Agilent Technologies

Sources

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Agilent Technologies
395 Page Mill Road
Palo Alto, CA 94304 U.S.A.

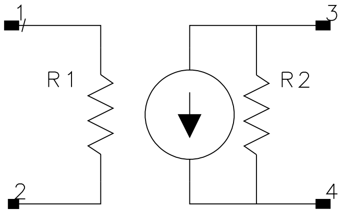
Acknowledgments

Contents

Chapter 1: Sources, Controlled

CCCS (Linear Current-Controlled Current Source)

Symbol



Parameters

G = complex current gain; for example, polar(10,45), or P(j×omega)/Q(j×omega)

R1 = input resistance, in ohms

R2 = output resistance, in ohms

F = frequency at which current gain magnitude is down by 3 dB, in hertz

T = time delay associated with current gain, in seconds

Range of Usage

For ideal current source use the following settings:

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 Nonlinear Devices library.

2. This source is assumed to be noiseless.

3. $\beta(f) = G \times \dfrac{e^{-j(2\pi f T)}}{1 + j(f / F)}$ (for F > 0)

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

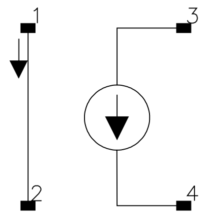
f = simulation frequency in hertz
F = reference frequency in hertz
T = CCCS time delay in seconds
$\beta(f)$ = frequency-dependent current gain

4. For time-domain analysis, the frequency-domain analytical model is used.

5. This source has no default artwork associated with it.

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

Symbol



Parameters

Gain = constant gain term

Num = numerator coefficients of transfer function

Den = denominator coefficients of transfer function

TimeStep = sampling time period

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.

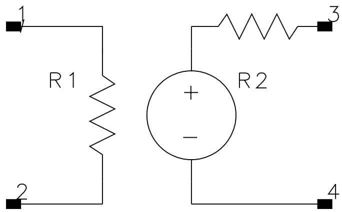
2. The Gain parameter must be a constant and must not depend on frequency. It, and the polynomial coefficients, should not be complex valued.

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

G = complex transresistance; for example, polar(10,45) or P(j×omega)/Q(j×omega)

T = time delay associated with transresistance, in seconds

R1 = input resistance, in ohms

R2 = output resistance, in ohms

F = frequency at which transresistance magnitude is down by 3dB, in hertz

ImpNoncausalLength = non-causal function impulse response order (value type: integer)

ImpMode = convolution mode (value type: integer)

ImpMaxFreq = maximum frequency to which device is evaluated, in hertz

ImpDeltaFreq = sample spacing in frequency, in hertz

ImpMaxOrder = maximum impulse response order (value type: integer)

ImpWindow = smoothing window (value type: integer)

ImpRelTol = relative impulse response truncation factor

ImpAbsTol = absolute impulse response truncation factor

Range of Usage

For ideal current source use the following settings:

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 library.)
2. This source is assumed to be noiseless.
3. $$(f) = G \times \frac{e^{-j(2\pi fT)}}{1 + j(f/F)} \text{ (for F > 0)}$$

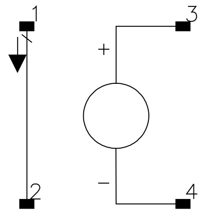
   $$(f) = G \times e^{-j(2\pi fT)} \text{ (for F = 0)}$$

   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

Gain = constant gain term

Num = numerator coefficients of transfer function

Den = denominator coefficients of transfer function

TimeStep = sampling time period

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

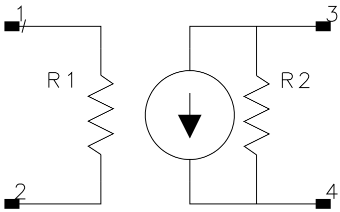
   $$Z21(z) = \frac{Vout(z)}{Iin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$

   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 (Linear Voltage-Controlled Current Source)

Symbol



Parameters

G = complex transconductance; for example, polar(15,45), or P(j×omega)/Q(j×omega)

R1 = input resistance, in ohms

R2 = output resistance, in ohms

F = frequency at which transconductance magnitude is down by 3dB, in hertz

Range of Usage

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 Nonlinear Devices library.

2. This source is assumed to be noiseless.

3. $G(f) = G \times \frac{e^{-j(2\pi fT)}}{1 + j(f / F)}$ (for F0 $\neq$ 0)

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

   where

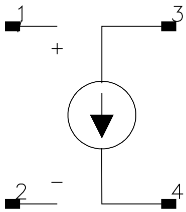
f = simulation frequency in hertz
F = reference frequency in hertz
T = VCCS time delay in seconds
$G(f)$ = frequency-dependent transconductance

4. For time-domain analysis, the frequency-domain analytical model is used.

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

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

Symbol



Parameters

Gain = constant gain term

Num = numerator coefficients of transfer function

Den = denominator coefficients of transfer function

TimeStep = sampling time period

Notes/Equations

1. This model is a voltage source whose output is linearly proportional to its short circuit input current. Similar to the VCCS 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 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

   $$Z21(z) = \frac{Vout(z)}{Iin(z)} = Gain \times \frac{a_0 + a_1 \times z^{-1} + \ldots + a_{M-1} \times z^{M-1} + a_M \times z^{-M}}{b_0 + b_1 \times z^{-1} + \ldots + b_{N-1} \times z^{N-1} + b_N \times z^{-N}}$$

   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.

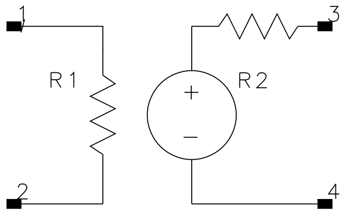
   For a sampled signal, preface this model with either the sample-hold or sampler model. Note that the frequency response of the Z-domain transfer function is cyclical and repeats every 1/TimeStep Hertz.

   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 (Linear Voltage-Controlled Voltage Source)

Symbol



Parameters

G = complex voltage gain; for example, polar(10,45), or P(j×omega)/Q(j×omega)

R1 = input resistance, in ohms

R2 = output resistance, in ohms

F = frequency at which voltage gain magnitude is down by 3 dB, in hertz

Range of Usage

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 Nonlinear Devices library.
2. This component is assumed to be noiseless.
3. Voltage gain =

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

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

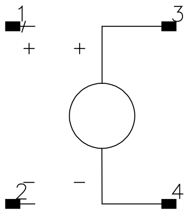
where

f = simulation frequency in hertz
F = reference frequency in hertz
T = VCVS time delay in seconds
$\mu(f)$ = frequency-dependent voltage gain

4. For time-domain analysis, the frequency-domain analytical model is used.
5. This component has no default artwork associated with it.

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

Symbol



Parameters

Gain = constant gain term

Num = numerator coefficients of transfer function

Den = denominator coefficients of transfer function

TimeStep = sampling time period

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.

Chapter 2: 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.

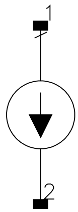
Independent voltage sources, current sources, and power source are provided in Advanced Design System. Power sources have built-in impedances that can also be used as reference impedance for S-parameter simulation.

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 $V = Re + j \times Im$, 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.

I_AC (AC current source)

Symbol



Parameters

Idc = dc current

Iac = ac current; value used for ac analysis only

Freq = frequency; default is global analysis frequency

I_Noise = noise current magnitude, per sqrt(Hz)

Notes/Equations

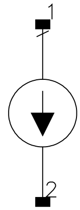
1. I_AC is an ideal ac current source. Positive current flows into the source at pin 1 and out of the source at pin 2.
2. This source is used in all simulations. When not in use, it is treated as an open circuit.
3. Table 2-1 lists the DC operating point parameters that can be sent to the dataset.

Table 2-1. DC Operating Point Information

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

I_DC (DC current source)

Symbol



Parameters

Idc = dc current

Iac = ac current; value used for ac analysis only

Notes/Equations

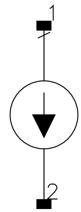
1. I_DC is an ideal dc current source. Positive current flows into the source at pin 1 and out of the source at pin 2.
2. This source is used in all simulations. When not in use, it is treated as an open circuit.
3. Table 2-2 lists the DC operating point parameters that can be sent to the dataset.

Table 2-2. DC Operating Point Information

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

I_1Tone (Current Source, Single Frequency)

Symbol



Parameters

I = current at center frequency

Freq = center frequency

I_USB = current of upper sideband small signal tone; value used for small-signal mixer simulation

I_LSB = current of lower sideband small-signal tone; value used for small-signal mixer simulation

Idc = dc current

Iac = ac current; value used for ac analysis

FundIndex = frequency index; an alternate way of specifying center frequency, used in MDS

Other = output string to netlist

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.

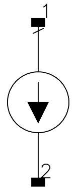
2. For time-domain analyses, transient and envelope, the I current parameter can be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the I current parameter is a 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. Table 2-3 lists the DC operating point parameters that can be sent to the dataset.

Table 2-3. DC Operating Point Information

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

I_nTone (Current Source, N Frequencies and Amplitudes)

Symbol



Parameters

Freq = Nth frequency tone

I = Nth tone amplitude

Idc = dc component

Iac = ac current; value used for ac analysis only

Other = output string to netlist

Range of Usage

Freq > 0

Notes/Equations

1. This current 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 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.

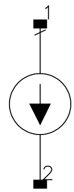
2. For time-domain analyses, transient and envelope, the I current parameter can be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the I current parameter is a 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. Table 2-4 lists the DC operating point parameters that can be sent to the dataset.

Table 2-4. DC Operating Point Information

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

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

Symbol



Parameters

Freq = fundamental frequency

I = Nth harmonic amplitude

Idc = dc component

Iac = ac current; value used for ac analysis only

FundIndex = frequency index; an alternate way of specifying fundamental frequency used in MDS

Other = output string to netlist

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.

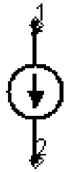
2. For time-domain analyses, transient and envelope, the I current parameter can be an expression of time. When a source with a time varying expression is used in a steady-state analysis such as harmonic balance, then its value at time=0 is used. Care must be exercised if the I current parameter is a 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. Table 2-5 lists the DC operating point parameters that can be sent to the dataset.

Table 2-5. DC Operating Point Information

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

I_HB_Dataset (Current Source, HB Dataset Variable)

Symbol



Parameters

Dataset = Dataset filename

Variable = Dataset variable (string and reference or file-based)

Idc =DC component (default: 0 mA)

Iac = AC current, use polar () for phase (default: polar(1,0) mA)

Notes/Equations

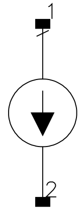
1. Table 2-6 lists the DC operating point parameters that can be sent to the dataset.

Table 2-6. DC Operating Point Information

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

I_SpectrumDataset (Current Source, Frequency Spectrum Defined in Dataset)

Symbol



Parameters

Dataset = dataset name

Expression = dataset variable or expression

Freq = fundamental frequency

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.

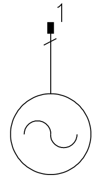
5. The harmonic values must be numeric and can be given as real (integer) or complex values. If given as real values, they will be converted to complex (zero imaginary part) before being used in a simulation.
6. The designer must ensure the rationality of the expression that is used. If an expression 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. Table 2-7 lists the DC operating point parameters that can be sent to the dataset.

Table 2-7. DC Operating Point Information

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

OSCwPhNoise (Oscillator with Phase Noise)

Symbol



Parameters

Freq = frequency

P = output power

Rout = output resistance

PhaseNoise = phase noise data

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 transient simulation.

   A harmonic balance simulation example is shown in Figure 2-1 and Figure 2-2.

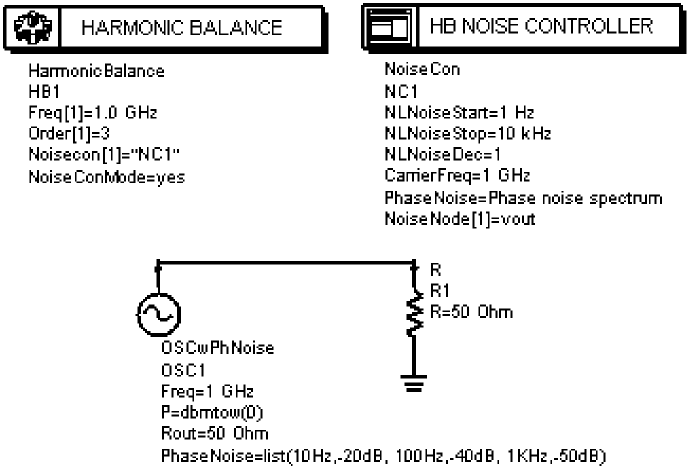


Figure 2-1. Harmonic Balance Setup

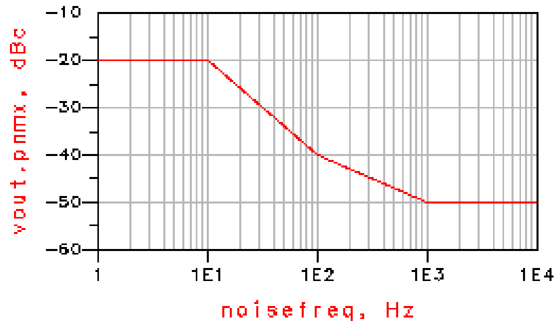
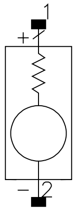


Figure 2-2. Harmonic Balance Noise Simulation Results

P_AC (AC Power Source)

Symbol



Parameters

Num = port number

Z = reference impedance, use 1+j*0 for complex

Pac = ac power, use polar(dbmtow(0), 0) for phase

Freq = frequency, in Hz

Noise = enable/disable port thermal noise: yes (default), no

Vdc = open circuit dc voltage

Temp = temperature of port in degrees Celsius. Default equals the circuit ambient temperature

Notes/Equations

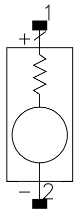
1. P_AC is an ac power source used for ac simulation. When not in use it is treated as an impedance.
2. The Noise parameter only affects the amount of noise generated by the port. If Noise=yes, the amount of noise generated is based on this temperature. This parameter is not used on the input and output 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. Table 2-8 lists the DC operating point parameters that can be sent to the dataset.

Table 2-8. DC Operating Point Information

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

P_1Tone (Power Source, Single Frequency)

Symbol



Parameters

Num = port number

Z = source impedance

P = power at center frequency

Freq = center frequency

P_USB = power of upper sideband small-signal tone; value used for small- signal mixer simulation

P_LSB = power of lower sideband small-signal tone; value used for small- signal mixer simulation

Mod = modulation function

Noise = enable/disable port thermal noise: yes or no

Pac = ac power; value used for ac simulation

FundIndex = frequency index; an alternate way of specifying center frequency, used in MDS

Vdc = open circuit dc voltage

Other = output string to netlist

Temp = element temperature in degrees Celsius. Default equals the circuit ambient temperature

Notes/Equations

1. The phase 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.

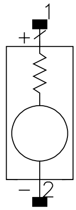
6. In small-signal mixer simulation, the simulator sets the operating point of the circuit using the carrier signal alone as the source. The two sidebands must be set such that they have no effect on the operating point of the circuit.
7. Set Noise=0 to have no noise generated by this source.
8. The 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. Table 2-9 lists the DC operating point parameters that can be sent to the dataset.

Table 2-9. DC Operating Point Information

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

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

Symbol



Parameters

Num = port number

Z = source impedance

Freq = fundamental frequency

P = Nth harmonic power level

Noise = enable/disable port thermal noise: yes or no

Pac = ac power; value used for ac simulation

FundIndex = frequency index; an alternate way of specifying center frequency, used in MDS

Vdc = open circuit dc voltage

Other = output string to netlist

Temp = element temperature in degrees Celsius. Default equals the circuit ambient temperature

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.

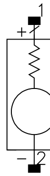
3. The output impedance of the source is defined by the Z-parameter. The output impedance may be complex, but dc, transient, and baseband envelope analyses do not support non-real impedances.
4. The signal level is defined by the power parameter P. The signal level is set such that the power delivered 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. Table 2-10 lists the DC operating point parameters that can be sent to the dataset.

Table 2-10. DC Operating Point Information

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

P_nTone (Power Source, N Frequencies and Power Levels)

Symbol



Parameters

Num = port number

Z = source impedance

Freq = Nth frequency tone

P = Nth tone power level

Noise = enable/disable port thermal noise: yes or no

Pac = ac power; value used for ac simulation

Vdc = open circuit dc voltage

Other = output string to netlist

Temp = element temperature in degrees Celsius. Default equals the circuit ambient temperature

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 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.

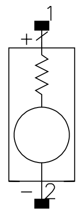
3. The output impedance of the source is defined by the Z-parameter. The output impedance may be complex, but dc, transient, and baseband envelope analyses do not support non-real impedances.
4. The signal level is defined by the power parameter P. The signal level is set such that the power delivered 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. Table 2-11 lists the DC operating point parameters that can be sent to the dataset.

Table 2-11. DC Operating Point Information

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

P_SpectrumDataset (Power Source, Frequency Spectrum Defined in Dataset)

Symbol



Parameters

Num = port number

Z = source impedance

Freq = fundamental frequency

Dataset = dataset name

Expression = dataset variable or expression

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. Table 2-12 lists the DC operating point parameters that can be sent to the dataset.

Table 2-12. DC Operating Point Information

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

V_1Tone (Voltage Source, Single Frequency)

Symbol

Parameters

V = voltage at center frequency

Freq = center frequency

V_USB = voltage of upper sideband small-signal tone; value used for small-signal mixer simulation

V_LSB = voltage of lower sideband small-signal tone; value used for small-signal mixer simulation

Vdc = dc voltage

Vac = ac voltage; value used for ac simulation

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying center freq, used in MDS

Other = output string to netlist

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. Table 2-13 lists the DC operating point parameters that can be sent to the dataset.

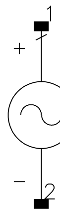
Table 2-13. DC Operating Point Information

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.

V_AC (AC Voltage Source)

Symbol



Parameters

Vdc = dc voltage, in volts

Vac = ac voltage, in volts; value used for ac analysis only

SaveCurrent = flag to save branch current

Freq = frequency

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.

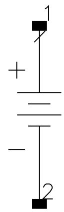
3. Table 2-14 lists the DC operating point parameters that can be sent to the dataset.

Table 2-14. DC Operating Point Information

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

V_DC (DC Voltage Source)

Symbol



Parameters

Vdc = dc voltage, in volts

Vac = ac voltage, in volts; value used for ac analysis only

SaveCurrent = flag to save branch current

Notes/Equations

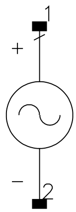
1. V_DC can be used in all simulations. When not in use, it is treated as a short circuit.
2. Table 2-15 lists the DC operating point parameters that can be sent to the dataset.

Table 2-15. DC Operating Point Information

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

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

Symbol



Parameters

Freq = fundamental frequency

V = Nth harmonic amplitude

Vdc = dc voltage

Vac = ac voltage; value used for ac analysis only

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying fundamental freq, used in MDS

Other = output string to netlist

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. Table 2-16 lists the dc operating point parameters that can be sent to the dataset.

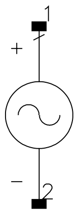
Table 2-16. DC Operating Point Information

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.

V_nTone (Voltage Source, N Frequencies and Amplitudes)

Symbol



Parameters

Freq = Nth frequency tone

V = Nth tone amplitude

Vdc = dc voltage

Vac = ac voltage; value used for ac simulation only

SaveCurrent = flag to save branch current

Other = output string to netlist

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. Table 2-17 lists the dc operating point parameters that can be sent to the dataset.

Table 2-17. DC Operating Point Information

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.

V_SpectrumDataset (Voltage Source, Frequency Spectrum Defined in Dataset)

Symbol

Parameters

Dataset = dataset name

Expression = dataset variable or expression

Freq = fundamental frequency

SaveCurrent = flag to save branch current

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.

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.

   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).

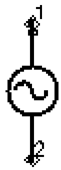
7. Table 2-18 lists the dc operating point parameters that can be sent to the dataset.

Table 2-18. DC Operating Point Information

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

Vf_BitSeq (Fourier Transform of Bit Sequence Waveform)

Symbol



Parameters

Vlow = minimum voltage level, in V, fV, pV, nV, uV, mV, or kV (default: 0V)

Vhigh = maximum voltage level, in V, fV, pV, nV, uV, or mV (default: 5V)

Rate = bit rate, in MHz, Hz, kHz, GHz (default: 1 MHz)

Rise = rise time of pulse, in nsec, fsec, psec, nsec, usec, or msec (default: 1 nsec)

Fall = fall time of pulse, in nsec, fsec, psec, nsec, usec, or msec (default: 1 nsec)

BitSeq = bit sequence (default: 1101010100101)

Notes/Equations

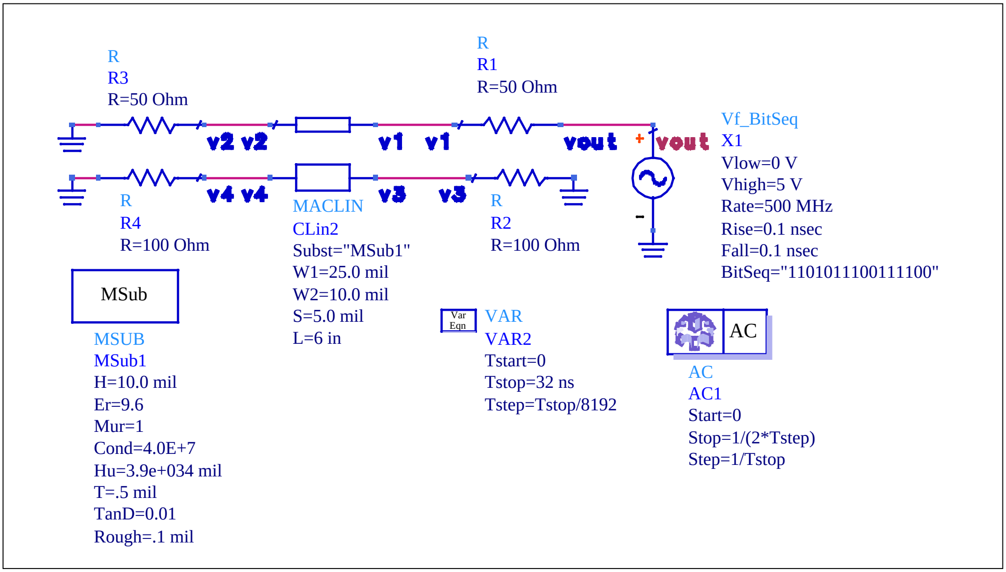
1. BitSeq allows you to vary the waveform of a pulse: an arbitrary bit pattern such as 1101010100101 (default). When the end of the sequence is reached, the sequence is repeated. A specification of 1 sets voltage to Vhigh, 0 sets it to Vlow.
2. When using Vf_BitSeq, a VAR statement must be included in the schematic to define Tstart, Tstop, and Tstep. These variables must be consistent with the simulation controller parameters.

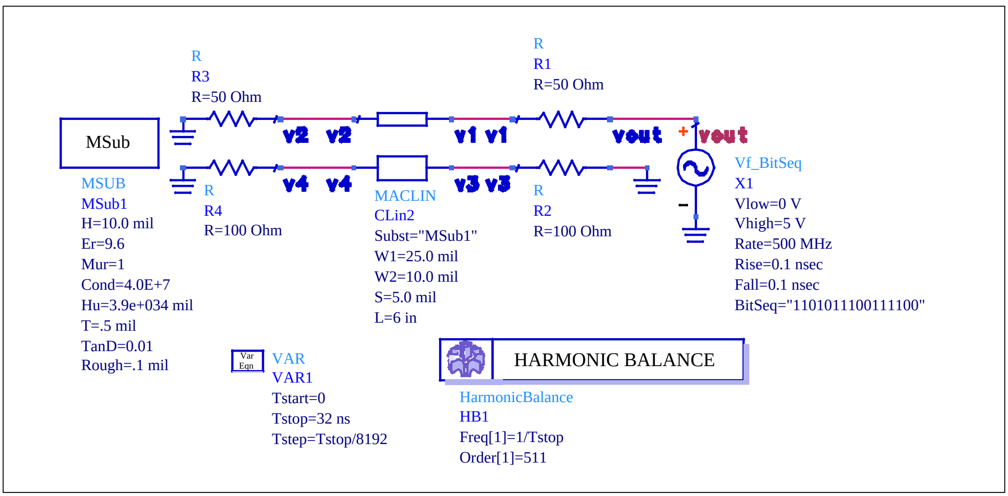
   Tstop should be exactly one bit cycle for good results. For example, if BitRate=500MHz, then Bit period=1/BitRate=1/500MHz=2nsec. BitSeq=1101011100111100 is 16 bits long, so Tstop = 32nsec (16bits $\times$ 2nsec). See the schematics below.

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

   For Harmonic Balance simulations the recommended controller settings are: Freq[1] = 1/Tstop; increase Order[1] to a large value so that there are enough harmonics to give an accurate Fourier series representation of a pulse waveform.

3. Vf_BitSeq is recommended for use in frequency analyses; for transient simulations VtBitSeq can be used.





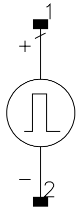
4. Table 2-19 lists the dc operating point parameters that can be sent to the dataset.

Table 2-19. DC Operating Point Information

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

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

Symbol



Parameters

Vpeak = peak voltage amplitude of pulse, in volts

Vdc = dc offset

Freq = fundamental frequency component (1 / T_0, where T_0 is the pulse-period) of pulse-train

Width = pulse-width, in seconds

Rise = rise-time, in seconds

Fall = fall-time, in seconds

Delay = time delay, in seconds

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

Harmonics = number of harmonics

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying fundamental freq, used in MDS

Range of Usage

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

Notes/Equations

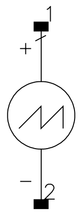
1. Vf_Pulse is a time-periodic rectangular pulse-train voltage source that can be used in all simulations. However, the Vf_Pulse source is short-circuited for AC simulation. The time-periodic signal is converted to discrete frequency components that are harmonically related and represented using the 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. Table 2-20 lists the dc operating point parameters that can be sent to the dataset.

Table 2-20. DC Operating Point Information

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

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

Symbol



Parameters

Vpeak = peak voltage amplitude of wave, in volts

Vdc = dc offset

Freq = frequency

Delay = time delay, in seconds

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

Harmonics = number of harmonics

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying fundamental freq, used in MDS

Range of Usage

Delay $\geq$ 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.

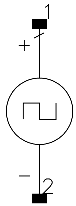
4. The number of terms in the Fourier series used to represent this source in the frequency domain is equivalent to the order chosen for the harmonic balance simulation.
5. You can synthesize a similar time-periodic signal by connecting in series a number of sinusoidal steady-state sources at harmonically related frequencies and having amplitudes and phases that are the corresponding Fourier coefficients.
6. Table 2-21 lists the dc operating point parameters that can be sent to the dataset.

Table 2-21. DC Operating Point Information

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

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

Symbol



Parameters

Vpeak = peak voltage amplitude of pulse, in volts

Vdc = dc offset

Freq = frequency

Rise = rise-time, in seconds

Fall = fall-time, in seconds

Delay = time delay, in seconds

Weight = compensation for Gibb's Phenomenon if rise- or fall-time is 0; activated=yes; ignored if rise and fall are non-0

Harmonics = number of harmonics

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying fundamental freq, used in MDS

Range of Usage

Delay $\geq$ 0; Rise $\geq$ 0; Fall $\geq$ 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 positive voltage with respect to pin 1.
3. If either rise-time (Rise) or fall-time (Fall) 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. Table 2-22 lists the dc operating point parameters that can be sent to the dataset.

Table 2-22. DC Operating Point Information

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

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

Symbol

Parameters

Vpeak = peak voltage amplitude of wave, in volts

Vdc = dc offset

Freq = frequency

Delay = time delay, in seconds

Harmonics = number of harmonics

SaveCurrent = flag to save branch current

FundIndex = frequency index; an alternate way of specifying fundamental freq, used in MDS

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.

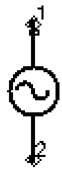
4. Table 2-23 lists the dc operating point parameters that can be sent to the dataset.

Table 2-23. DC Operating Point Information

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

V_HB_Dataset (Voltage Source, HB Dataset Variable)

Symbol



Parameters

Dataset = dataset filename

Variable = dataset variable

Vdc= DC voltage (default: 0 V)

Vac = AC voltage, use polar() for phase; default: polar (1,0) V

SaveCurrent = flag to save branch current (default: 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 (*amplifier_ckt1.dsn)* in Figure 2-3, a dataset named *amp_ckt1.ds* is generated and includes the nodal voltage variable *Vout*. The circuit in *amp_ckt1.dsn* contains an amplifier with a gain of 10 dB.

The schematic in Figure 2-4 (*both_amps.dsn*) 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.

Simulation results are shown in Figure 2-5 (the output spectrum and waveform are shown for the swept values of the amplifier gain).

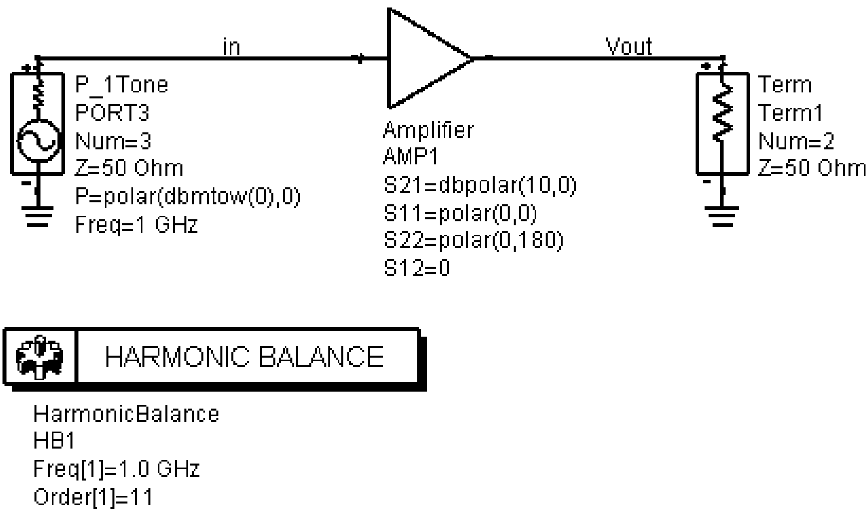


Figure 2-3. Single Stage Amplifier

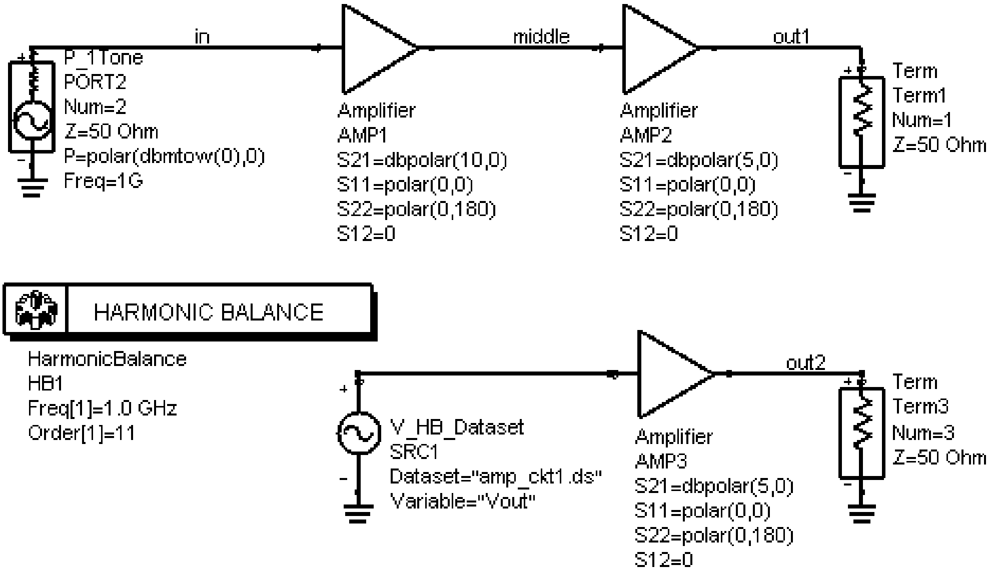


Figure 2-4. Single Stage Amplifier using V_HB_Dataset Source

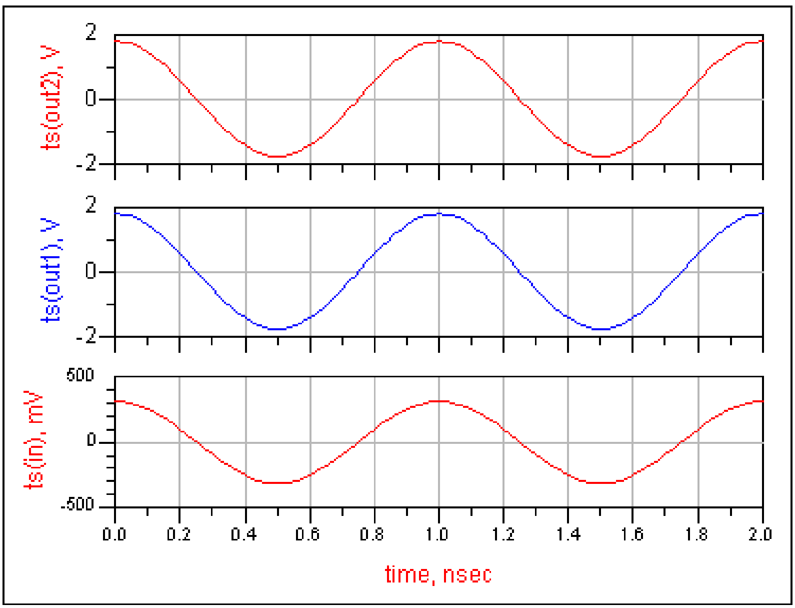


Figure 2-5. Simulation Results

6. Table 2-24 lists the dc operating point parameters that can be sent to the dataset.

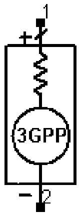
Table 2-24. DC Operating Point Information

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

Chapter 3: Sources, Modulated

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

Symbol



Parameters

Freq = Carrier frequency

Power = Output power at RF output

R = Output impedance of RF output

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 msec) of 3GPP data (38400 chips at 1.384 µsec per chip).
4. It is recommended that simulation timestep be set to (1/3.84/4 µsec), 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=no

- 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

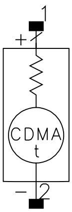
Power = dbmtow(Pavs)

(R = 50 Ohm)

6. For an overview of 3GPP (WCDMA) systems, refer to the 3GPPFDD Design Library, Introduction chapter (*Manuals* > *Components* > *Signal Processing Components* > *3GPPFDD)*.

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

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_prj* directory.

4. 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.

5. Recommended controller setups for Envelope simulation are:

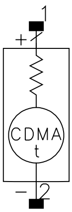
   - Envelope item
     Freq[1] = RFfreq
     Order[1] = 1
     StatusLevel=2
     Stop=tstop

Step=tstep
Other=SavetoDataset=no

- 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
  FO=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

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_prj* directory.

4. 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 the source interpolates between data samples and results in distorted spectrum.

5. Recommended controller setups for Envelope simulation are:

    - Envelope item
      Freq[1] = RFfreq
      Order[1] = 1
      StatusLevel=2
      Stop=tstop

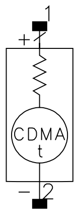
Step=tstep
Other=SavetoDataset=no

- 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
  FO=RFfreq
  Power = dbmtow(Pavs)
  Z=50 Ohm

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

LinMod = additional linear modulation

Toffset = time offset into data array

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. 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.
4. Recommended controller setups for Envelope simulation are:
   - Envelope item

     Freq[1] = RFfreq

     Order[1] = 1

     StatusLevel=2

     Stop=tstop

Step=tstep

Other=SavetoDataset=no

- 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

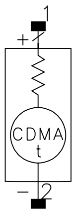
FO=RFfreq

Power = dbmtow(Pavs)

Z=50 Ohm

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

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_prj*. directory.
4. 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.
5. Recommended controller setups for Envelope simulation are:
   - Envelope item

     Freq[1] = RFfreq

     Order[1] = 1

     StatusLevel=2

     Stop=tstop

Step=tstep

Other=SavetoDataset=no

- 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

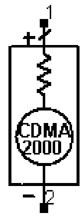
FO=RFfreq

Power = dbmtow(Pavs)

Z=50 Ohm

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

Symbol



Parameters

Freq = Carrier frequency

Power = Output power at RF output

R = Output impedance of RF output

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 (10 msec) of 3GPP data (38400 chips at 1.384 μsec per chip).
4. It is recommended that simulation timestep be set to (1/1.2288/4 μsec), 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=no

- 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

Freq = RFfreq

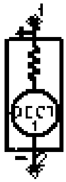
Power = dbmtow(Pavs)

(R = 50 Ohm)

6. For an overview of CDMA2000 systems, refer to the cdma2000 Design Library, Introduction chapter (*Manuals > Components > Signal Processing Components > cdma2000)*.

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

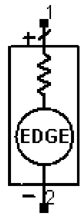
Notes/Equations

1. This model generates a digitally modulated RF signal that has the modulation characteristics of a DECT signal. Bit time is 0.868 μsec. NRZ data is Gaussian-filtered with BT=0.5.

2. 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

Freq = Carrier frequency

Power = Output power at RF output

R = Output impedance of RF output

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 msec) of EDGE data (1250 symbols at 48/13 μsec 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 msec), 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

Other=SavetoDataset=no

- VAR item

  sym_rate = 1625/6 kHz

  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

  FO = RFfreq

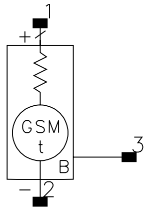
  Power = dbmtow(Pavs)

  (R = 50 Ohm)

6. For an overview of EDGE systems, refer to the EDGE Design Library, Introduction chapter (*Manuals* > *Components* > *Signal Processing Components* > *EDGE).*

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

Symbol



Parameters

F0 = carrier frequency

Power = RF output power

Rout = RF output resistance

DataRate = digital modulation data rate

InitBits = initial state of PRBS data generator

Notes/Equations

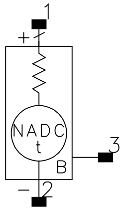
1. This model generates a continuously digitally modulated RF signal that has the modulation characteristics of a transmitted GSM signal. It does not contain GSM framing or pulse modulation characteristics. It consists of a pseudorandom data generator (PRBS) feeding a Gaussian filter with a bandwidth 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. 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

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

LinMod = additional linear modulation

Toffset = time offset into data array

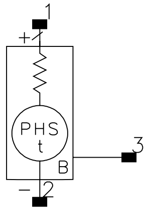
Notes/Equations

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 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 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

F0 = carrier frequency

Power = RF output power

Z = RF output impedance

LinMod = additional linear modulation

Toffset = time offset into data array

Notes/Equations

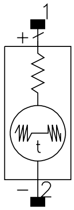
1. This model generates a continuously digitally modulated RF signal that has the modulation characteristics of a transmitted PHS signal. It does not contain framing or pulse modulation characteristics. This source is implemented by interpolating data from a stored data file, which is faster than recalculating the source.

2. The user can define the carrier frequency, power and output impedance of the RF output.

3. 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 –1 to +1V baseband digital data stream is also available as an output and has a 1-ohm source resistance.

PtRF_Pulse (Pwr Src, RF Pulse Train)

Symbol



Parameters

Num = port number (value type: integer)

Z = source impedance

P = carrier power during pulse

Freq = RF carrier frequency

OffRatio = linear amplitude ratio of off to on pulse portions

Delay = delay time before first pulse

Rise = rise time of pulse

Fall = fall time of pulse

Width = width of constant portion of pulse

Period = pulse repetition period

Chirp = linear frequency modulation during pulse

Phase0 = initial phase of pulse carrier

Noise = enable port thermal noise: YES, NO

Pac = ac power

Vdc = open circuit dc voltage

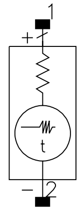
Notes/Equations

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.

PtRF_Step (Pwr Src, RF Step)

Symbol



Parameters

Num = port number (value type: integer)

Z = source impedance

P = steady state power

Freq = RF frequency

Delay = time delay before step

Rise = rise time of step

Noise = enable port thermal noise: YES, NO

Pac = ac power

Vdc = open circuit dc voltage

Notes/Equations

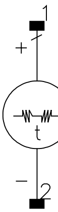
1. This RF step power source creates an RF carrier that is turned on after the start of the time-domain simulation. The carrier frequency is defined by Freq. For envelope simulations, Freq identifies the closest analysis frequency. If the frequency is not close enough to an analysis frequency, a warning 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

Freq = RF carrier frequency

Vpeak = voltage envelope of pulse

OffRatio = linear amplitude ratio of off to on pulse portions

Delay = time delay before first pulse

Rise = rise time of pulse

Fall = fall time of pulse

Width = width of constant portion of pulse

Period = pulse repetition period

Chirp = linear frequency modulation during pulse

Phase0 = initial phase of pulse carrier

Vdc = dc voltage

Vac = ac voltage

SaveCurrent = save branch current: YES, NO

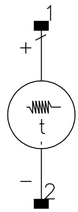
Notes/Equations

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_Step (Voltage Source, RF Step)

Symbol



Parameters

Freq = RF frequency

V = voltage envelope of step

Delay = time delay before step

Rise = rise time of step

Vdc = dc voltage

Vac = ac voltage

SaveCurrent = save branch current: YES, NO

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.

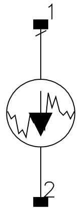
2. The carrier is turned on at the time specified by the Delay parameter. The turn-on duration is defined by the Rise parameter and uses the Gaussian-shaped rise time defined by the **(**erf_pulse() function).

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.

Chapter 4: Sources, Noise

I_Noise (Noise Current Source)

Symbol



Parameters

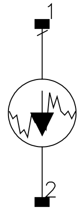
I_Noise = noise current magnitude, in amperes

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

K = multiplicative constant

Ie = dc bias current exponent

A0 = additive constant in the denominator

A1 = multiplication factor for the frequency

Fe = frequency exponent

Elem = ID of an element such as R, FET, BJT

Pin = element pin number or name

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

Table 4-1 summarizes the values to which the parameters must be set to realize the types of noise sources.

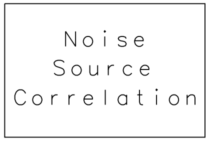
Table 4-1. Parameter values for noise sources

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. This component has no default artwork associated with it.

NoiseCorr (Noise Source Correlation)

Symbol



Parameters

CorrCoeff = correlation coefficient

Source1 = source 1 name

Source2 = source 2 name

Notes/Equations

1. This source is used in noise analysis only; it is ignored in other simulations.
2. The sources that are correlated can be current or voltage sources.

   The correlation coefficient is defined in this equation:

$$CorrCoeff = \frac{\langle n_1, n_2^* \rangle}{\sqrt{|n_1|^2 |n_2|^2}}$$

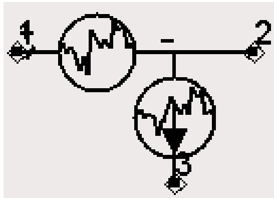
   where

   CorrCoeff is the correlation coefficient between the sources

   n_1 and n_2 are rms values of the noise generated by each source.

Noisy2Port (Linear Noisy 2ort Network)

Symbol



Parameters

NFmin = minimum noise figure

Rn = noise resistance

Sopt = optimum match for minimum noise figure

Notes/Equations

1. This source is used in noise analysis only; for other simulations, voltage source will be replaced by a short circuit and current source will be replaced by an open circuit.
2. If NFmin, Sopt, and Rn are used to characterize noise, the following relation must be satisfied for a realistic model.

$$\frac{Rn}{Zo} \geq \frac{To(Fmin-1)|1+Sopt|^2}{T\ 4} \frac{(1-|S_{11}|^2)}{|1-Sopt\ S_{11}|^2}$$

   A warning message will be issued if Rn does not meet this criterion. If the noise parameters attempt to describe a system that requires negative noise (due to Rn being too small), the negative part of the noise will be set to zero and a warning message will be issued.

3. Sopt is always with respect to a reference impedance of 50 ohms. The reference impedance is not changeable.

V_Noise (Noise Voltage Source)

Symbol

Parameters

V_Noise = noise voltage amplitude, in volts

SaveCurrent = save branch current: YES, NO

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=1μV 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

   $$1\mu V\sqrt{\frac{1}{0.1\,msec}} = 100\mu V$$

   For baseband envelope, noise is distributed in a bandwidth out to 0.5/Step, rms noise voltage of the baseband envelope is

   $$1\mu V\sqrt{\frac{0.5}{0.1\,msec}} = 70.7\mu V$$

V_NoiseBD (Bias-dependent Noise Voltage Source)

Symbol

Parameters

K = multiplicative constant

Ie = dc bias current exponent

A0 = additive constant in the denominator

A1 = multiplication factor for the frequency

Fe = frequency exponent

Elem = ID of an element such as R, FET, BJT

Pin = element pin number or name

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: $\langle v^2 \rangle = \dfrac{Kf \times Idc^{Af}}{f^{Ffe}}$

Burst noisei: $\langle v^2 \rangle = \dfrac{Kb \times Idc^{Ab}}{1 + \left(\dfrac{f}{Fb}\right)^2}$

Shot noise: $\langle v^2 \rangle = 2 \times q \times Idc$

Thermal noise: $\langle v^2 \rangle = 4 \times k \times T \times g$

Table 4-2 summarizes the values to which the parameters must be set to realize the types of noise sources.

Table 4-2. Parameter values for noise sources

Parameter	Flicker	Burst	Shot	Thermal
K	Kf	Kb	$2 \times q$	$4 \times k \times T \times g$
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.

Chapter 5: Sources, Time Domain

Introduction

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

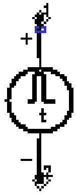
Vt prefixes are transient voltage sources; It prefixes are transient current sources; Pt prefixes are transient power sources.

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.

ClockWjitter (Voltage Source: Clock with Jitter)

Symbol



Parameters

Low = low-level voltage (default: 0V)

High = high-level voltage (default: 1V)

Rout = output resistance (default: 1 ohm)

Delay = delay time (default: 0 nsec)

Rise = rise time (default: 1 nsec)

Fall = fall time (default: 1nsec)

Width = pulse width (default: 3 nsec)

Period = pulse period (default: 10 nsec)

Jitter = jitter time (default: 0 nsec)

Range of Usage

Delay $\geq$ 0, Rise $\geq$ 0, Fall $\geq$ 0
Width > 0
Width + Rise + Fall $\leq$ 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 $\pm 3\sigma$. The pulse width is not affected by the jitter.
3. A transient simulation example is shown in Figure 5-1.

Figure 5-1. Transient Simulation Setup

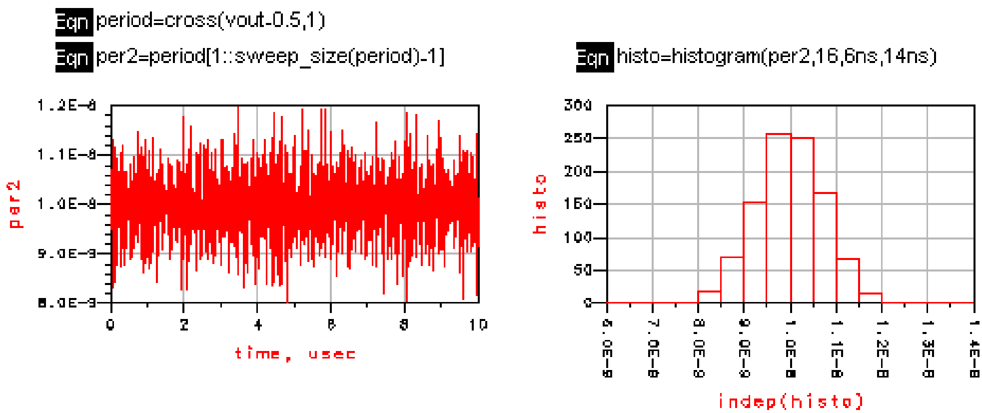
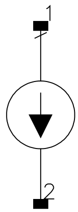


Figure 5-2. Simulation Results

I_DC (DC current source)

Symbol



Parameters

Idc = dc current (default: 1 mA)

Iac = ac current; value used for ac analysis only

Notes/Equations

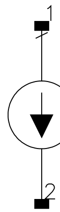
1. I_DC is an ideal dc current source. Positive current flows into the source at pin 1 and out of the source at pin 2.
2. This source is used in all simulations. When not in use, it is treated as an open circuit.
3. Table 5-1 lists the DC operating point parameters that can be sent to the dataset.

Table 5-1. DC Operating Point Information

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

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

Symbol



Parameters

Dataset = dataset name

Expression = dataset variable or expression

Freq = carrier frequency (default: 0 GHz)

Gain = gain to apply to dataset values; can be complex and time varying (default: 1.0)

Tmax = maximum dataset time to use

Toffset = initial dataset time offset

Tscale = time speed-up scaling factor

Idc = dc offset current (default: 0 mA)

Interpolation = interpolation method (default: 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 & 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 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.

5. 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.

   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

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

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

   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.

6. Refer to the DataAccessComponent documentation for a description of the different interpolation options available for ItDataset.

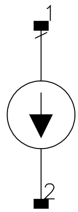
7. Table 5-2 lists the DC operating point parameters that can be sent to the dataset.

Table 5-2. DC Operating Point Information

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

ItExp (Current Source, Exponential Decay)

Symbol



Parameters

I_Low = initial current (default: 0 mA)

I_High = pulse current (default: 1 mA)

Delay1 = rise delay time (default: 0 nsec)

Tau1 = rise time constant (default: 1 nsec)

Delay2 = fall delay time (default: 1 nsec)

Tau2 = fall time constant (default: 1 nsec)

Range of Usage

$Delay1 \geq 0$
$Tau1 \geq 0$
$Delay2 \geq 0$
$Tau2 \geq 0$

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:

   $$I = I\_Low \qquad 0 \leq t \leq Delay1$$

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

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

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

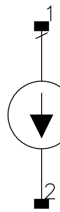
3. Table 5-3 lists the DC operating point parameters that can be sent to the dataset.

Table 5-3. DC Operating Point Information

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

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

Symbol



Parameters

I_Low = initial current (default: 0 mA)

I_High = pulse current (default: 1 mA)

Delay = time delay (default: 0 nsec)

Edge = rise and fall edge type: linear (default), cosine, erf

Rise = rise time (default: 1 nsec)

Fall = fall time (default: 1 nsec)

Width = pulse width (default: 3 nsec)

Period = pulse period (default: 10 nsec)

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*. (See Figure 5-3.)

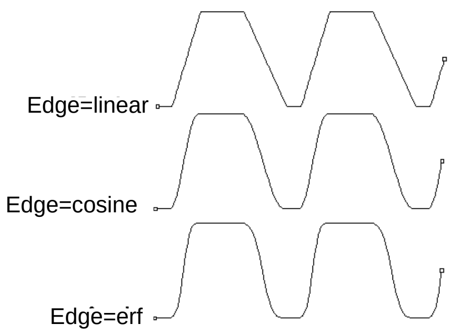


Figure 5-3. ItPulse Waveforms with Different Edges

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 Figure 5-4; the intermediate points during rise and fall time are determined by interpolation.

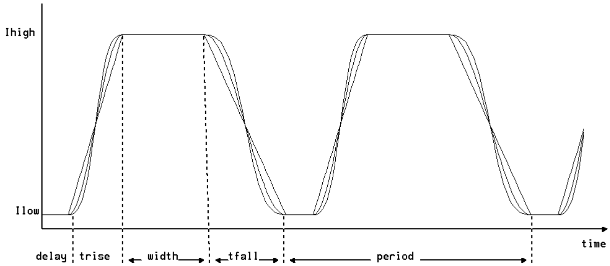


Figure 5-4.

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 Figure 5-3.)

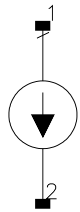
4. Table 5-4 lists the DC operating point parameters that can be sent to the dataset.

Table 5-4. DC Operating Point Information

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

ItPWL (Current Source, Piecewise Linear)

Symbol



Parameters

I_Tran = pwl (time, time-current pairs) or pwlr (time, Ncycles, time-current pairs)

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. Table 5-5 lists the DC operating point parameters that can be sent to the dataset.

Table 5-5. DC Operating Point Information

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

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

Symbol

Parameters

Idc = initial current offset, in amperes (default: 0 mA)

Amplitude = sinusoidal wave amplitude, in amperes (default: 1 mA)

CarrierFreq = carrier frequency, in Hertz (default: 1 GHz)

ModIndex = modulation index (default: 0.5)

SignalFreq = signal frequency, in Hertz (default: 1 MHz)

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.

$$\mathrm{Idc} + \mathrm{Amplitude} \times (\sin(2\pi \mathrm{CarrierFreq} \times \mathrm{time}) \\ + \mathrm{ModIndex}\ \sin(2\pi \mathrm{SignalFreq} \times \mathrm{time}))$$

$$\mathrm{Iac} + A \times \sin(2\pi f_c t + \alpha \times \sin 2\pi f_s t$$

3. Table 5-6 lists the DC operating point parameters that can be sent to the dataset.

Table 5-6. DC Operating Point Information

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

ItSine (Current Source, Decaying Sine Wave)

Symbol

Parameters

Idc = initial current offset (default: 0 mA)

Amplitude = sinusoidal wave amplitude (default: 1 mA)

Freq = sinusoidal wave frequency (default: 1 GHz)

Delay = time delay (default: 0 nsec)

Damping = damping factor (default: 0 1/sec)

Phase = initial phase (default: 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.

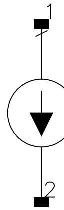
3. Table 5-7 lists the DC operating point parameters that can be sent to the dataset.

Table 5-7. DC Operating Point Information

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

ItStep (Current Source, Step)

Symbol



Parameters

I_Low = initial current (default: 0 mA)

I_High = pulse current (default: 1 mA)

Delay = time delay(default: 0 nsec)

Rise = rise time (default: 1 nsec)

Notes/Equations

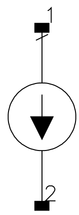
1. In SPICE, the equivalent to this source is a current or voltage source with the step waveform argument STEP and its parameters.
2. Table 5-8 lists the DC operating point parameters that can be sent to the dataset.

Table 5-8. DC Operating Point Information

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

ItUserDef (Current Source, User-Defined)

Symbol



Parameters

I_Tran = transient current (default: damped_sin(time))

Idc = dc current

Iac = ac current (default 1 mA)

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

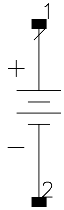
   ```
   it = pwl (time, 0, 0, 1, 10ns, 1, 15ns, 0) + damped_sin (time)
   ```
4. The Iac parameter is used in AC simulations and does not affect transient simulation. An example for specifying magnitude and phase would be Iac=polar(2,45), where 2 is the magnitude and 45 is the phase. For more parameter options (such as frequency) on an AC source, use the I_AC component on the Sources-Freq Domain palette.
5. Table 5-9 lists the DC operating point parameters that can be sent to the dataset.

Table 5-9. DC Operating Point Information

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

V_DC (DC Voltage Source)

Symbol



Parameters

Vdc = dc voltage, in volts (default: 1.0V)

Vac = ac voltage, in volts; value used for ac analysis only

SaveCurrent = save branch current (default: yes)

Notes/Equations

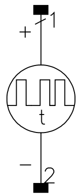
1. V_DC can be used in all simulations. When not in use, it is treated as a short circuit.
2. Table 5-10 lists the dc operating point parameters that can be sent to the dataset.

Table 5-10. DC Operating Point Information

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

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

Symbol



Parameters

Vlow = minimum voltage level (default: 0V)

Vhigh = maximum voltage level (default: 5V)

Rate = bit rate (default: 50 MHz)

Rise = rise time of pulse (default: 1 nsec)

Fall = fall time of pulse (default: 1 nsec)

BitSeq = bit sequence (default: 101010)

SaveCurrent = save branch current: YES (default), NO

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.

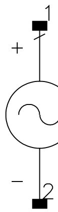
2. VtBitSeq is used for transient simulations; Vf_BitSeq is recommended for frequency simulations.
3. Table 5-11 lists the dc operating point parameters that can be sent to the dataset.

Table 5-11. DC Operating Point Information

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

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

Symbol



Parameters

Dataset = dataset name

Expression = dataset variable or expression

Freq = carrier frequency (default: 0 GHz)

Gain = apply to dataset values; may be complex and time varying (default: 1.0)

Tmax = maximum dataset time to use

Toffset = initial dataset time offset

Tscale = time speed-up scaling factor

Vdc = dc offset voltage (default: 0 V)

Interpolation = interpolation method (default: linear)

SaveCurrent = save branch current: yes (default), no

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. 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.

3. 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 the amplitude modulation of the carrier.

4. 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.

   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

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

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

with the modulo remainder function

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

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

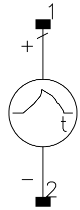
5. Refer to the DataAccessComponent documentation for a thorough description of the different interpolation options available for VtDataset.
6. Table 5-12 lists the dc operating point parameters that can be sent to the dataset.

Table 5-12. DC Operating Point Information

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

VtExp (Voltage Source, Exponential Decay)

Symbol



Parameters

Vlow = initial voltage (default: 0V)

Vhigh = peak voltage (default: 1V)

Delay1 = rise time delay (default: 0 nsec)

Tau1 = rise time constant (default: 1 nsec)

Delay2 = fall time delay (default: 1 nsec)

Tau2 = fall time constant (default: 1 nsec)

SaveCurrent = save branch current: yes (default), no

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:

$$t1 = \frac{t - Delay1}{Tau1} \qquad t2 = \frac{t - Delay2}{Tau2}$$

   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

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

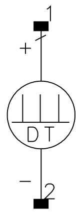
3. Table 5-13 lists the dc operating point parameters that can be sent to the dataset.

Table 5-13. DC Operating Point Information

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

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

Symbol



Parameters

Vlow = minimum voltage level (default: 0V)

Vhigh = maximum voltage level (default: 1V)

Period = time between repetitive impulses (default: 100 nsec)

Delay = time delay before first impulse (default: 0 nsec)

Rout = output resistance (default: 1 ohm)

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 Figure 5-5.

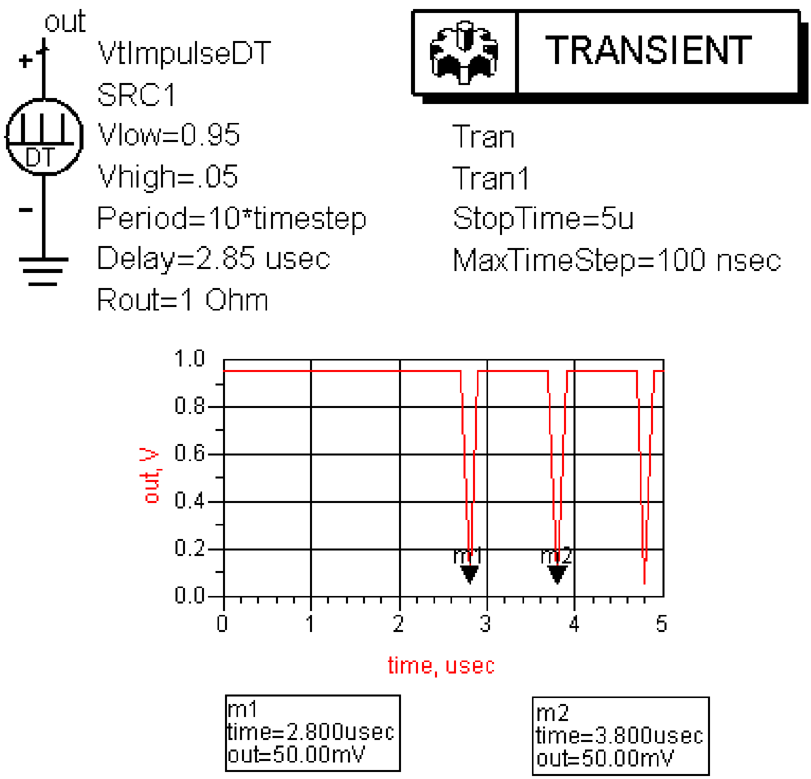


Figure 5-5. Negative-Going Impulse

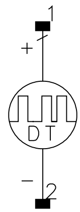
4. Table 5-14 lists the dc operating point parameters that can be sent to the dataset.

Table 5-14. DC Operating Point Information

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

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

Symbol



Parameters

Vlow = minimum voltage level (default: 0V)

Vhigh = maximum voltage level (default: 1V)

Rate = bit rate (default: 24.3 kHz)

Delay = initial time delay to first transition (default: 0 nsec)

Taps = bits used to generate feedback (default: bin(“10000000000000100”)

Seed = initial value loaded into the shift register (default: bin(“10101010101010101”)

Rout = output resistance (default: 1 ohm)

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. Figure 5-6 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.

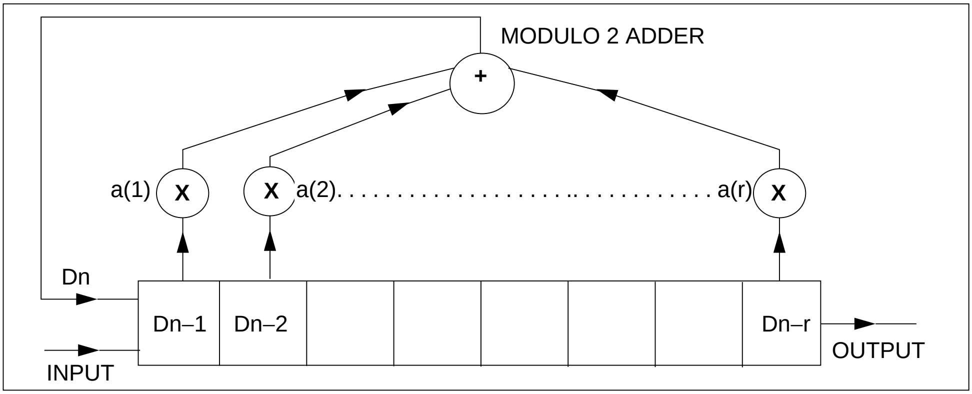


Figure 5-6. LFSR Model

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.

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

where

$D(0) = \text{Seed}_2\ (0)$
$D(-1) = \text{Seed}_2\ (1)$
.
.
.
$D(1-r) = \text{Seed}_2\ (r-1)$

and

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

where

$\text{Seed}_2(k) \in \{0,1\} \quad \text{for } 0 \leq k < r.$
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,

$D(0) = Seed_2\ (0) = 0$
$D(-1) = Seed_2\ (1) = 1$
$D(-2) = Seed_2\ (2) = 0$
.
.
.
$D(-6) = Seed_2\ (6) = 0$

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

$$D(n) = (D(n-7) + D(n-3) + D(n-2) + D(n-1)) \bmod 2$$

is specified by the list [7, 3, 2, 1].

Table 5-15 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.

Table 5-15. Feedback Connections for Linear *m*-Sequences *

Number of Stages	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,]

Table 5-15. Feedback Connections for Linear *m*-Sequences (continued)*

Number of Stages	Code Length	Maximal Taps
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] [7, 6, 5, 4, 2, 1] [7, 5, 4, 3, 2, 1]
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] [8, 7, 6, 5, 2, 1] [8, 6, 4, 3, 2, 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] [9, 6, 5, 4, 2] [9, 7, 6, 4, 3, 1] [9, 8, 7, 6, 5, 3]
10	1023	[10, 3] [10, 8, 3, 2] [10, 4, 3, 1] [10, 8, 5, 1][10, 8, 5, 4] [10, 9, 4, 1] [10, 8, 4, 3] [10, 5, 3, 2] [10, 5, 2, 1] [10, 9, 4, 2]
11	2047	[11, 1] [11, 8, 5, 2] [11, 7, 3, 2] [11, 5, 3, 5] [11, 10, 3, 2] [11, 6, 5, 1] [11, 5, 3, 1] [11, 9, 4, 1] [11, 8, 6, 2] [11, 9, 8, 3]
12	4095	[12, 6, 4, 1] [12, 9, 3, 2] [12, 11, 10, 5, 2, 1] [12, 11, 6, 4, 2, 1] [12, 11, 9, 7, 6, 5] [12, 11, 9, 5, 3, 1] [12, 11, 9, 8, 7, 4] [12, 11, 9, 7, 6, 5] [12, 9, 8, 3, 2, 1] [12, 10, 9, 8, 6, 2]
13	8191	[13, 4, 3, 1] [13, 10, 9, 7, 5, 4] [13, 11, 8, 7, 4, 1] [13, 12, 8, 7, 6, 5] [13, 9, 8, 7, 5, 1] [13, 12, 6, 5, 4, 3] [13, 12, 11, 9, 5, 3] [13, 12, 11, 5, 2, 1] [13, 12, 9, 8, 4, 2] [13, 8, 7, 4, 3, 2]
14	16,383	[14, 12, 2, 1] [14, 13, 4, 2] [14, 13, 11, 9] [14, 10, 6, 1] [14, 11, 6, 1] [14, 12, 11, 1] [14, 6, 4, 2] [14, 11, 9, 6, 5, 2] [14, 13, 6, 5, 3, 1] [14, 13, 12, 8, 4, 1] [14, 8, 7, 6, 4, 2] [14, 10, 6, 5, 4, 1] [14, 13, 12, 7, 6, 3] [14, 13, 11, 10, 8, 3]
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]

Table 5-15. Feedback Connections for Linear *m*-Sequences (continued)*

Number of Stages	Code Length	Maximal Taps
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]

Table 5-15. Feedback Connections for Linear *m*-Sequences (continued)*

Number of Stages	Code Length	Maximal Taps
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]

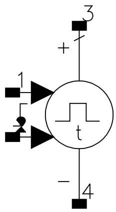
5. Table 5-16 lists the dc operating point parameters that can be sent to the dataset.

Table 5-16. DC Operating Point Information

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

VtOneShot (Voltage Source, Retriggerable Pulse Train)

Symbol



Parameters

Delay = time delay from trigger to pulse start (default: timestep)

Width = pulse width (default: 5*timestep)

Vhigh = pulse voltage (default: 5V)

Notes/Equations

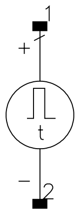
1. This source is implemented in FDD for use with transient and envelope simulations. The retriggerable one-shot is a predefined application of the retriggerable source VtRetrig. It outputs a pulse of amplitude Vhigh and specified width and delay after every trigger event. Due to the trigger delay of 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. Table 5-17 lists the dc operating point parameters that can be sent to the dataset.

Table 5-17. DC Operating Point Information

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

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

Symbol



Parameters

Vlow = initial voltage (default: 0V)

Vhigh = pulse voltage (default: 1V)

Delay = delay time (default: 0 nsec)

Edge = rising and falling edge type (default: linear)

Rise = rise time (default: 1 nsec)

Fall = fall time (default: 1 nsec)

Width = pulse width (default: 3 nsec)

Period = pulse period (default: 10 nsec)

SaveCurrent = save branch current: yes (default), no

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 Figure 5-7.)

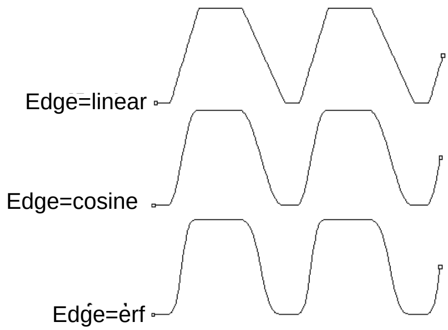


Figure 5-7. ItPulse Waveforms with Different Edges

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 Figure 5-8; the intermediate points during rise and fall time are determined by interpolation.

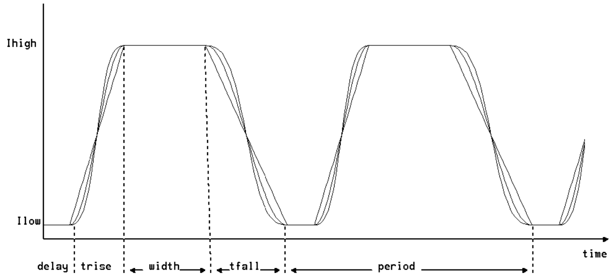


Figure 5-8. Waveform shape

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 Figure 5-7.)

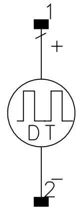
4. Table 5-18 lists the dc operating point parameters that can be sent to the dataset.

Table 5-18. DC Operating Point Information

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

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

Symbol



Parameters

Vlow = initial voltage (default: 0V)

Vhigh = pulse voltage (default: 1V)

Delay = time delay (default: 0 nsec)

Width = pulse width (default: 3 nsec)

Period = pulse period (default: 10 nsec)

Rout = output resistance (default: 1 ohm)

Notes/Equations

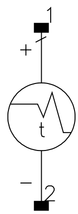
1. This source is used in envelope and transient simulations.
2. Period, Width, and Delay are rounded to the nearest integer multiple of the analysis time step. The pulse width must be an integer number of simulation time steps. The pulse source is in the high state for a time interval equal to Width, 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. Table 5-19 lists the dc operating point parameters that can be sent to the dataset.

Table 5-19. DC Operating Point Information

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

VtPWL (Voltage Source, Piecewise Linear)

Symbol



Parameters

V_Tran = time-voltage pairs: pwl(time, time-voltage pairs) or pwlr(time, Ncycles, time-voltage pairs)

SaveCurrent = save branch current: yes (default), no

Notes/Equations

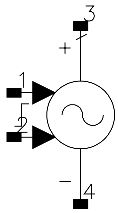
1. The piecewise linear voltage versus time data are specified with a pwl() function. The syntax for pwl is pwl(time, T_i, V_i, ...) . Each pair of values (T_i, V_i) specifies that at time = T_i, the voltage is V_i. The value of the source at intermediate values of time is determined by using linear 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. Table 5-20 lists the dc operating point parameters that can be sent to the dataset.

Table 5-20. DC Operating Point Information

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

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

Symbol



Parameters

V = user-defined waveform equation (default: 1us-(time-_tt(1)))

Rout = output resistance (default: 1 ohm)

Thresh = trigger threshold on rising edge (default: 0.5V)

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 msec after the trigger event.

   Figure 5-9 shows a more complicated example, where a function wav() is defined to create a truncated sinc() waveform, which is then generated following every trigger event. This wav() example function also uses the FDD function _tn() (the trigger count number) to linearly increase the sinc() waveform bandwidth with each new trigger. 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.
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.

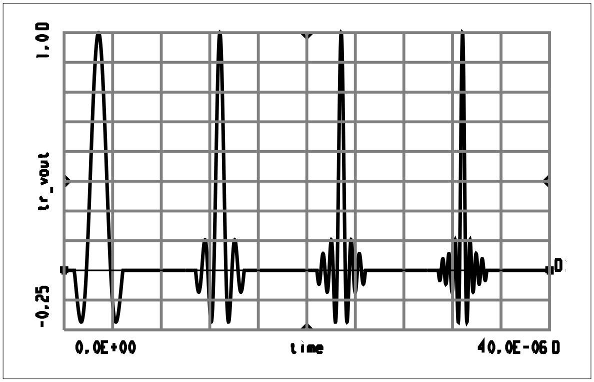


Figure 5-9. Truncated sinc() waveform

5. Table 5-21 lists the dc operating point parameters that can be sent to the dataset.

Table 5-21. DC Operating Point Information

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

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

Symbol

Parameters

Vdc = initial voltage offset (default: 0V)

Amplitude = amplitude of signal (default: 1V)

CarrierFreq = carrier frequency (default: 1 GHz)

ModIndex = modulation index (default: 0.5)

SignalFreq = signal frequency (default: 1 MHz)

SaveCurrent = save branch current: yes (default), no

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.

   $$Vout = Vdc + Amplitude \times \sin(2 \times \pi \times CarrierFreq \times time + ModIndex \times \sin(2 \times \pi \times SignalFreq \times time))$$

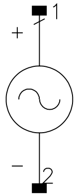
3. Table 5-22 lists the dc operating point parameters that can be sent to the dataset.

Table 5-22. DC Operating Point Information

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

VtSine (Voltage Source, Decaying Sine Wave)

Symbol



Parameters

Vdc = initial voltage offset (default: 0V)

Amplitude = amplitude of sinusoidal wave (default: 1V)

Freq = frequency of sinusoidal wave (default: 1 GHz)

Delay = time delay (default: 0 nsec)

Damping = damping factor, 1/sec (default: 0 1/sec)

Phase = initial phase value (default: 0)

SaveCurrent = save branch current: yes, no (default: 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.

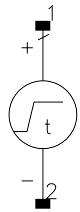
4. Table 5-23 lists the dc operating point parameters that can be sent to the dataset.

Table 5-23. DC Operating Point Information

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

VtStep (Voltage Source, Step)

Symbol



Parameters

Vlow = initial voltage (default: 0V)

Vhigh = pulse voltage (default: 1V)

Delay = delay time (default: 0 nsec)

Rise = rise time (default: 1 nsec)

SaveCurrent = save branch current: yes (default), no

Notes/Equations

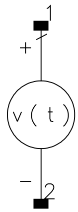
1. In SPICE, the equivalent to this source is a voltage source with the step waveform argument STEP and its parameters.
2. Table 5-24 lists the dc operating point parameters that can be sent to the dataset.

Table 5-24. DC Operating Point Information

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

VtUserDef (Voltage Source, User-Defined)

Symbol



Parameters

V_Tran = transient voltage (default: damped_sin(time))

Vdc = dc voltage

Vac = ac voltage (default: 1V)

SaveCurrent = save branch current: yes (default), no

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. Table 5-25 lists the dc operating point parameters that can be sent to the dataset.

Table 5-25. DC Operating Point Information

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