAR component and create a variable called *fileIndex*, setting it to non-negative number between 0 and 2 (since there are 3 files).
- Place a PRBSsrc instance on the schematic, choose *Mode* = [Bit File], and open the dialog box for the *BitFile* parameter. Select "File Based Parameter" from the Parameter Entry Mode list and assign / select the DAC instance introduced in step [c] above. Specify Dependent parameter Name to be Filename in this case because that is the header information in the database file "PRBS.files".
- Use a ParamSweep component to sweep the "fileIndex" from 0 through 2 in steps of 1. This should generate successive output streams from the PRBSsrc instance from

the three bit files.

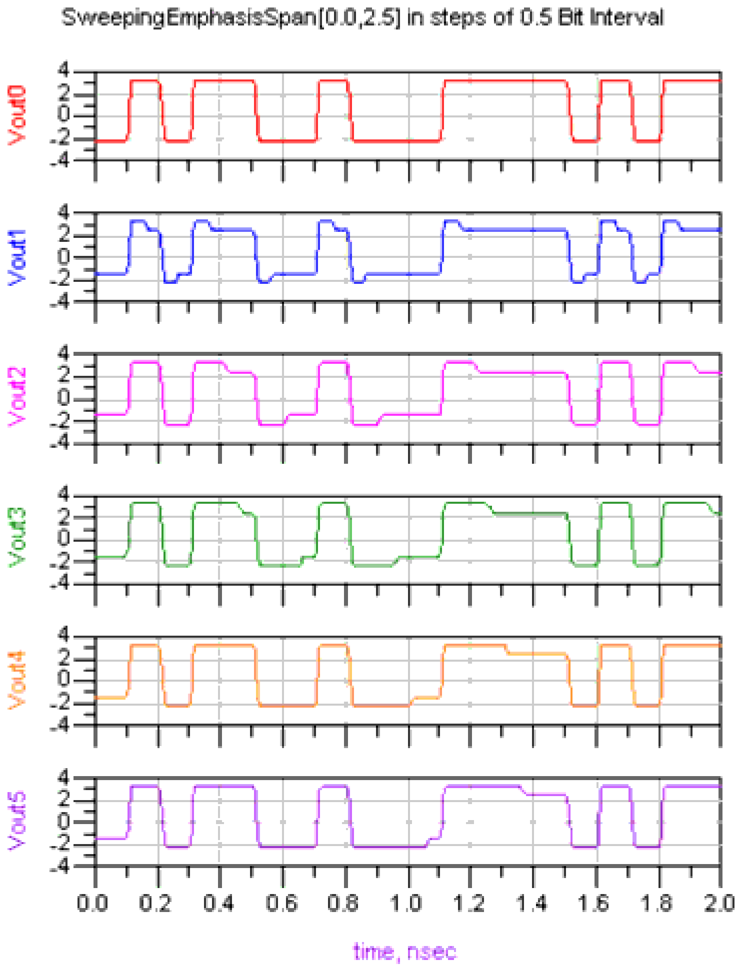
The peak dynamic range of the waveform is to be specified using the highest and lowest voltage levels achieved by the source using *Vhigh* and *Vlow* parameters. If *Vlow* is specified to be higher in value than *Vhigh*, bit inversion will occur. When both are set to the same value, the output is a flat line at that value as shown in the following image.

Peak values determine digital content of bit stream



The output resistance of this source can be varied from zero towards positive values. When *Rout* is set to zero, it operates as a pure voltage source. When non-zero, the resistance appears in series with the specified voltage levels.
PRBSsrc allows reduction of dynamic range after a sufficient amount of time has lapsed over repeated sequence of '1's or '0's. This feature is known as de-emphasis and the full functionality is specified using the parameters *DeEmphasisMode*, *DeEmphasis* and *EmphasisSpan* if *EnableDeEmphasis* is active.

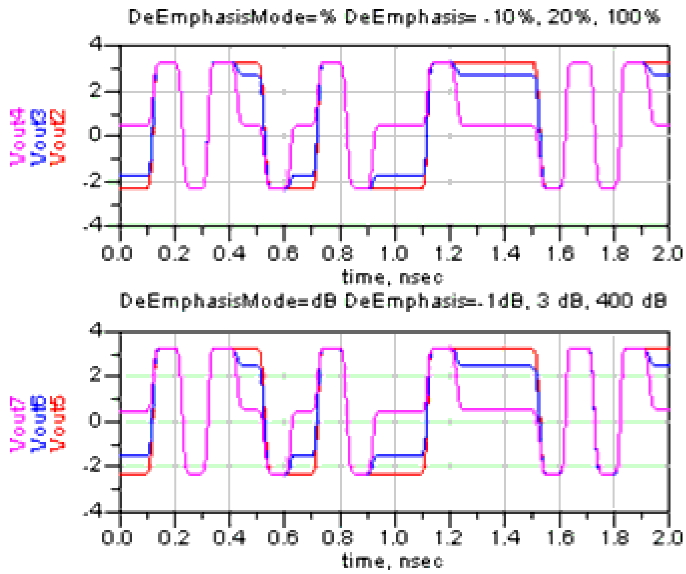
Effect of increasing *EmphasisSpan* on the bit stream "010110010001111101011"



DeEmphasisMode can be set to [Percent reduction] or to [dB Loss], both signifying decrease in steady or shelf dynamic range relative to peak dynamic range as follows:

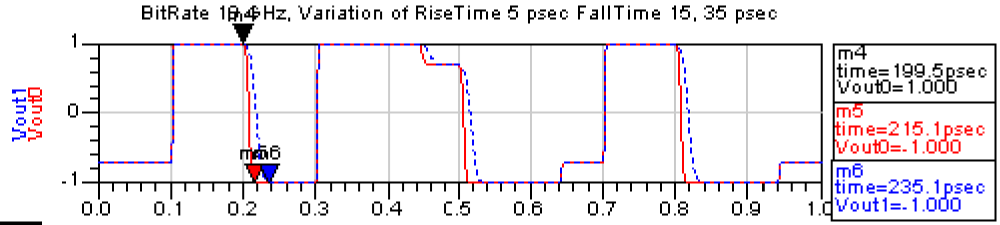
- For [Percent reduction], *DeEmphasis* = 100 * (1.0 - (*VhighShelf* - *VlowShelf*)/(*Vhigh* - *Vlow*))
- For [dB Loss], *DeEmphasis* = 20 * log10 ((*Vhigh* - *Vlow*)/(*VhighShelf* - *VlowShelf*))
  Using supplied numeric value of *DeEmphasis*, *Vlow* and *Vhigh*, *VhighShelf* and *VlowShelf* are computed internally, and applied after the duration of *EmphasisSpan* has passed following the start of a level transition. Note that *EmphasisSpan* is a non-negative real number specifying the rational multiple of bit intervals that the waveform must be held at peak value before de-emphasis is permitted. Bit interval is internally defined as the reciprocal of *BitRate* parameter. If there is a data change within this duration, the level transition is from peak to peak. In the following image, *DeEmphasisMode* = [Percent reduction], *DeEmphasis* = 30 % and *EmphasisSpan* = swept {0.0:0.5:2.5} bit intervals.
  The lowest value of *DeEmphasis*, whether expressed as [Percent reduction] or as [dB Loss] of dynamic range, is zero, which amounts to no reduction in peak levels. The highest value of de-emphasis is just under 100%, at which point *VhighShelf* and *VlowShelf* meet at the same voltage value. Warnings will be issued if either limit is exceeded. Note that when *DeEmphasisMode* is set to [dB Loss], theoretically there is no upper limit to achieve 100% de-emphasis.

Effect of varying DeEmphasis in each DeEmphasisMode



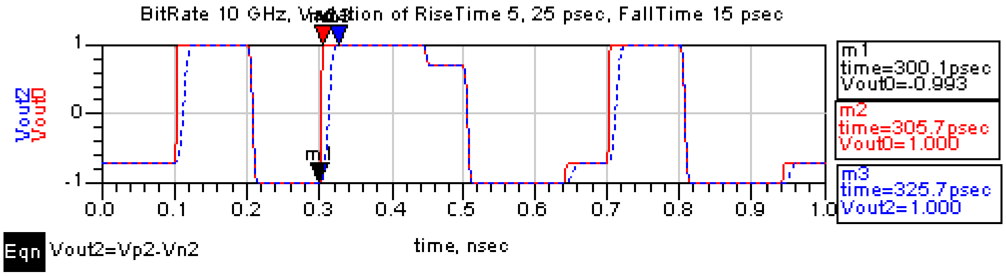
The *EdgeShape* parameter allows the selection of standard analytical functions for defining the waveform during transitions between any two voltage levels. Supported values are [Linear transition], [Raised Cosine transition] and [Error Function transition].
BitRate is the inverse of the duration of the average bit interval, expressed in Hz which is equivalent to bits / second. Note that actual bit intervals may vary from one data bit to another when jitter effects are injected into the source.
Rise and fall times are applied uniformly across all level changes as appropriate, and interpreted subject to the setting of *TransitReference*. With the default definition of transition reference as [0%-100%] the value assigned to the *RiseTime* parameter applies exactly to level changes from *Vlow* to *Vshelf* during de-emphasis while '0's are active and *Vlow* to *Vhigh* during data transition. Similarly, the *FallTime* parameter applies exactly to level changes from *Vhigh* to *VhighShelf* during de-emphasis while '1's are active and *Vhigh* to *Vlow* during a '1' to '0' transition. When *TransitReference* of [20%-80%] is selected, the supplied rise and fall times are interpreted to mean the duration spent by the waveform traversing between 20% through 80% of the upward range or between 80% through 20% of the downward range respectively. The following image shows how varying only *RiseTime*, only *FallTime* and only *TransitReference* changes the waveform along the time axis. The *TransitReference* parameter works in conjunction with the *EdgeShape* parameter to determine the effective transition span as shown in the images that follow.

Effect of *RiseTime, FallTime* and *TransitReference* on waveform.

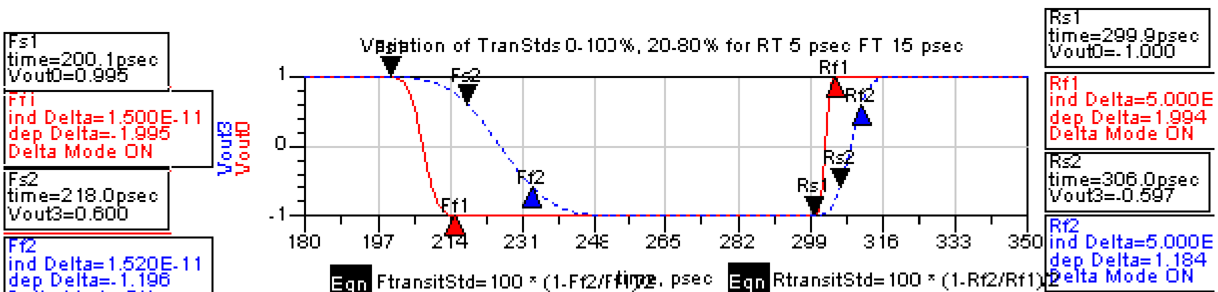


Eqn Vout0 = Vp0-Vn0

Eqn Vout1=Vp1-Vn1



Eqn Vout2=Vp2-Vn2



Eqn FtransitStd=100 * (1-Ff2/Ff1)/2

Eqn RtransitStd=100 * (1-Rf2/Rf1)/2

Eqn Vout3=Vp3-Vn3

FtransitStd	RtransitStd
20.018	20.319

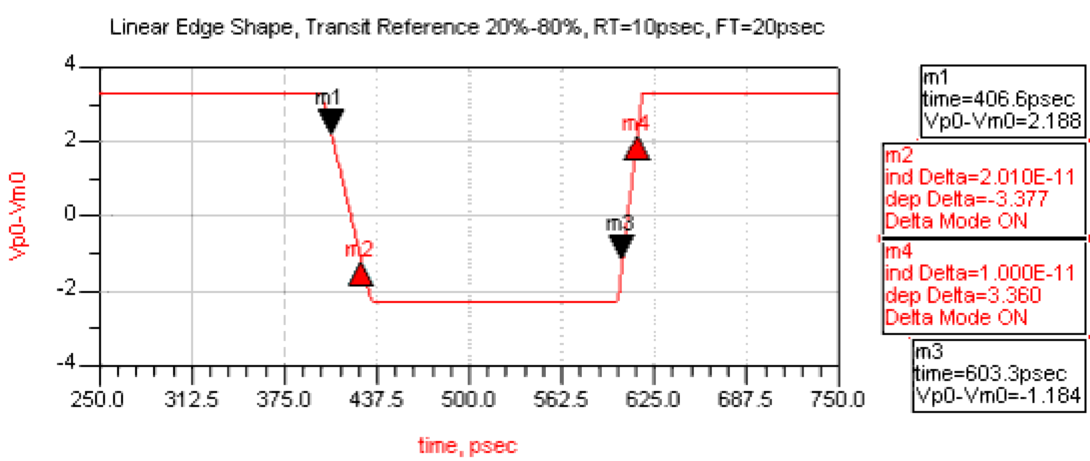
Effective rise and fall times vary based on *EdgeShape* for identical *RiseTime, FallTime* and *TransitReference* settings.

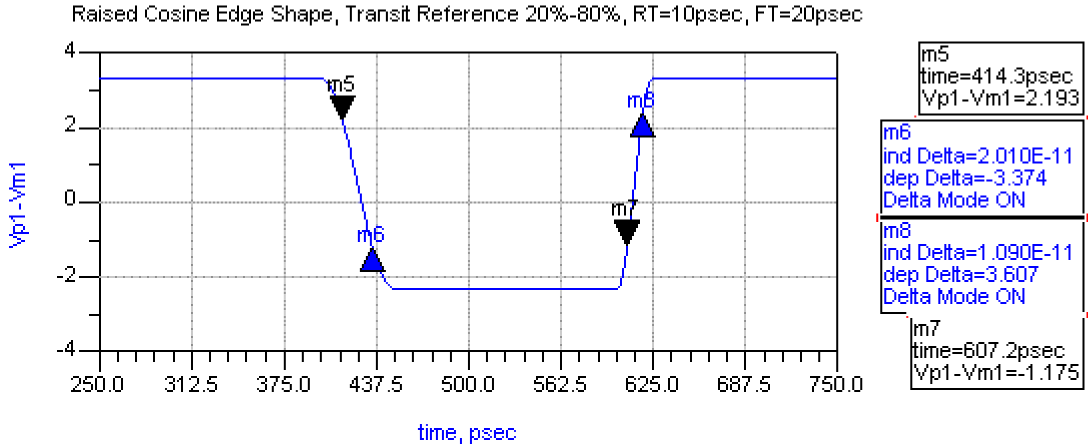
Eqn VpeakRange=3.3-(-2.3)

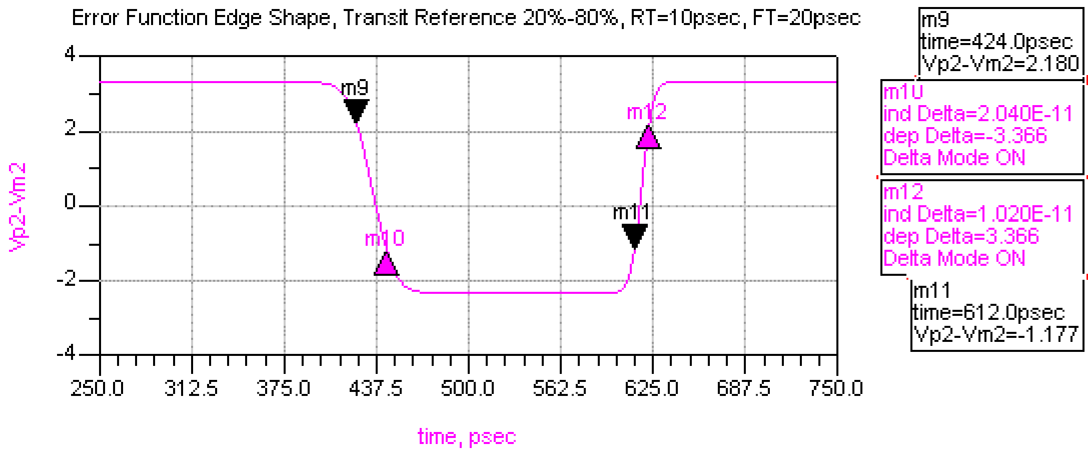
Eqn V80p=0.8 * VpeakRange + (-2.3)

Eqn V20p=0.2 * VpeakRange + (-2.3)

V80p	V20p
2.180	-1.180

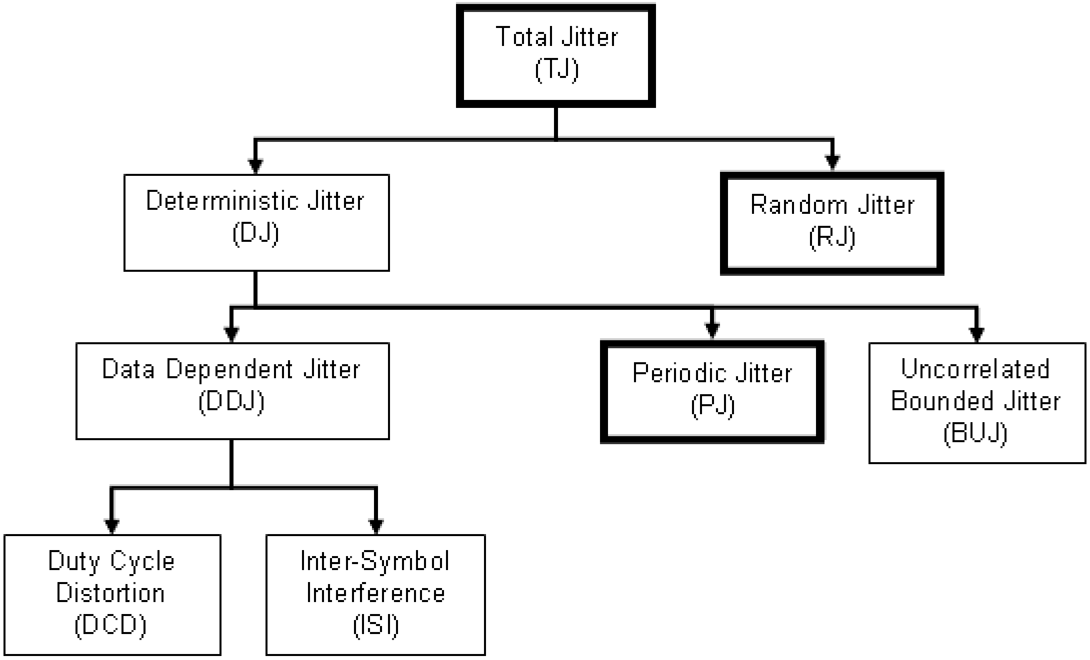






Jitter is defined as the deviation along time axis of the actual bit interval boundary from the expected time point when one data bit is followed by the next. It is most easily observed during '0' to '1' or '1' to '0' transitions using an eye diagram when successive waveforms are overlaid on each other over one expected bit interval. Given sufficient number of '0's and '1's detection of jitter can be simplified to observation of the histogram distribution of waveform points at the zero-crossing between the binary states. PRBSsrc supports two classes of jitter, both of which are independent of data content produced by the source, namely *Random Jitter* and *Periodic Jitter*. The hierarchy of conventional jitter description is shown in the following image.

Conventional classification of jitter in digital waveforms. PRBSsrc features only Random and Periodic Jitter.



Random Jitter is defined as timing disturbances that occur as the result of device noise and flicker effects in the transmission hardware. It is defined as a unimodal Gaussian distribution with a mean of zero and standard deviation of RJrms along the time axis. The modeling of such jitter is made feasible by bounding it using the measurement bandwidth parameter *RJbw*. By default PRBSsrc sets *RJrms* to zero implying no jitter and *RJbw* to 1 THz, which is equivalent to unbounded measurement. When setting finite values of random jitter, ensure that the unit of *RJrms* is compatible with *BitRate* and rise and fall times. Also apply appropriate measurement bandwidth via *RJbw* if this quantity is known.
Periodic Jitter is defined as timing disturbance that occurs as a result of Electro-Magnetic Interference (EMI) from switching on and off of power supplies. It results in deviation of the bit transition boundary in a periodic fashion where the amplitude of the variation occurs along the time axis and is denoted by *PJamp*. The frequency of variation, which is unrelated to the *BitRate* of the digital signal, is denoted by *PJfreq*.
Three variations of periodic waveforms are supported in contemporary jitter injection and measurement instruments, namely, [Sinusoid], [Square] and [Triangle]. PRBSsrc emulates all three periodic jitter types which can be set via the *PJwave* parameter. Up to three constituent modes may be specified using the *PJamp* and *PJfreq* parameters for the selected jitter wave shape.

- Sinusoidal jitter pattern is implemented for fixed amplitude along time axis and fixed frequency which determines the distribution of samples over time but random phase. Consequently, the histogram of a unimodal sinusoidal periodic jitter shows sharp peaks at either end with a shallow valley in the center, described conventionally as the Bathtub-curve. The jitter waveform varies around the transition time point as for one or more

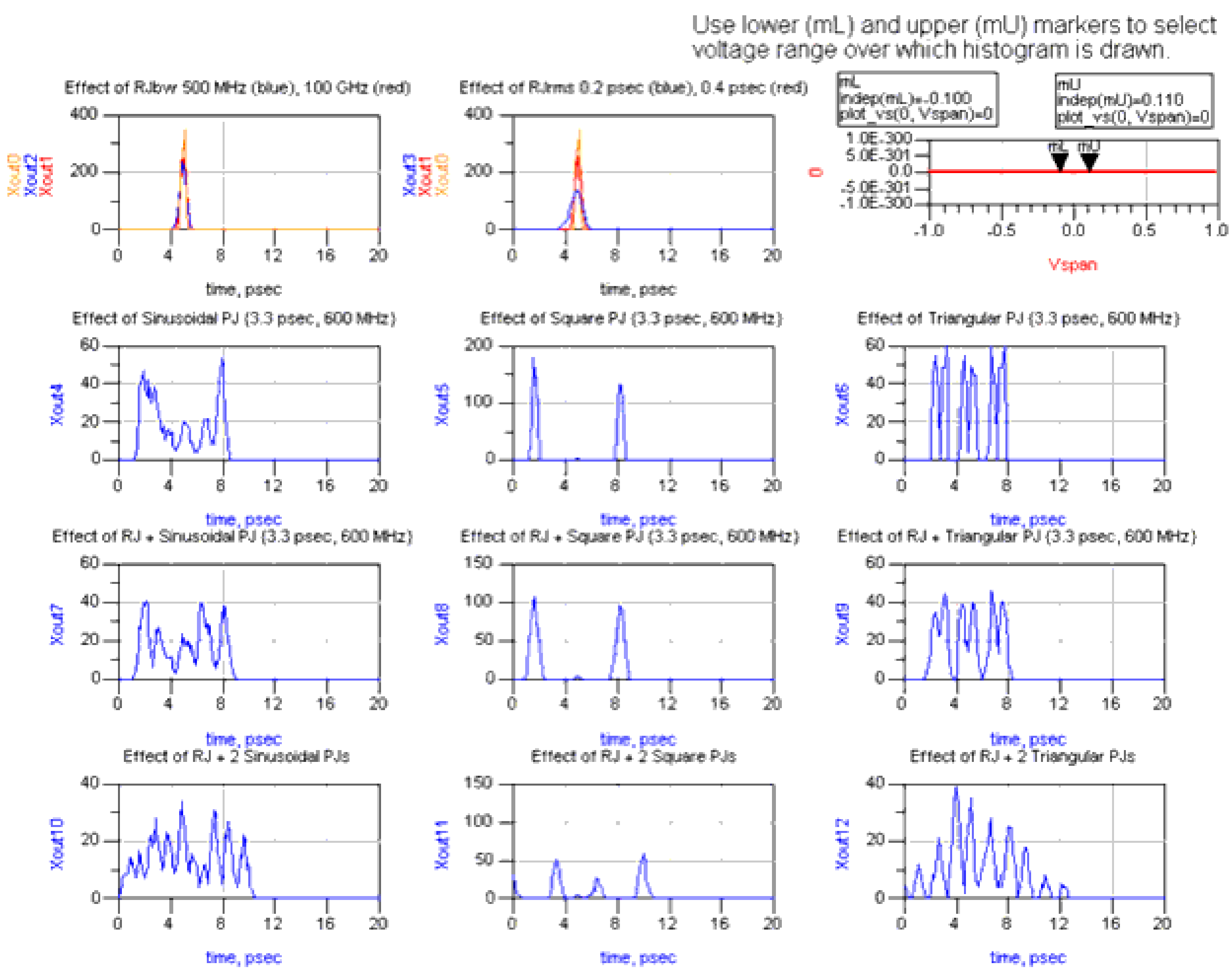
```
PJsine(i,t)=PJamp(i)*sin(2*PJfreq(i)*t + random_phase) for each i = {1,2,3}
```

- Square jitter pattern is purely deterministic where jitter samples are deposited only at either extremity of the histogram, corresponding to positive and negative levels of the waveform. The jitter waveform varies around the transition time point as for one or more

```
PJsquare(i,t)= -PJamp(i) for 0 <= t < 0.5/PJfreq(i) for each i = {1,2,3}
                PJamp(i) for 0.5/PJfreq(i) <= t < 1/PJfreq(i)
```

- Triangle jitter pattern, which is also purely deterministic allows a multimodal yet somewhat uniform distribution of samples throughout the jitter interval. *PJtriangle* (i,j) distributes samples evenly along a balanced sawtooth wave that traverses between -/+ *PJamp*(i) with frequency of *PJfreq*(i) for one or more i = {1,2,3} Random Jitter may be combined with one or more modes of any one type of Periodic Jitter to devise timing uncertainties with various distributions. Some examples are shown in the following image.

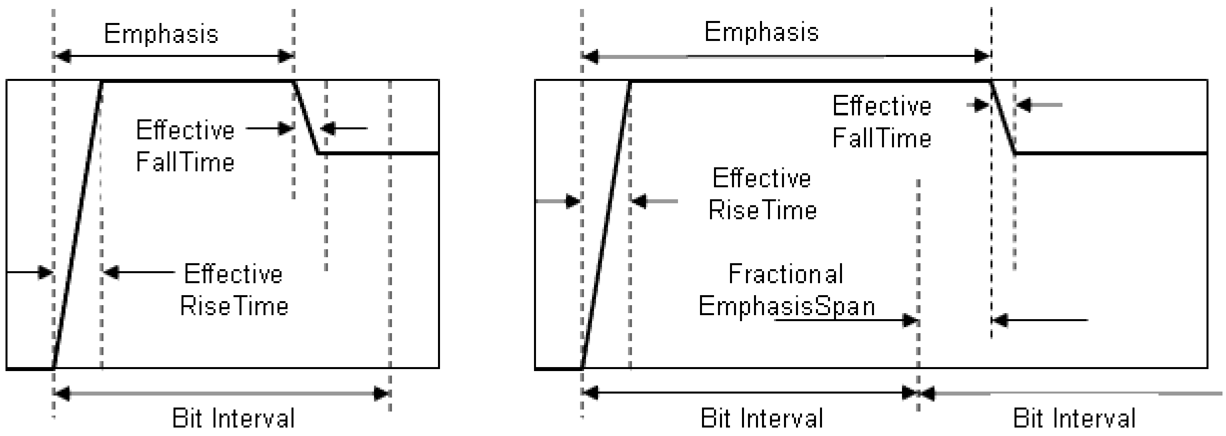
Combination of Random and Periodic Jitters of various types and modes produce histograms representing different timing aberrations in PRBSsrc.



The feasibility of simulating a waveform given *BitRate* , *EmphasisSpan* , *RiseTime* , *FallTime* , *TransitReference* , *RJrms* and the *PJamp* [] vector deduced based on *EmphasisSpan* as follows:
Case A: 0.0 < *EmphasisSpan* < 1.0 so a single bit has to accommodate both effective rise and fall times as well as the remainder of emphasis duration.
Case B: *EmphasisSpan* is zero or else > 1.0 so single bit has to accommodate the longer of effective rise and fall times plus the fractional duration of emphasis.
Jitter variability is computed as the maximum of 6-sigma of random jitter and double of all

periodic jitter amplitudes. This is added to the relevant case to arrive at a limit of minimum bit interval necessary to generate the waveform through all possible states and transitions. The reciprocal of this value is maximum supportable bit rate. If supplied *BitRate* is below the maximum value, the simulation is allowed to proceed else it is halted with an error message about maximum supportable bit rate.

Interdependency of timing parameters in PRBSsrc: *BitRate*, *TransitReference*, *RiseTime*, *FallTime* and *EmphasisSpan* together determine whether the underlying deterministic waveform is feasible or not. This is followed by Jitter based limitations imposed on the maximum permissible *BitRate*.



Case A: EmphasisSpan < 1.0 **Case B: EmphasisSpan >= 1.0**

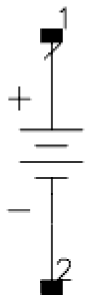
For a comprehensive tutorial on the use model of the PRBSsrc, refer to the Examples > SignalIntegrity > PRBSsrc_wrk and associated literature.

References

1. IEEE Standards 181 - IEEE Standard on Transitions, Pulses, and Related Waveforms, IEEE Intrumentation and Measurement (I&M) Society, 7 July 2003.
2. Pseudo-Random Number Generation Routine for the MAX765 Microprocessor, Application Note 1743, Maxim Integrated Products Inc., 25 September 2002.
3. Kim, K., Huang, J., Kim, Y. and Lombardi, F., On the Modeling and Analysis of Jitter in ATE Using Matlab, Proceedings of the 2005 20th IEEE International Symposium on Defect and Fault Tolerance in VLSI Engineering (DFT'05), IEEE Computer Society.
4. Ou, N., Farahmand, T., Kuo, A., Tabatabei, S. and Ivanov, A., Jitter Models for the Design and Test of Gbps-Speed Serial Interconnects, IEEE Design & Test of Computers, July-August 2004, pp 302-313.

V DC (DC Voltage Source, Time Domain)

Symbol



Parameters

Name	Description	Units	Default
Vdc	dc voltage	V	1.0
Vac	AC voltage, use polar() for phase		None
SaveCurrent	Flag to save branch current: yes, no	None	yes

Notes/Equations

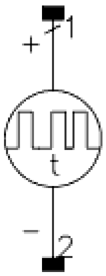
1. V_DC can be used in all simulations. When not in use, it is treated as a short circuit.
2. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

3. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtBitSeq (Voltage Source, Pseudo Random Pulse Train Defined at Continuous Time by Bit Sequence)

Symbol



Parameters

Name	Description	Units	Default
Vlow	minimum voltage level	V	0
Vhigh	maximum voltage level	V	5
Rate	bit rate	MHz	50
Rise	rise time of pulse	nsec	1
Fall	fall time of pulse	nsec	1
BitSeq	bit sequence	None	"101010"
SaveCurrent	Flag to save branch current: yes, no	None	yes
Delay	time delay before the waveform starts to emanate from the source	nsec	0

Notes/Equations

1. *BitSeq* allows you to vary the waveform of a pulse: an arbitrary bit pattern such as 101010 (default), or considerably longer and more varied, such as 11100001111101. When the end of the sequence is reached, the sequence is repeated. A specification of 1 sets voltage to *Vhigh*, 0 sets it to *Vlow*.

   Note To edit *BitSeq* , enter a value enclosed with double quote symbols.

2. *VtBitSeq* is used for transient simulations; *Vf_BitSeq* is recommended for frequency simulations.
3. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

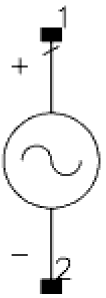
4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).
5. The rise or fall time is used to start a level transition half a transition interval prior to the zero-crossing point, the mid point between *Vlow* and *Vhigh*. This ensures that the mathematical definition of the transition time coincides with the geometric definition of the level transition. However, this is a non-causal definition of transition, because

it requires a priori knowledge of bit **i+1** value while the simulation is executing the waveform for bit **i**. As such, the explicit sequence of bits supplied to *BitSeq* parameter enables a look-ahead feature because all future bits are known in advance. However, for file based bit sequences, where current time instant is used to extract the instantaneous bit value from the file, VtBitSeq is not appropriate. Use the source *VtPRBS (Time-domain Pseudo-Random Bit Sequence Voltage Source)* (ccsrc) in [Bit File] mode to read simple ASCII bit files and generate causal waveforms where level transition begins at the beginning of a bit interval and not half a transition width prior to that. Also see example design Signal Integrity > VtPRBS_wrk > PRBS_BitFileSweep for use model.

6. *VtBitSeq* only provides linear shaped waveform during level transitions. For more options such as raised cosine or error function shaped transitions, use the *VtPRBS (Time-domain Pseudo-Random Bit Sequence Voltage Source)* (ccsrc) component as shown in the example design Signal Integrity > VtPRBS_wrk > PRBS_EdgeShape.

VtDataset (Voltage Source, Time Domain Waveform Defined in Dataset)

Symbol



Parameters

Name	Description	Units	Default
Dataset	dataset name	None	None
Expression	dataset variable or expression	None	None
Freq	carrier frequency	GHz	0
Gain	apply to dataset values; can be complex and time varying	None	1.0
Tmax	maximum dataset time to use		None
Toffset	initial dataset time offset		None
Tscale	time speed-up scaling factor	None	None
Vdc	dc offset voltage	V	0
Interpolation	interpolation mode: Linear, Cubic Spline, Cubic, Value Lookup, Ceiling Value Lookup, Floor Value Lookup, and Value	None	Linear
SaveCurrent	Flag to save branch current: yes, no	None	yes

Notes/Equations

1. This data-based, time-domain waveform voltage source is defined by a time domain dataset variable. The dataset variable must have time as its independent swept axis. This source can be used in transient or envelope simulation.
2. Set the Expression parameter to the dependent variable name of the dataset. If the dataset has *time & voltage* for example, this must be set to *voltage*.
3. The carrier frequency defined by the Freq parameter is independent of the dataset. For envelope simulation, the Freq parameter identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning is issued and the source voltage is set to zero for that analysis.
4. If Tmax is not given, the simulation Tstop must not exceed the time range of the stored variable. The output voltage at a given time is the interpolated dataset variable value at that time multiplied by the Gain parameter, evaluated at that time value. The dataset interpolation, if needed, is performed using linear or spline interpolation of the real and imaginary values. The Gain parameter can be complex and time varying. When this source represents a baseband signal (transient or the baseband part of an envelope signal), then only the real part of the signal is generated. For non-baseband signals this output voltage is the complex envelope at

the specified carrier frequency. The dataset variable and Gain parameter may be real, even for non-baseband signals, in which case they are simply defining carrier amplitude modulation.

If Tmax is given, this source also allows the time axis to be scaled and will re-cycle through the dataset as many times as is necessary. This allows a single waveform that was captured, either by measurements or by simulation, and stored into a dataset to be used in different simulations with different time scales, and be translated to different carrier frequencies and converted into an indefinitely long, periodic waveform.

The Tmax parameter is the maximum dataset time value to use from the dataset. If time values greater than this are requested by the simulation, it will cycle back to dataset time=0.

The Toffset parameter is the dataset time value that this source initially starts at when simulation time=0. This allows different instances of this source to effectively create different waveforms by starting at different points in the dataset. Toffset won't be considered unless Tmax is set.

The Tscale parameter is the scaling applied to the simulator time to get the dataset time. A number greater than 1 speeds up the waveform, increasing the apparent frequency and bandwidth of the stored waveform.

The relationship between the dataset time, Tds, and the actual simulation time, *time*, is

$$Tds = time, \quad \mathrm{Tmax} = 0$$

$$Tds = (Toffset + rem(Tscale \times time, Tmax), \quad \mathrm{Tmax} \mathrel{!=} 0)$$

with the modulo remainder function

$$rem(x, y) = \left(x - int(\frac{x}{y}) \times y\right)$$

It is possible to use a negative Tscale factor to time-reverse a waveform, although Toffset must be set to greater than Tscale × Tstop, to avoid using a negative number in the rem( ) function.

5. The interpolation modes are Linear, Cubic Spline, Cubic, Value Lookup, Ceiling Value Lookup, Floor Value Lookup, and Value. Consider an arbitrary set of time-voltage data pairs: V_0 at t=0, V_1 at $t=t_1$, V_2 at $t=t_2$, ... , V_n at $t=t_n$.

   Using the Value Lookup interpolation mode, the interpolated voltage will be determined as follows:

$$\text{Value Lookup}\begin{cases} v_0 & 0 < t < \frac{t_1}{2} \\ \frac{v_0 + v_1}{2} & t = \frac{t_1}{2} \\ v_1 & \frac{t_1}{2} < t < \frac{t_1 + t_2}{2} \\ \frac{v_1 + v_2}{2} & t = \frac{t_1 + t_2}{2} \\ v_2 & \frac{t_1 + t_2}{2} < t < \frac{t_2 + t_3}{2} \\ \frac{v_2 + v_3}{2} & t = \frac{t_2 + t_3}{2} \\ v_{n-1} & \frac{t_{n-2} + t_{n-1}}{2} < t < \frac{t_n + t_{n-1}}{2} \\ \frac{v_{n-1} + v_n}{2} & t = \frac{t_n + t_{n-1}}{2} \end{cases}$$

Using the Ceiling Value Lookup interpolation mode, the interpolated voltage will be determined as follows:

$$\text{Ceiling Value Lookup}\begin{cases} v_0 & t = 0 \\ v_1 & 0 < t \le t_1 \\ v_2 & t_1 < t \le t_2 \\ v_n & t_{n-1} < t \le t_n \end{cases}$$

Using the Floor Value Lookup interpolation mode, the interpolated voltage will be determined as follows:

$$\text{Floor Value Lookup}\begin{cases} v_0 & 0 \le t < t_1 \\ v_1 & t_1 \le t < t_2 \\ v_2 & t_2 \le t < t_3 \\ v_n & t_{n-1} \le t < t_n \end{cases}$$

The Value interpolation mode is to be used when the mode is variable or unknown. The entered parameter for Value interpolation mode should be a string (or integer) from the following set:
"linear" (0)
"spline" (1)
"cubic" (2)
"index_lookup" (3)
"value_lookup" (4)
"ceil_value_lookup" (5)
"floor_value_lookup" (6)
Refer to the *DataAccessComponent (Data Access Component)* (ccsim) documentation for additional information about the interpolation modes available for VtDataset.

6. The following table lists the dc operating point parameters that can be sent to the

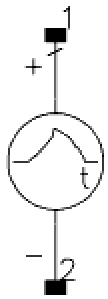
dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

7. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtExp (Voltage Source, Exponential Decay)

Symbol



Parameters

Name	Description	Units	Default
Vlow	initial voltage	V	0
Vhigh	Pulse voltage	V	1
Delay1	rise time delay	nsec	0
Tau1	rise time constant	nsec	1
Delay2	fall time delay	nsec	1
Tau2	fall time constant	nsec	1
SaveCurrent	Flag to save branch current: yes, no	None	yes

Range of Usage

Delay1 ≥ 0
Delay2 ≥ 0
Tau1 ≥ 0
Tau2 ≥ 0

Notes/Equations

1. In SPICE, the equivalent to this source is a voltage source with the exponential waveform argument EXP and its parameters. If Tau1 or Tau2 = 0, it is replaced by MaxTimeStep from the transient simulation or Step from the envelope simulation.
2. The source output voltage, V, is given by the following:

$$t1 = \frac{t - Delay1}{Tau1}$$

$$t2 = \frac{t - Delay2}{Tau2}$$

Case 1: Delay1 < Delay2

$$V = \begin{cases} Vlow & 0 \le t \le Delay1 \\ Vlow + (Vhigh - Vlow) \times (1 - \exp(-t1)) & Delay1 \le t \le Delay2 \\ Vlow + (Vhigh - Vlow) \times (1 - \exp(-t1)) + (Vlow - Vhigh) \times (1 - \exp(-t2)) & Delay2 < t \end{cases}$$

Case 2: Delay2 < Delay1

$$V = \begin{cases} Vlow & 0 \le t \le Delay2 \\ Vlow + (Vlow - Vhigh) \times (1 - \exp(-t2)) & Delay2 \le t \le Delay1 \\ Vlow + (Vhigh - Vlow) \times (1 - \exp(-t1)) + (Vlow - Vhigh) \times (1 - \exp(-t2)) & Delay1 < t \end{cases}$$

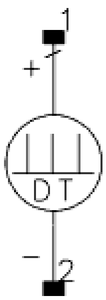
3. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtImpulseDT (Voltage Source, Impulse Train Defined at Discrete Time Steps)

Symbol

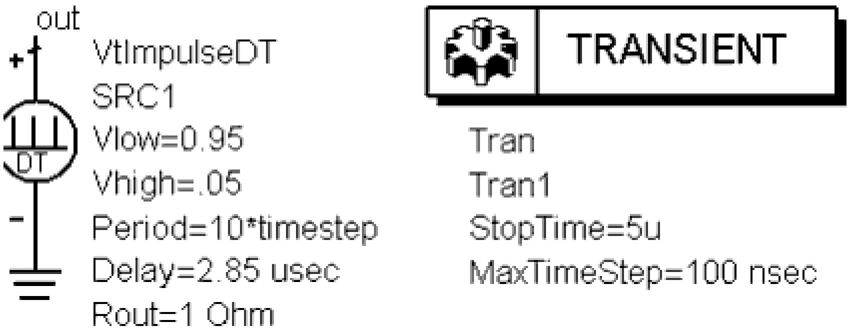


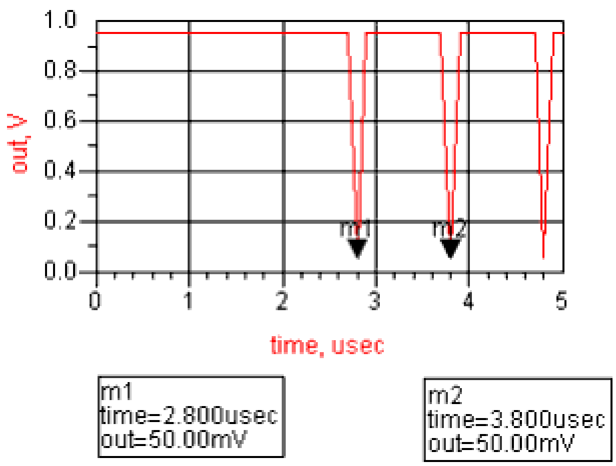
Parameters

Name	Description	Units	Default
Vlow	minimum voltage level	V	0
Vhigh	maximum voltage level	V	1
Period	time between repetitive impulses	nsec	100
Delay	time delay before first impulse	nsec	0
Rout	output resistance	Ohm	1

Notes/Equations

1. This source is used in envelope and transient simulations.
2. Both the delay and the period are rounded to the nearest integer multiple of the analysis time step. The impulse source is in the high state for only one time sample each period, with an open circuit voltage equal to Vhigh and an output impedance set by Rout.
3. It is possible to set Vlow to a voltage more positive than Vhigh in order to generate a negative-going impulse train, as shown in the following image.





Negative-Going Impulse

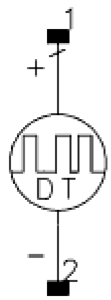
4. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtLFSR_DT (Voltage Source, Pseudo-Random Pulse Train Defined at Discrete Time Steps)

Symbol

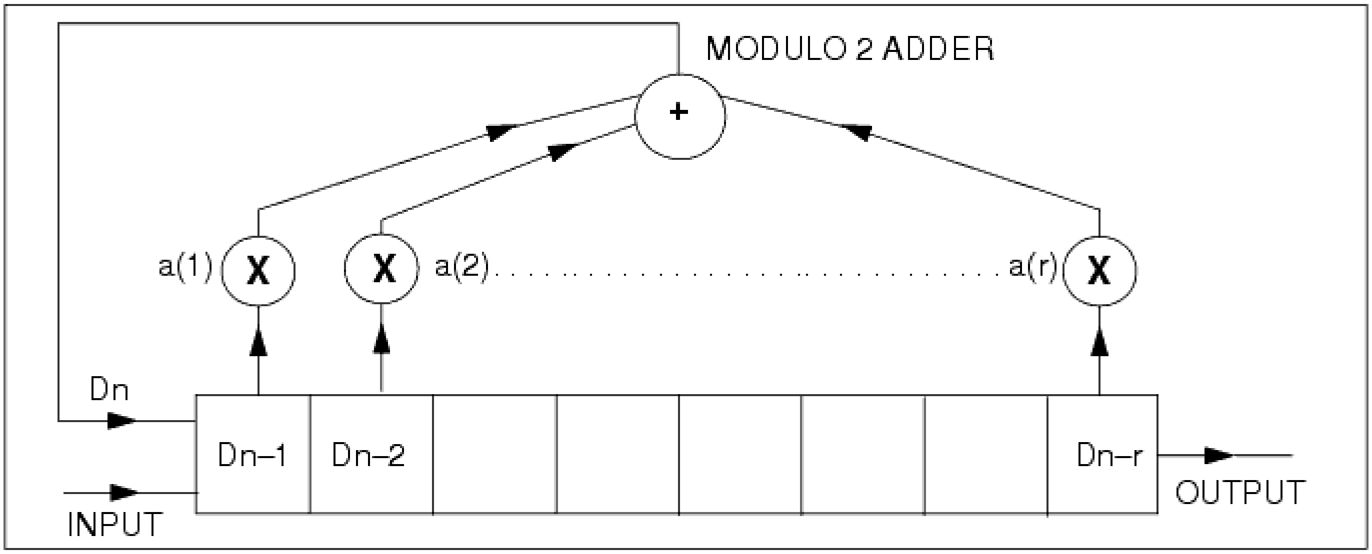


Parameters

Name	Description	Units	Default
Vlow	minimum voltage level	V	0
Vhigh	maximum voltage level	V	1
Rate	bit rate	kHz	24.3
Delay	initial time delay to first transition	nsec	0
Taps	bits used to generate feedback	None	bin("10000000000000100")
Seed	initial value loaded into the shift register	None	bin("10101010101010101")
Rout	output resistance	Ohm	1

Notes/Equations

1. This is a discrete-time source for use in envelope and transient simulations. The pulse width must be is an integer number of simulation time steps.
2. This component can be used to generate PN sequences with user-defined recurrence relations.
3. The linear feedback shift register component can be used to generate PN sequences with user-defined recurrence relations. The input to the LFSR is a binary sequence. The following figure illustrates an LFSR model.
   Data is shifted to the right in the shift register. The length of the shift register is r. The numbers a(1), a(2), ... , a(r) are the binary feedback coefficients specified by Taps.
   The shift register length r is defined by the largest value in Taps. For example, a Taps of 7 3 2 1 results in a shift register length of 7; the maximum value allowed in Taps is 31, which results in a maximum shift register length of 31.



The initial contents of the shift are specified by the value of Seed. The maximum meaningful value for Seed is $(2^{**}r)^{-1}$ for a specific Taps. The maximum Seed value allowed is $(2^{**}31)^{-1}$.
The following equations describe the operation of LFSR.

$$D(n) = \left[\sum_{k=1}^{r} a(k)D(n-k)\right]\text{mod2 for n} \geq 1$$

where
$D(0) = Seed_2(0)$

$D(-1) = Seed_2(1)$

.
.
.
$D(1-r) = Seed_2(r-1)$

and

$$Seed = \sum_{k \geq o} \text{Seed}_2(k)2^k$$

where $Seed_2(k)$ E (0,1) for 0 k < r.

Example: Let Seed=2, and r=7
Then
$Seed_2(0) = 0$

$Seed_2(1) = 1$

$Seed_2(2) = 0$

.
.
.
$Seed_2(6) = 0$

Therefore,
D(0) = Seed (0) = 0

2

D(-1) = $Seed_2$(1) = 1

D(-2) = $Seed_2$(2) = 0

.
.
.

D(-6) = $Seed_2$(6) = 0

4. The binary feedback coefficients are specified by Taps, which is a list of feedback coefficients. The coefficients are specified by listing the locations where the feedback coefficients equal 1. For example, the recurrence relation
D(n) = (D(n-7) + D(n-3) + D(n-2) + D(n-1))mod 2
is specified by the list [7, 3, 2, 1].
The following* is an extensive list of feedback coefficients for linear feedback shift registers showing one or more alternate feedback connections for a given number of stages.

Number	**Code Length**	**Maximal Taps**
2	3	[2, 1]
3	7	[3, 1]
4	15	[4, 1]
5	31	[5, 2] [5, 4, 3, 2] [5, 4, 2, 1]
6	63	[6, 1] [6, 5, 2, 1,] [6, 5, 3, 2,]
7	127	[7, 1] [7, 3] [7, 3, 2, 1,] [7, 4, 3, 2,] [7, 6, 4, 2] [7, 6, 3, 1] [7, 6, 5, 2]
8	255	[8, 4, 3, 2] [8, 6, 5, 3] [8, 6, 5, 2] [8, 5, 3, 1] [8, 6, 5, 1] [8, 7, 6, 1]
9	511	[9, 4] [9, 6, 4, 3] [9, 8, 5, 4] [9, 8, 4, 1] [9, 5, 3, 2] [9, 8, 6, 5] [9, 8, 7, 2]
10	1023	[10, 3] [10, 8, 3, 2] [10, 4, 3, 1] [10, 8, 5, 1][10, 8, 5, 4] [10, 9, 4, 1]
11	2047	[11, 1] [11, 8, 5, 2] [11, 7, 3, 2] [11, 5, 3, 5] [11, 10, 3, 2] [11, 6, 5, 1]
12	4095	[12, 6, 4, 1] [12, 9, 3, 2] [12, 11, 10, 5, 2, 1] [12, 11, 6, 4, 2, 1]
13	8191	[13, 4, 3, 1] [13, 10, 9, 7, 5, 4] [13, 11, 8, 7, 4, 1] [13, 12, 8, 7, 6, 5]
14	16,383	[14, 12, 2, 1] [14, 13, 4, 2] [14, 13, 11, 9] [14, 10, 6, 1] [14, 11, 6, 1]
15	32,767	[15, 13, 10, 9] [15, 13, 10, 1] [15, 14, 9, 2] [15, 1] [15, 9, 4, 1] [15, 12, 3, 1] [15, 10, 5, 4] [15, 10, 5, 4, 3, 2] [15, 11, 7, 6, 2, 1] [15, 7, 6, 3, 2, 1][15, 10, 9, 8, 5, 3] [15, 12, 5, 4, 3, 2] [15, 10, 9, 7, 5, 3] [15, 13, 12, 10] [15, 13, 10, 2] [15, 12, 9, 1] [15, 14, 12, 2] [15, 13, 9, 6] [15, 7, 4, 1] [15, 4] [15, 13, 7, 4]
16	65,535	[16, 12, 3, 1] [16, 12, 9, 6] [16, 9, 4, 3] [16, 12, 7, 2] [16, 10, 7, 6] [16, 15, 7, 2] [16, 9, 5, 2] [16, 13, 9, 6] [16, 15, 4, 2] [16, 15, 9, 4]
17	131,071	[17, 3] [17, 3, 2] [17, 7, 4, 3] [17, 16, 3, 1] [17, 12, 6, 3, 2, 1] [17, 8, 7, 6, 4, 3] [17, 11, 8, 6, 4, 2] [17, 9, 8, 6, 4, 1] [17, 16, 14, 10, 3, 2] [17, 12, 11, 8, 5, 2]
18	262,143	[18, 7] [18, 10, 7, 5] [18, 13, 11, 9, 8, 7, 6, 3] [18, 17, 16, 15, 10, 9, 8, 7] [18, 15, 12, 11, 9, 8, 7, 6]
19	524,287	[19, 5, 2, 1] [19, 13, 8, 5, 4, 3] [19, 12, 10, 9, 7, 3] [19, 17, 15, 14, 13, 12, 6, 1] [19, 17, 15, 14, 13, 9, 8, 4, 2, 1] [19, 16, 13, 11, 19, 9, 4, 1] [19, 9, 8, 7, 6, 3] [19, 16, 15, 13, 12, 9, 5, 4, 2, 1] [19, 18, 15, 14, 11, 10, 8, 5, 3, 2] [19, 18, 17, 16, 12, 7, 6, 5, 3, 1]

20	1, 048,575	[20, 3] [20, 9, 5, 3] [20, 19, 4, 3] [20, 11, 8, 6, 3, 2] [20, 17, 14, 10, 7, 4, 3, 2]
21	2,097,151	[21, 2] [21, 14, 7, 2] [21, 13, 5, 2] [21, 14, 7, 6, 3, 2] [21, 8, 7, 4, 3, 2] [21, 10, 6, 4, 3, 2] [21, 15, 10, 9, 5, 4, 3, 2] [21, 14, 12, 7, 6, 4, 3, 2] [21, 20, 19, 18, 5, 4, 3, 2]
22	4,194,303	[22,1] [22, 9, 5, 1] [22, 20, 18, 16,6, 4, 2, 1] [22, 19, 16, 13, 10, 7, 4, 1] [22, 17, 9, 7, 2, 1] [22, 17, 13, 12, 8, 7, 2, 1] [22, 14, 13, 12, 7, 3, 2, 1]
23	8,388,607	[23, 5] [23, 17, 11, 5] [23, 5, 4, 1] [23, 12, 5, 4] [23, 21, 7, 5] [23, 16, 13, 6, 5, 3] [23, 11, 10, 7, 6, 5] [23, 15, 10, 9, 7, 5, 4, 3] [23, 17, 11, 9, 8, 5, 4, 1] [23, 18, 16, 13, 11, 8, 5, 2]
24	16,777,215	[24, 7, 2] [24, 4, 3, 1] [24, 22, 20, 18, 16, 14, 11, 9, 8, 7, 5, 4] [24, 21, 19, 18, 17, 16, 15, 14, 13, 10, 9, 5, 4, 1]
25	33,554, 431	[25, 3] [25, 3, 2, 1] [25, 20, 5, 3] [25, 12, 5, 4] [25, 17, 10, 3, 2, 1] [25, 23, 21, 19, 9, 7, 5, 3] [25, 18, 12, 11, 6, 5, 4] [25, 20, 16, 11, 5, 3, 2, 1] [25, 12, 11, 8, 7, 6, 4, 3]
26	67,108,863	[26, 6, 2, 1] [26, 22, 21, 16, 12, 11, 10, 8, 5, 4, 3, 1]
27	134,217,727	[27, 5, 2, 1] [27, 18, 11, 10, 9, 5, 4, 3]
28	268,435,455	[28, 3] [28, 13, 11, 9, 5, 3] [28, 22, 11, 10, 4, 3] [28, 24, 20, 16, 12, 8, 4, 3, 2, 1]
29	536,870,911	[29, 2] [29, 20, 11, 2] [29, 13, 7, 2] [29, 21, 5, 2] [29, 26, 5, 2] [29, 19, 16, 6, 3, 2] [29, 18, 14, 6, 3, 2]
30	1,073,741,823	[30, 23, 2, 1] [30, 6, 4, 1] [30, 24, 20, 16, 14, 13, 11, 7, 2, 1]
31	2,147,483,646	[31, 29, 21, 17] [31, 28, 19, 15] [31, 3] [31, 3, 2, 1] [31, 13, 8, 3] [31, 21, 12, 3, 2, 1] [31, 20, 18, 7, 5, 3] [31, 30, 29, 25] [31, 28, 24, 10] [31, 20, 15, 5, 4, 3] [31, 16, 8, 4, 3, 2]
32	4,294,967,295	[32, 22, 2, 1] [32, 7, 5, 3, 2, 1] [32, 28, 19, 18, 16, 14, 11, 10, 9, 6, 5, 1]
33	8,589,934,591	[33, 13] [33, 22, 13, 11] [33, 26, 14, 10] [33, 6, 4, 1] [33, 22, 16, 13, 11, 8]
61	2, 305, 843, 009, 213, 693, 951	[61, 5, 2, 1]
89	618, 970, 019, 642, 690, 137, 449, 562, 112	[89, 6, 5, 3]

*Reprinted by permission of John Wiley & Sons. From Spread Spectrum Systems, 2nd edition, p. 87, Robert C. Dixon. Copyright © 1984 by John Wiley & Sons, Inc.

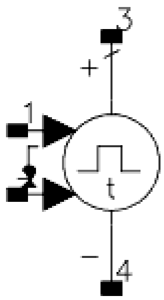
5. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	**Description**	**Units**
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtOneShot (Voltage Source, Retriggerable Pulse Train)

Symbol



Parameters

Name	Description	Units	Default
Delay	time delay from trigger to pulse starts	None	timestep
Width	pulse width	None	5*timestep
Vhigh	pulse voltage	V	5

Notes/Equations

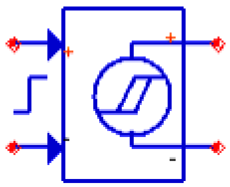
1. This source is implemented in FDD for use with transient and envelope simulations. The retriggerable one-shot is a predefined application of the retriggerable source VtRetrig. It outputs a pulse of amplitude Vhigh and specified width and delay after every trigger event. Due to the trigger delay of 1 to 2 time steps, the actual pulse width will be shorter than specified by this same amount, if the one-shot delay is specified to be less than 1 time step.
2. The trigger input is an infinite impedance, differential input. A trigger event occurs whenever the baseband voltage difference across the two inputs passes through 0.5V with a positive slope. The output impedance is fixed at 50 ohms.
3. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtPRBS (Time-domain Pseudo-Random Bit Sequence Voltage Source)

Symbol



Parameters

Name	Description	Units	Range of Usage	Default
Mode	Source of digital input		[Enumerated, see Note 2]	[Maximal Length LFSR]
RegisterLength	Length of internal LFSR to be used for maximal length sequence		[2, 32]	8
Taps	User-defined taps for internal LFSR for generic binary sequence		String of [2, 32] bits	"10001110"
Seed	User-defined seed for internal LFSR for generic binary sequence		String of [2, 32] bits	"10101010"
BitSequence	Parametric bit sequence		String of bits	"10101010"
BitFile	ASCII file containing bit sequence		[See Note 4]	""
Trigger	Source of trigger signal used to time data output		[Enumerated, see Note 4]	[Internal]
VtriggerThreshold	Threshold voltage for detecting external trigger	V	(-inf, inf)	0.5 V
TriggerEdge	Edge sensitivity at trigger input		[Enumerated, see Note 3]	[Rising and Falling Edges]
Vlow	Lowest voltage of dynamic range	V	(-inf, inf)	0.0 V
Vhigh	Highest voltage of dynamic range	V	(-inf, inf)	1.0 V
Rout	Output resistance	Ohm	[0, inf]	50 Ohm
PAMencoding	Encoding scheme for pulse amplitude modulation		[Enumerated, see Note 6]	[Binary Little Endian]
PAMlevels	Number of waveform levels for pulse amplitude modulation		[2:2048]	2
EnableDeEmphasis	Flag for enabling de-emphasis feature		TRUE or FALSE	TRUE
DeEmphasisMode	De-emphasis specification unit		[Enumerated, see Note 7]	[Percent reduction]
DeEmphasis	De-emphasized dynamic range relative to peak dynamic range		[0, 99.999%]	0.0
DeEmphasisTaps	Number of de-emphasis taps		[1, inf)	1
EmphasisSpan	Rational multiple of bit interval used for emphasis		[0, 32] †	0.0
EdgeShape	Analytical edge shape during level		[Enumerated, see	[Linear transition]

	transitions		Note 8]	
BitRate	Clock rate of generated bit stream	Hz	[0, inf) †	1 GHz
RiseTime	Duration of transition from any relatively lower to higher level	sec	[0, inf) †	10 psec
FallTime	Duration of transition from any relatively higher to lower level	sec	[0, inf) †	10 psec
TransitReference	Transition reference as a percentage of relative dynamic range		[Enumerated, see Note 10]	[0% - 100%]
Delay	Initial time delay	sec	[0, inf)	0 psec
EnableRJ	Flag for enabling random jitter		TRUE or FALSE	TRUE
RJrms	Standard deviation of random jitter	sec	[0, inf) †	0.0 sec
RJbw	Bandwidth for measurement of random jitter	Hz	[0, inf) †	1 THz
EnablePJ	Flag for enabling periodic jitter		TRUE or FALSE	TRUE
PJwave[]	Wave shape of mode p of periodic jitter, p = {1,2,3}		[Enumerated, see Note 11]	[Sinusoid]
PJamp[]	Amplitude of mode p of periodic jitter, p = {1,2,3}	sec	[0, inf) †	0.0 sec
PJfreq[]	Frequency of mode p of periodic jitter, p = {1,2,3}	Hz	[0, inf)	100 MHz

† Refer to Note 12 for explanation of how all user values for timing parameters are used to determine feasibility of operation.

Notes / Equations

1. The time-domain pseudo-random bit sequence voltage source, VtPRBS, is capable of generating waveforms distorted along amplitude and time axes, to represent realistic binary signals at an arbitrary point in a communication system. It is assumed that the user is sufficiently knowledegable about the transmission conditions present at the point of interest to describe distortions of the waveform using various amplitude and timing parameters of this source.
2. Digital information may be supplied independently to a VtPRBS instance in one of four possible Modes. Regardless of *Mode* or length of digital information supplied, the data is repeated as often as necessary to complete time domain simulation. The parameters for data entry in each mode are described in the following table.

Mode	**Active Parameters**	**Comment**
Maximal Length LFSR	RegisterLength	Maximal length pseudo random sequence for an x-bit register is 2^x-1 bits long. The Taps and Seed settings are automatically generated within the source for any value of register length between 2 and 32 bits.
User Defined LFSR	Taps	Uses the shorter of these two bit strings to estimate LFSR length.
Explicit Bit Sequence	BitSequence	Arbitrary number of bits may be specified by manually editing the bit string. Internally up to 2^{32}-1 bits are supported before the bit sequence is repeated.
Bit File	BitFile	File(s) should be in ASCII format with '!' character used to mark comment lines. See Note 4 for details.

3. For Maximal Length LFSR mode, seed is fixed value depending on Register length.
4. Each of the four above modes may be operated either using an internal clock which

operates at *BitRate* with or without jitter or using an external voltage trigger supplied across the inputs of this component. The *VtriggerThreshold* parameter is used to specify the voltage level across which externally received zeroes and ones can be distringuished from each other. When the *Trigger* parameter is set to [External] mode, the *TriggerEdge* parameter can be used to set edge sensitivity of threshold detection. In addition to the eight effective modes of operation created by combination of [Internal] and [External] trigger types and the four independent modes of data entry, a ninth mode of operation can be invoked by setting the *Trigger* parameter to [Copy External Data]. In this case, the data assignment to *Mode* parameter is ignored and the component imitates the data sequence arriving at the external trigger inputs, modifying the waveform and transition times to its own internal settings. When copying external data both rising and falling edges of the trigger signal are detected and therefore the setting of *TriggerEdge* parameter is ignored. Neither jitter nor de-emphasis features are enabled when external trigger is either used to clock indedendent data or copy data to the output. The reason for this restriction is because under external trigger, there bit interval durations are not fixed and therefore variation in emphasis span, which is required for de-emphasis or variation of transition times, which is required for jitter, cannot be defined.

5. When specifying digital information in the ASCII file format, ensure that comment lines are preceded by the '!' character. Valid binary data is read from uncommented lines or sections of lines until a comment or end of line character is encountered. If multiple bit files need to be accessed in succession, do the following:
   1. Place all files in the data subdirectory of current ADS workspace. In this example, we use 3 separate files listed below. Note that no format-specific extention is required
   2. Using the keyword "dscrdata" for discrete data, create an ASCII database file e.g. PRBS.files in the data subdirectory as shown.

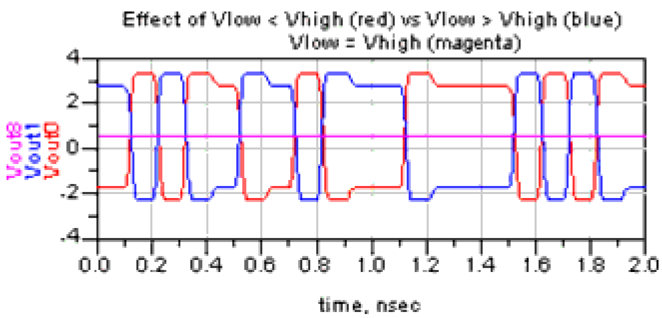
```
BEGIN dscrdata
% Filenumber Filename
1 prbs1.txt
2 myprbs.file
3 your_arbitrary_bitfile.ext
END dscrdata
```

1.

- Place a DataAccessComponent (DAC) on the schematic. Ensure that its File = "PRBS.files" Type = [Discrete], InterpMode = [Index Lookup], iVar = 1, iVal = <fileIndex>. Ignore settings of all other parameters such as *ExtrapMode* or *InterpDom*.
- Introduce a VAR component and create a variable called *fileIndex*, setting it to non-negative number between 0 and 2 (since there are 3 files).
- Place a VtPRBS instance on the schematic, choose *Mode* = [Bit File], and open the dialog box for the *BitFile* parameter. Select [File Based Parameter] from the Parameter Entry Mode list and assign / select the DAC instance introduced in step 3 above. Specify dependent parameter Name to be "Filename" in this case because that is the header information in the database file "PRBS.files".
- Use a ParamSweep component to sweep the *fileIndex* from 0 through 2 in steps of 1. This should generate successive output streams from the VtPRBS instance from the three bit files.

The peak dynamic range of the waveform is to be specified using the highest and lowest voltage levels achieved by the source using *Vhigh* and *Vlow* parameters. If *Vlow* is specified to be higher in value than *Vhigh*, bit inversion will occur. When both are set to the same value, the output is a flat line at that value as shown in the following image.

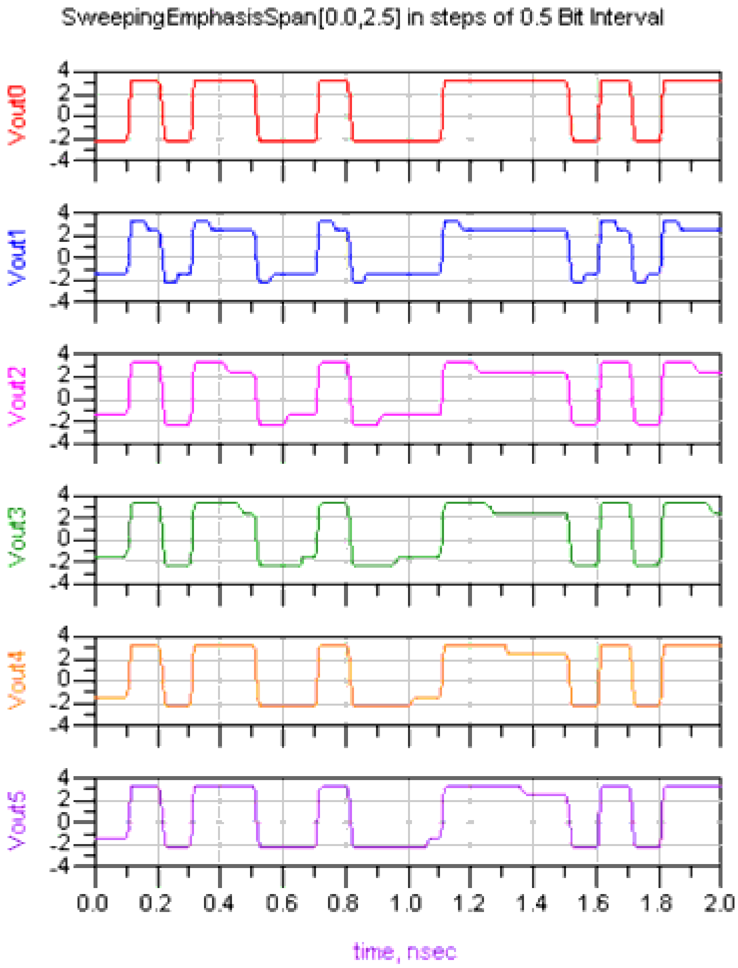
Peak values determine digital content of bit stream



Rout, the output resistance of this source can be varied from zero towards positive values. When *Rout* is set to zero, it operates as a pure voltage source. When non-zero, the resistance appears in series with the specified voltage levels.

VtPRBS allows reduction of dynamic range after a sufficient amount of time has lapsed over repeated sequence of '1's or '0's. This feature is known as de-emphasis and the full functionality is specified using the parameters *DeEmphasisMode*, *DeEmphasis*, *DeEmphasisTaps* and *EmphasisSpan* if *EnableDeEmphasis* is active.

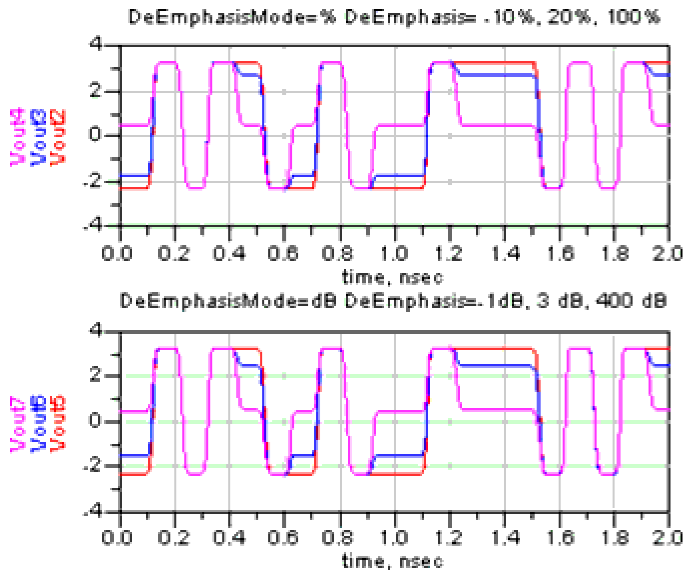
Effect of increasing *EmphasisSpan* on the bit stream "01011001000111101011"



DeEmphasisMode can be set to [Percent reduction] or to [dB Loss], both signifying decrease in steady or shelf dynamic range relative to peak dynamic range as follows:

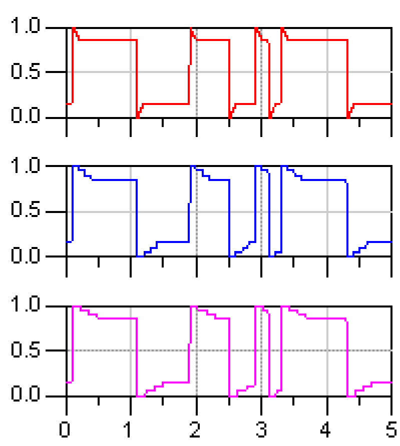
- For [Percent reduction], *DeEmphasis* = 100 * (1.0 - (*VhighShelf* - *VlowShelf*)/(*Vhigh* - *Vlow*))
- For [dB Loss], *DeEmphasis* = 20 * log10 ((*Vhigh* - *Vlow*)/(*VhighShelf* - *VlowShelf*))
  Using supplied numeric value of *DeEmphasis*, *Vlow* and *Vhigh*, *VhighShelf* and *VlowShelf* are computed internally, and applied after the duration of *EmphasisSpan* has passed following the start of a level transition. Note that *EmphasisSpan* is a non-negative real number specifying the rational multiple of bit intervals that the waveform must be held at peak value before de-emphasis is permitted. Bit interval is internally defined as the reciprocal of *BitRate* parameter. If there is a data change within this duration, the level transition is from peak to peak. In the following image, *DeEmphasisMode* = [Percent reduction], *DeEmphasis* = 30 % and *EmphasisSpan* = swept {0.0:0.5:2.5} bit intervals.
  The lowest value of *DeEmphasis*, whether expressed as [Percent reduction] or as [dB Loss] of dynamic range, is zero, which amounts to no reduction in peak levels. The highest value of de-emphasis is just under 100%, at which point *VhighShelf* and *VlowShelf* meet at the same voltage value. Warnings will be issued if either limit is exceeded. Note that when *DeEmphasisMode* is set to [dB Loss], theoretically there is no upper limit to achieve 100% de-emphasis.

Effect of varying DeEmphasis in each DeEmphasisMode



DeEmphasisTaps are used to regulate the maximum number of de-emphasis levels achieved for sustained sequences of 0s or 1s. The number of levels that can be physically accomodated in equal increments or decrements from peak values to zero-crossing, determines the actual number of taps implemented. Each span of peak level and tap-level is governed by *EmphasisSpan*. If the last possible tap level is reached, then this level is sustained until a logic transition is achieved. Multi-tap de-emphasis should not be confused with pulse amplitude modulation (PAM) which is explained in Note x. In the following figure, 3-tap de-emphasis is achieved for *EmphasisSpan*s of 0.3, 1.0 and 1.3 bit intervals respectively.

Effect of DeEmphasisTaps=3 for various settings of EmphasisSpan



The *EdgeShape* parameter allows the selection of standard analytical functions for defining the waveform during transitions between any two voltage levels. Supported values are [Linear transition], [Raised Cosine transition] and [Error Function transition].
VtPRBS supports the generation of pulse amplitude modulated signals in one of four encoding schemes which can be selected using the *PAMencoding* parameter. The number of waveform levels selected for PAM can be set to any value N, where 2 < N <= 2048 at

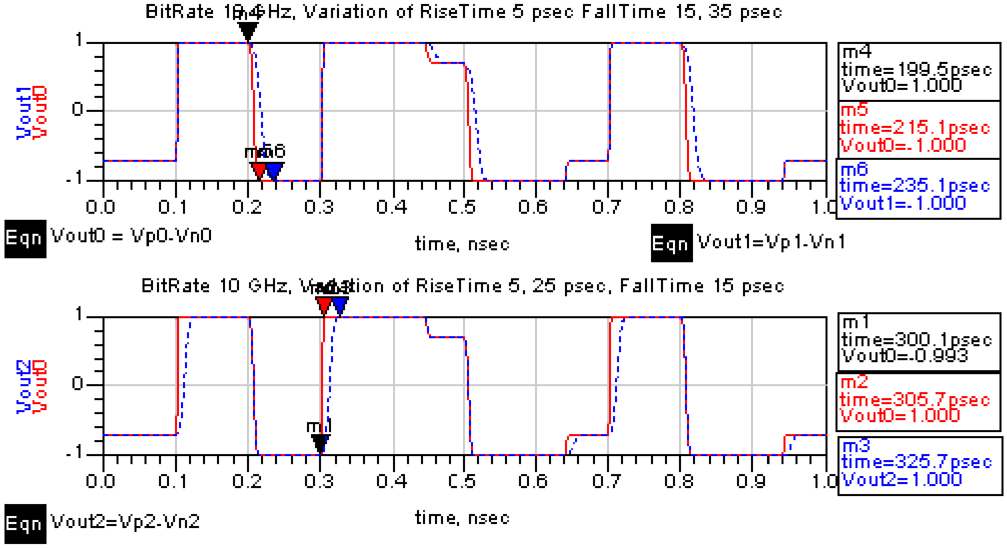
the *PAMlevels* parameter. This number is internally rounded up to the next higher power of 2. PAM is operational only when *Trigger* is set to [Internal]. During PAM activity, de-emphasis and jitter generation features are suspended. Big-endian encoding assumes that the most significant bit of a M-bit (2,sup>M</sup> = N-ary coding) sequence is presented first, and vice versa for little endian. Thus in 3-bit or 8-ary PAM, the bit string "110101100" would represent the decimal levels "6,5,4" for big-endian representation because the first level is read as "110" which is "6" and the decimal numbers "3,5,1" in the little-endian one because the first level is read as "011" which is 3. Likewise "100" is read as "4" in big-endian but as "1" in little-endian. As opposed to binary encoding, Gray encoding ensures that consequtive numbers within the N-ary digital space, vary only by 1 bit. The relationship between binary and gray encoding is established for the decimal number 4, as shown in Figure 9 for big-endian 8-ary codes. Thus, the sequence "100" would be interpreted as the 4th level of big-endian binary PAM but as 7th level of big-endian Gray 8-ary PAM. In little-endian convention, this string would represent the 1st level of both binary and Gray encoded 8-ary PAM.

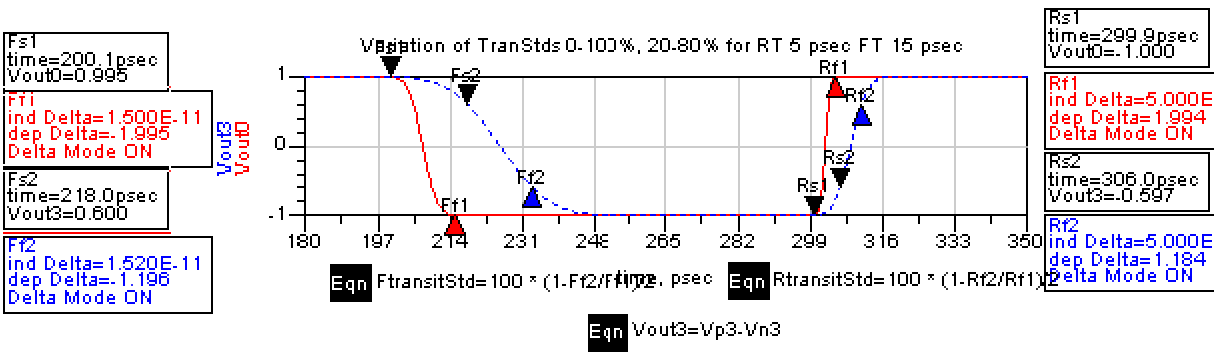
Decimal	Big Endian Binary	Little Endian Binary	Big Endian Gray	Little Endian Gray
0	000	000	000	000
1	001	100	001	100
2	010	010	011	110
3	011	110	010	010
4	100	001	110	011
5	101	101	111	111
6	110	011	101	101
7	111	111	100	001

BitRate is the inverse of the duration of the average bit interval, expressed in Hz which is equivalent to bits / second. Note that actual bit intervals may vary from one data bit to another when jitter effects are injected into the source.

Rise and fall times are applied uniformly across all level changes as appropriate, and interpreted subject to the setting of *TransitReference*. With the default definition of transition reference as [0%-100%] the value assigned to the *RiseTime* parameter applies exactly to level changes from *Vlow* to *Vshelf* during de-emphasis while '0's are active and *Vlow* to *Vhigh* during data transition. Similarly, the *FallTime* parameter applies exactly to level changes from *Vhigh* to *VhighShelf* during de-emphasis while '1's are active and *Vhigh* to *Vlow* during a '1' to '0' transition. When *TransitReference* of [20%-80%] is selected, the supplied rise and fall times are interpreted to mean the duration spent by the waveform traversing between 20% through 80% of the upward range or between 80% through 20% of the downward range respectively. The following image shows how varying only *RiseTime*, only *FallTime* and only *TransitReference* changes the waveform along the time axis. The *TransitReference* parameter works in conjunction with the *EdgeShape* parameter to determine the effective transition span as shown in the images that follow.

Effect of *RiseTime*, *FallTime* and *TransitReference* on waveform.





FtransitStd	RtransitStd
20.018	20.319

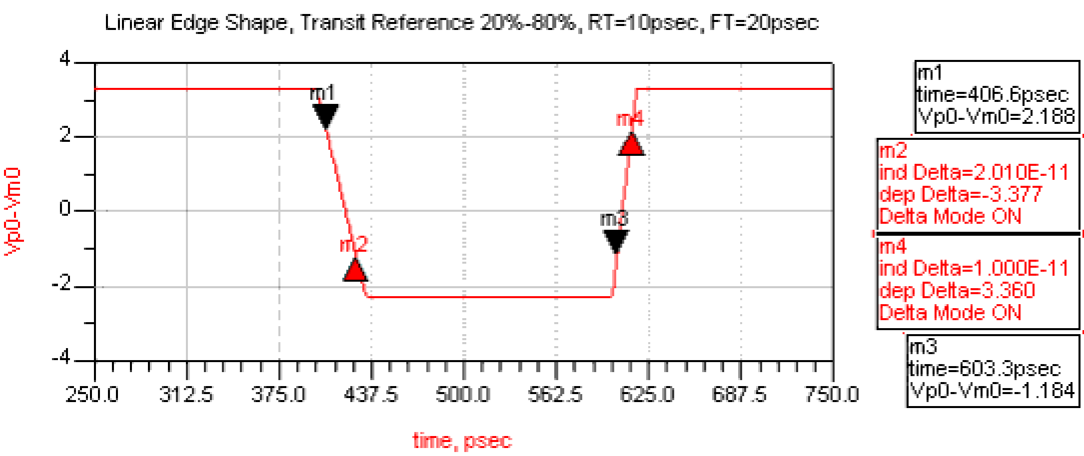
Effective rise and fall times vary based on *EdgeShape* for identical *RiseTime, FallTime* and *TransitReference* settings.

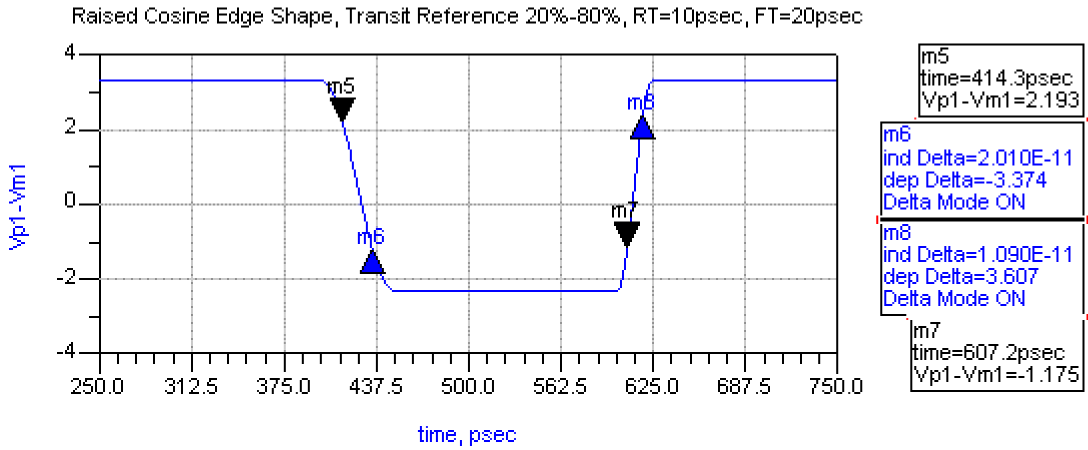
Eqn VpeakRange=3.3-(-2.3)

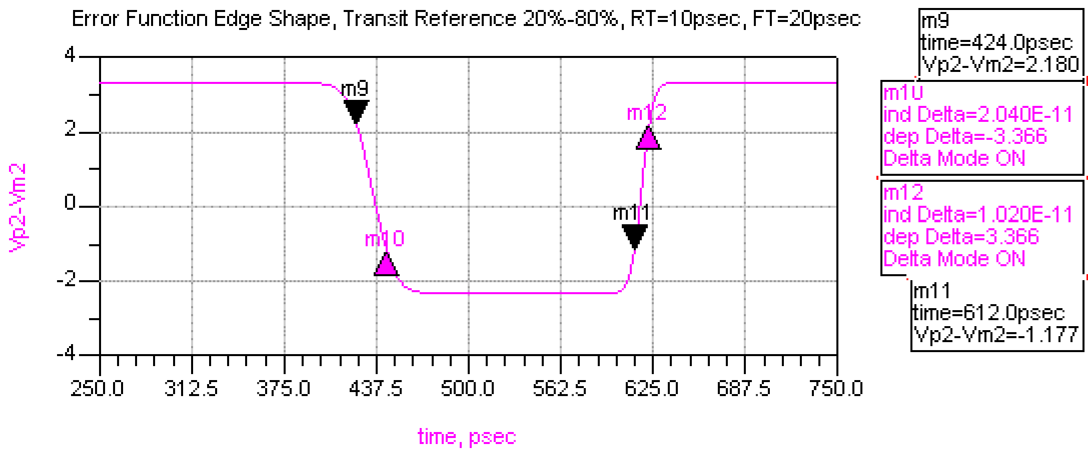
Eqn V80p=0.8 * VpeakRange + (-2.3)

Eqn V20p=0.2 * VpeakRange + (-2.3)

V80p	V20p
2.180	-1.180

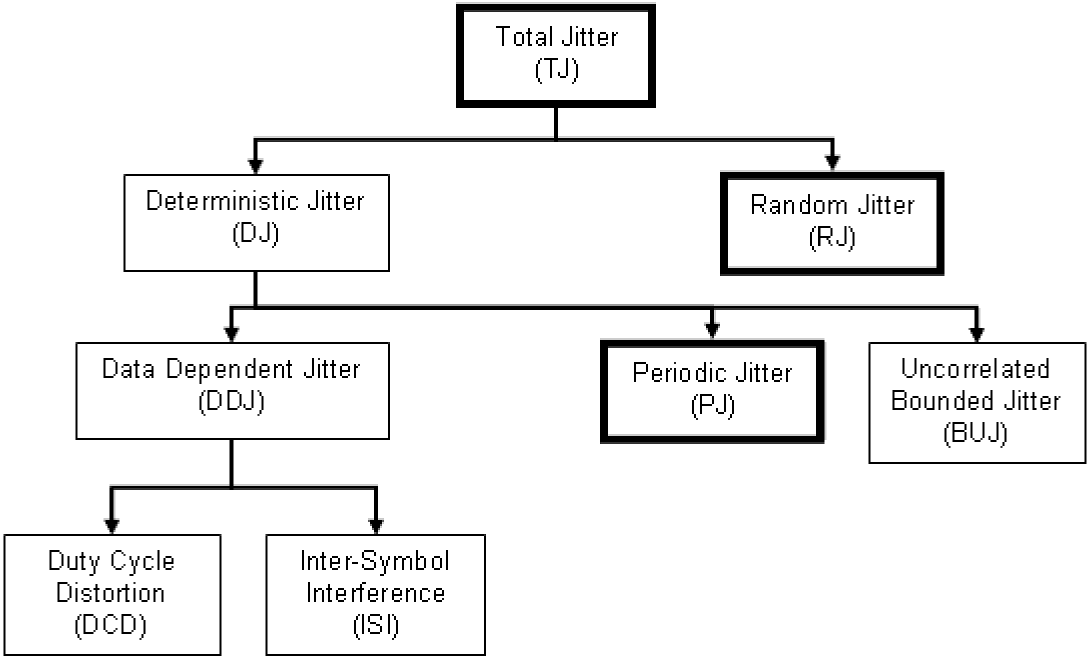






Jitter is defined as the deviation along time axis of the actual bit interval boundary from the expected time point when one data bit is followed by the next. It is most easily observed during '0' to '1' or '1' to '0' transitions using an eye diagram when successive waveforms are overlaid on each other over one expected bit interval. Given sufficient number of '0's and '1's detection of jitter can be simplified to observation of the histogram distribution of waveform points at the zero-crossing between the binary states.
VtPRBS supports two classes of jitter, both of which are independent of data content produced by the source, namely *Random Jitter* and *Periodic Jitter*. The hierarchy of conventional jitter description is shown in the following image.

Conventional classification of jitter in digital waveforms. VtPRBS features only Random and Periodic Jitter.



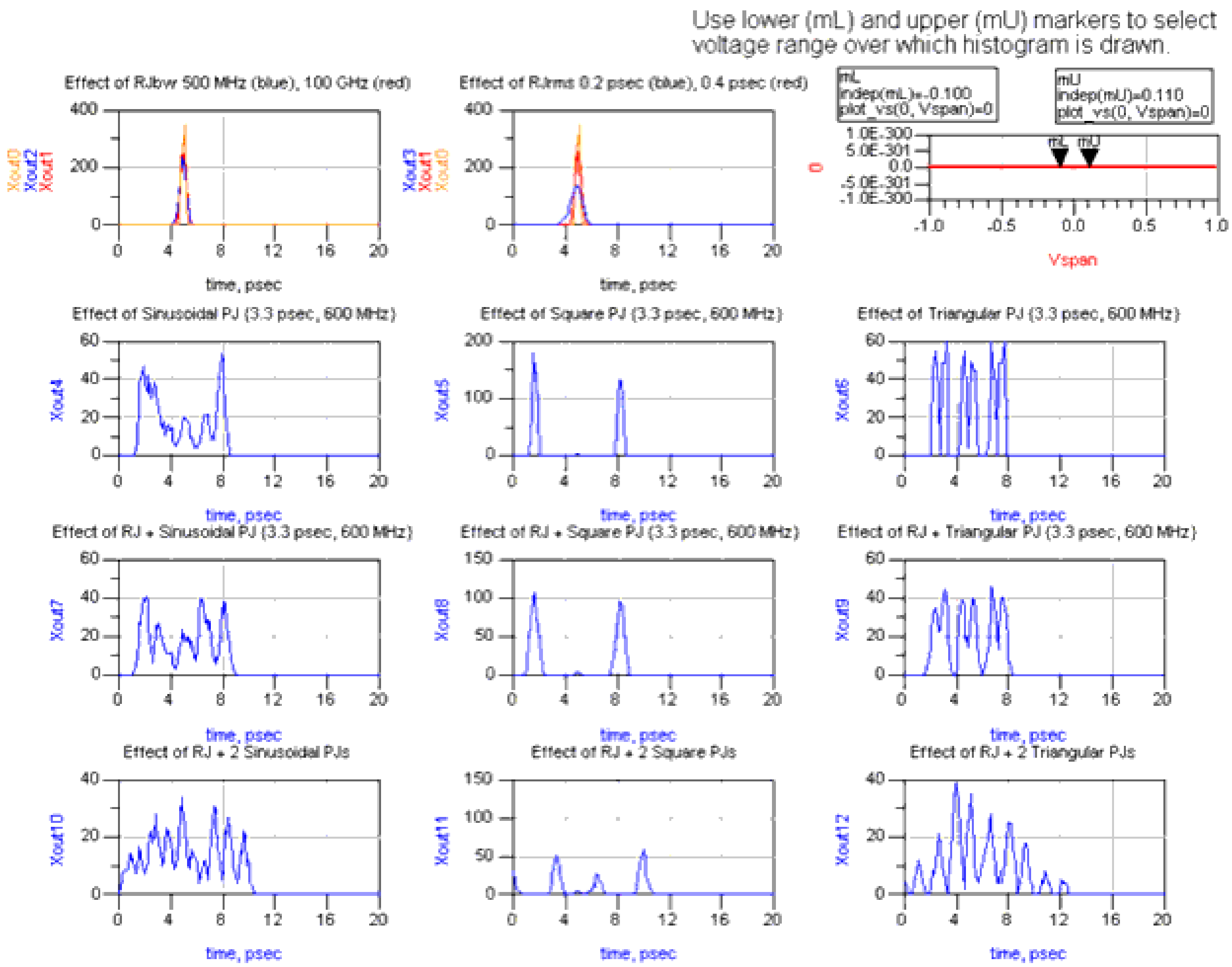
Random Jitter is defined as timing disturbances that occur as the result of device noise and flicker effects in the transmission hardware. It is defined as a unimodal Gaussian distribution with a mean of zero and standard deviation of RJrms along the time axis. The modeling of such jitter is made feasible by bounding it using the measurement bandwidth parameter *RJbw*. By default VtPRBS sets *RJrms* to zero implying no jitter and *RJbw* to 1 THz, which is equivalent to unbounded measurement. When setting finite values of random jitter, ensure that the unit of *RJrms* is compatible with *BitRate* and rise and fall times. Also apply appropriate measurement bandwidth via *RJbw* if this quantity is known.
Periodic Jitter is defined as timing disturbance that occurs as a result of Electro-Magnetic Interference (EMI) from switching on and off of power supplies. It results in deviation of the bit transition boundary in a periodic fashion where the amplitude of the variation occurs along the time axis and is denoted by *PJamp*. The frequency of variation, which is unrelated to the *BitRate* of the digital signal, is denoted by *PJfreq*.
Three variations of periodic waveforms are supported in contemporary jitter injection and measurement instruments, namely, [Sinusoid], [Square] and [Triangle]. VtPRBS emulates all three periodic jitter types which can be set via the *PJwave* parameter. Up to three constituent modes may be specified using the *PJamp* and *PJfreq* parameters for any of the three types of *PJwave* shapes.

- Sinusoidal jitter pattern is implemented for fixed amplitude along time axis and fixed frequency which determines the distribution of samples over time but random phase. Consequently, the histogram of a unimodal sinusoidal periodic jitter shows sharp peaks at either end with a shallow valley in the center, described conventionally as the Bathtub-curve. The jitter waveform is described by the following equation. The RMS value of such a waveform is *PJamp[i]*/sqrt(2).
PJsine(i,t)=PJamp(i) *sin(2*PJfreq(i) *t + random_initial_phase) for each i = {1,2,3}
- Square jitter pattern is purely deterministic where jitter samples are deposited only at either extremity of the histogram, corresponding to positive and negative levels of the waveform. Random initial starting point is assigned to the basic square waveform described by the following equation. The RMS value of such a waveform is *PJamp[i]*.
PJsquare(i,t)= -PJamp(i) for 0 <= t < 0.5/PJfreq(i) for each i = {1,2,3}

PJamp(i) for 0.5/PJfreq(i) <= t < 1/PJfreq(i)

- Triangle jitter pattern, which is also purely deterministic allows a multimodal yet somewhat uniform distribution of samples throughout the jitter interval. *PJtriangle* (i,j) distributes samples evenly along a balanced sawtooth wave that traverses between -/+ *PJamp*(i) with frequency of *PJfreq*(i) for one or more i = {1,2,3}. Random initial starting point is assigned to the basic triangular waveform. The RMS value of such a wave form is *PJamp[i]*/sqrt(3).
  Random Jitter may be combined with one or more modes of any one type of Periodic Jitter to devise timing uncertainties with various distributions. Some examples are shown in the following image.

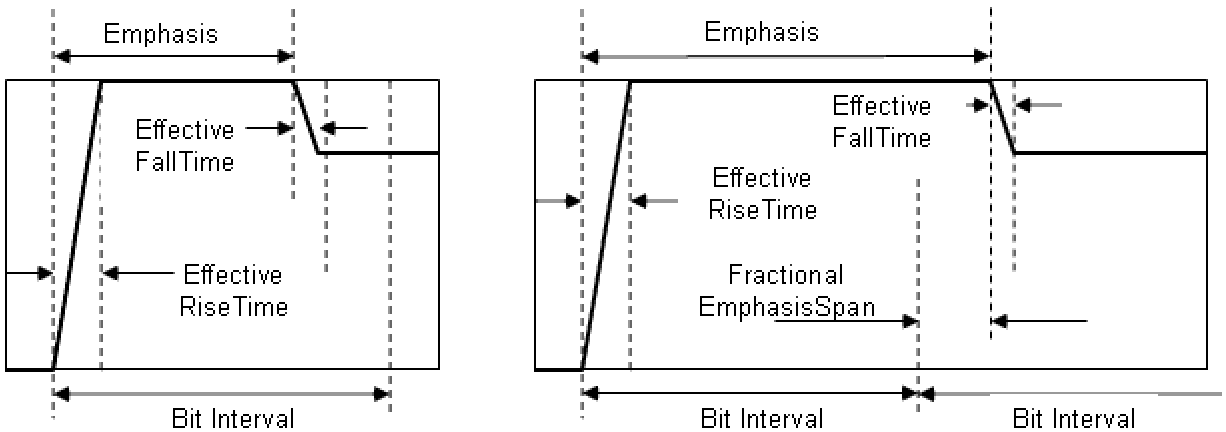
Combination of Random and Periodic Jitters of various types and modes produce histograms representing different timing aberrations in VtPRBS.



The feasibility of simulating a waveform given *BitRate* , *DeEmphsisTaps*, *EmphasisSpan* , *RiseTime* , *FallTime* , *TransitReference* , *RJrms* and the *PJamp* [] vector deduced based on *EmphasisSpan* as follows:
Case A: DeEmphasisTaps = 1 and 0.0 < *EmphasisSpan* < 1.0 so a single bit has to accommodate both effective rise and fall times as well as the remainder of emphasis duration. Ensure that *EmphasisSpan* is larger than both effective rise and fall times and the sum of *EmphasisSpan* and the larger of effective rise or effective fall times is less than or equal to a bit interval.

Case B: DeEmphasisTaps = 1 and *EmphasisSpan* is zero or else > 1.0 so single bit has to accommodate the longer of effective rise and fall times plus the fractional duration of emphasis.
Case C: DeEmphasisTaps > 1. Ensure that for all feasible levels of de-emphasis taps, transition from one level to another is always contained within a single bit interval. Reject cases where the transition zone crosses a bit boundary because then jitter cannot be applied to such a waveform.
In addition to these restrictions, jitter variability is computed as the maximum of 6-sigma of random jitter and double of all periodic jitter amplitudes. This is added to the most restrictive case from above to arrive at a limit of minimum bit interval necessary to generate the waveform through all possible states and transitions. The reciprocal of this value is maximum supportable bit rate. If supplied *BitRate* is below the maximum value, the simulation is allowed to proceed else it is halted with an error message about maximum supportable bit rate.
Since the concept of *BitRate* does not apply for externally triggered waveforms, it is the user's responsibility to set the trigger interval of the driver source appropriately for deriving meaningful waveforms from this source based on above mentioned cases.

Interdependency of timing parameters in VtPRBS: *BitRate*, *TransitReference*, *RiseTime*, *FallTime*, *DeEmphasisTaps* and *EmphasisSpan* together determine whether the underlying deterministic waveform is feasible or not. This is followed by Jitter based limitations imposed on the maximum permissible *BitRate*.



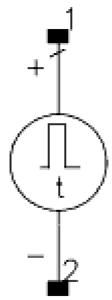
Case A: EmphasisSpan < 1.0 **Case B: EmphasisSpan >= 1.0**

For a comprehensive tutorial on the use model of the VtPRBS, refer to the Examples > SignalIntegrity > VtPRBS_wrk and associated literature.

References

1. IEEE Standards 181 - IEEE Standard on Transitions, Pulses, and Related Waveforms, IEEE Intrumentation and Measurement (I&M) Society, 7 July 2003.
2. Pseudo-Random Number Generation Routine for the MAX765 Microprocessor, Application Note 1743, Maxim Integrated Products Inc., 25 September 2002.
3. Kim, K., Huang, J., Kim, Y. and Lombardi, F., On the Modeling and Analysis of Jitter in ATE Using Matlab, Proceedings of the 2005 20th IEEE International Symposium on Defect and Fault Tolerance in VLSI Engineering (DFT'05), IEEE Computer Society.
4. Ou, N., Farahmand, T., Kuo, A., Tabatabei, S. and Ivanov, A., Jitter Models for the Design and Test of Gbps-Speed Serial Interconnects, IEEE Design & Test of Computers, July-August 2004, pp 302-313.

VtPulse (Voltage Source, Pulse with Linear, Cosine, or Error Function Edge Shape)



Parameters

Name	Description	Units	Default
Vlow	initial voltage	V	0
Vhigh	pulse voltage	V	1
Delay	time delay	nsec	0
Edge	rising and falling edge type: linear, cosine, elf	None	linear
Rise	rise time	nsec	1
Fall	fall time	nsec	1
Width	pulse width	nsec	3
Period	pulse period	nsec	10
SaveCurrent	Flag to save branch current: yes, no	None	yes

Range of Usage

Delay ≥ 0; Rise ≥ 0; Fall ≥ 0
Width > 0
Width + Rise + Fall ≤ Period

Notes/Equations

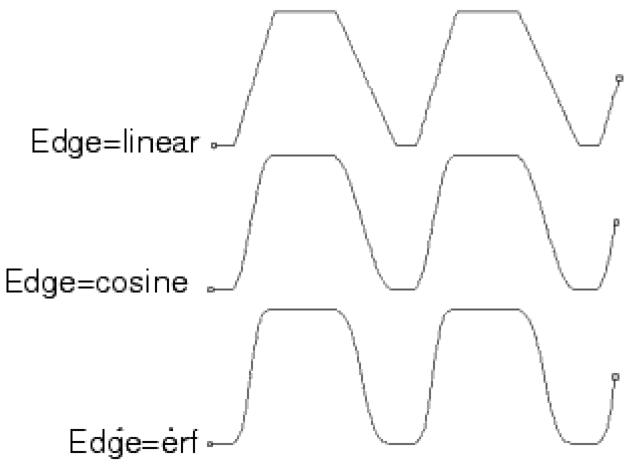
1. This item is a time-periodic rectangular pulse-train voltage source for use with transient and envelope simulation. It is treated as a short circuit in all other simulations.
2. If Rise or Fall = 0, it is replaced by MaxTimeStep from the transient simulation or Step from the envelope simulation.
3. If Edge=linear, the rising and falling edge is a linear ramp. In SPICE, the equivalent to this source is a current or voltage source with the pulse waveform argument

PULSE and its parameters.

Time	Value
0	low
Delay	low
Delay + Rise	high
Delay + Rise + Width	high
Delay + Rise + Width + Fall	low
Period	low

If Edge=erf, instead of the rise and fall portions being linear ramps, this source generates a pulse based on the error function, giving a different shape to the rising and falling edges. By not having abrupt changes in slope, the pulse shape is more realistic and its frequency spectrum decreases more rapidly.

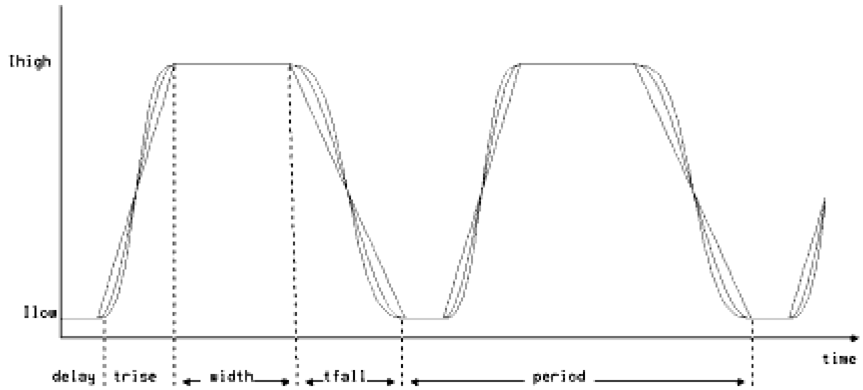
For the error function pulse, the rise and fall time define the total transition period and the maximum slope is greater than (*I_High - I_Low*)/*Rise*. (See ItPulse Waveforms with Different Edges.)



ItPulse Waveforms with Different Edges

This source uses *1-erfc (x)*, (-2 < *x* < 2) to generate the transition region and has a peak slope that is approximately 2.25 times the linear rise time. Due to the faster slope, the 3db bandwidth of the output pulse is larger for a given rise time.

The shape of the waveform is shown in Waveform shape; the intermediate points during rise and fall time are determined by interpolation.



Waveform shape

If Edge=cosine, this source generates cosine-shaped rising and falling edges. By not having abrupt changes in slope, the pulse shape is more realistic and its frequency spectrum decreases more rapidly.
For the cosine pulse, the rise and fall time define the total transition period and the maximum slope is greater than (*I_High-I_Low*)/*Rise*. (See ItPulse Waveforms with Different Edges.)

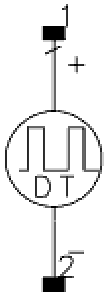
4. *DC Operating Point Information* lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding time domain sources, refer to the *Introduction.* (ccsrc)

VtPulseDT (Voltage Source, Pulse Train Defined at Discrete Time Steps)

Symbol



Parameters

Name	Description	Units	Default
Vlow	initial voltage	V	0
Vhigh	pulse voltage	V	1
Delay	time delay	nsec	0
Width	pulse width	nsec	3
Period	repeat period	nsec	10
Rout	output resistance	Ohm	1

Notes/Equations

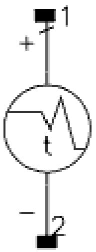
1. This source is used in envelope and transient simulations.
2. Period, Width, and Delay are rounded to the nearest integer multiple of the analysis time step. The pulse width must be an integer number of simulation time steps. The pulse source is in the high state for a time interval equal to Width, during which it has an open circuit output voltage equal to Vhigh. The output impedance is set by Rout.
3. As with the impulse source, Vlow can be set to a voltage more positive than Vhigh in order to generate a negative-going pulse train.
4. The use of a discrete time pulse source, as opposed to a standard pulse source, guarantees that there is no timing jitter in the pulse edges due to the waveform being sampled asynchronously by a fixed time interval simulation. By setting the period, width or delay equal to multiples of the time step variable, the source can be set up to track the analysis time step control, if desired.
5. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtPWL (Voltage Source, Piecewise Linear)

Symbol



Parameters

Name	Description	Units	Default
V_Tran	pwl(time, time-voltage pairs), or pwlr(time, Ncycles, time-voltage pairs)		pwl(time, 0ns,0V, 10ns,1V, 20ns,0V)
SaveCurrent	Flag to save branch current: yes, no	None	yes

Notes/Equations

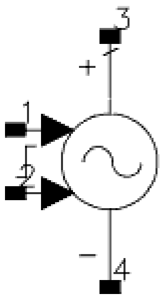
1. The piecewise linear voltage versus time data are specified with a pwl( ) function. The syntax for pwl is pwl(time, T_i, V_i, ...) . Each pair of values (T_i, V_i) specifies that at time=T_i, the voltage is V_i. The value of the source at intermediate values of time is determined by using linear interpolation on the input values.
2. In SPICE, the equivalent to this source is a voltage source with the piecewise linear waveform argument PWL and its parameters.
3. If the piecewise linear waveform is to be repeated for several cycles, a pwlr( ) function can be used. The syntax for pwlr( ) is pwlr(time, N_{cycles}, T_i, V_i, ...) where Ncycles is the number of cycles to be repeated.
4. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtRetrig (Voltage Source, Retriggerable, User-Defined Waveform)

Symbol

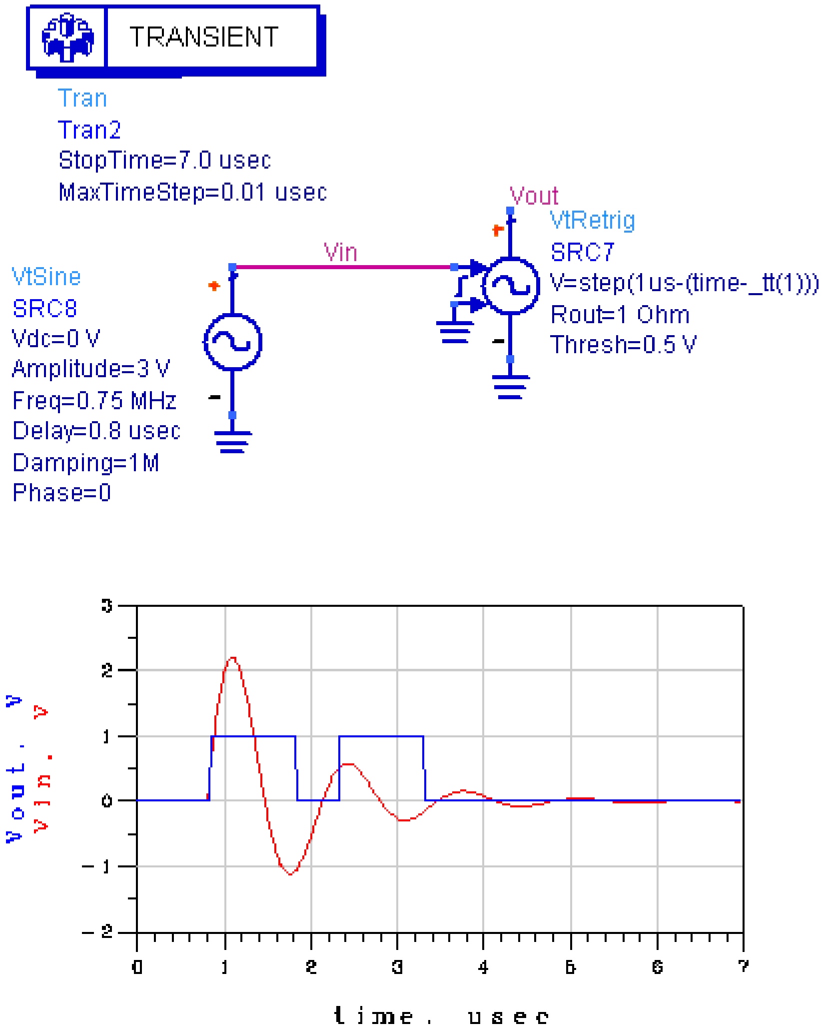


Parameters

Name	Description	Units	Default
V	user-defined waveform equation	None	step(1us-(time-_tt(1)))
Rout	output resistance	Ohm	1
Thresh	trigger threshold on rising edge	V	0.5

Notes/Equations

1. This source is used in envelope and transient simulations.
2. This retriggerable source allows you to use an equation to describe a baseband waveform segment; the waveform segment is then output every time an input trigger occurs. The waveform is typically described in terms of the time since the last trigger event, which is (time - _tt(1)). For example, the default equation simply generates a value equal to 1 until 1 usec after the trigger event. This is seen from V = step(1us - (time -_tt(1))) on the VtRetrig source.
   The following image shows a damped sinusoid input waveform to the trigger. When the damped sine amplitude becomes larger than the threshold of 0.5 V, the trigger output is equal to 1 V for 1 usec, then goes back to 0 V. Any of the time-domain equation capabilities of the simulator can be used to define this waveform, including reading data from a dataset or using a random time variable. The output voltage of the source, prior to any triggers, is 0.0. The output impedance of the source is set by Rout.



Damped sine( ) Waveform

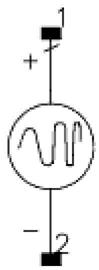
3. The trigger input is an infinite impedance, differential input. The trigger event is determined whenever the baseband voltage difference across the two inputs passes through the trigger threshold voltage with a positive slope. Due to the delay in the trigger detection, the minimum value of (time -_tt(1)) will be between 1 and 2 time steps. There is fixed delay of one time step in addition to the time between the interpolated trigger event and the next simulated time point.
4. Because the trigger input and the output voltage are baseband only signals, this model works equally well in either transient or circuit envelope simulations.
5. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtSFFM (Voltage Source, Single Frequency FM, SFFM Wave)

Symbol



Parameters

Name	Description	Units	Default
Vdc	initial voltage offset	V	0
Amplitude	amplitude of signal	V	1
CarrierFreq	carrier frequency	GHz	1
ModIndex	modulation index	None	0.5
SignalFreq	signal frequency	MHz	1
SaveCurrent	Flag to save branch current: yes, no	None	yes

Notes/Equations

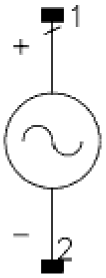
1. In SPICE, the equivalent to this source is a voltage source with the single-frequency FM source waveform argument SFFM and its parameters.
2. The shape of the waveform is described in the following equation.
   Vout = Vdc + Amplitude × sin(2 × π × CarrierFreq × time + ModIndex × sin(2 × π × SignalFreq × time))
3. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

4. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtSine (Voltage Source, Decaying Sine Wave)

Symbol



Parameters

Name	Description	Units	Default
Vdc	initial voltage offset	V	0
Amplitude	amplitude of sinusoidal wave	V	1
Freq	frequency of sinusoidal wave	GHz	1
Delay	time delay	nsec	0
Damping	damping factor	None	0
Phase	phase value	deg	0
SaveCurrent	Flag to save branch current: yes, no	None	no

Range of Usage

Freq > 0
Delay ≥ 0

Notes/Equations

1. In SPICE, the equivalent to this source is a voltage source with the sinusoidal waveform argument sin and its parameters. VtSine defines an ac sinusoidal voltage source, at a specified frequency and phase, including its turn-on characteristics for use with transient analysis.
2. VtSine has a value of [Vdc + Amplitude × sin(phase)] from t=0 until t=delay. Voltage then becomes an exponentially damped sine wave described by

$$V = Vdc + Amplitude \times \sin\left[2\pi\left(Freq(t - Delay) + \frac{Phase}{360}\right)\right]$$
$$\times e^{-(t - Delay) \times Damping}$$

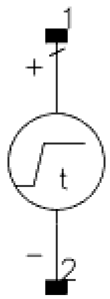
   where t is time.
3. This source can also be used in Harmonic Balance and Circuit Envelope simulations.
4. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

5. For general information regarding time domain sources, refer to the *Introduction* (ccsrc).

VtStep (Voltage Source, Step)

Symbol



Parameters

Name	Description	Units	Default
Vlow	initial voltage	V	0
Vhigh	pulse voltage	V	1
Delay	time delay	nsec	0
Rise	rise time	nsec	1
SaveCurrent	Flag to save branch current: yes, no	None	yes

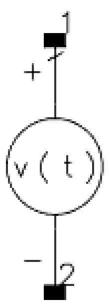
Notes/Equations

1. In SPICE, the equivalent to this source is a voltage source with the step waveform argument STEP and its parameters.
2. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

VtUserDef (Voltage Source, User-Defined)

Symbol



Parameters

Name	Description	Units	Default
V_Tran	transient voltage	None	damped_sin(time)
Vdc	DC voltage		None
Vac	AC voltage	V	1
SaveCurrent	Flag to save branch current: yes, no	None	yes

Notes/Equations

1. Typically, V_Tran is assigned an equation. This equation can be defined as a function of time by using the program reserved variable time in it. As the value of time is swept in transient or envelope simulation, the amplitude of the voltage source will take on the value of the equation.
2. A variable or equation is unitless. However, the value of V_Tran as given by the result of a variable or equation will be assumed to be in volts. The value of *time* will be the current simulation time in seconds.
3. There are several built-in functions that implement the standard SPICE sources, such as pwl and pulse. For a transient analysis, the VtUserDef source voltage is the sum of the value specified in the Vdc and V_Tran parameters.
   Example:
   `vt = pwl (time, 0ns, 0, 1ns, 1, 2ns, -2) X damped_sin (time)`
4. The Vac parameter is used in AC simulations and does not affect transient simulation. An example for specifying magnitude and phase would be Vac=polar(2,45), where 2 is the magnitude and 45 is the phase. For more parameter options (such as frequency) on an AC source, use the V_AC component on the Sources-Freq Domain palette.
5. The following table lists the dc operating point parameters that can be sent to the dataset.

Name	Description	Units
Is	Current	A
Power	DC power dissipated	W
Vs	Voltage	V

6. For general information regarding time domain sources, refer to the *Introduction*

(ccsrc).