A Guide
To The
RF/Analog Library
Table of Contents

RF/Analog Library -- Tokens Listed by Group................................................................. 5
RF/Analog Library -- Token Abbreviations Listed Alphabetically....................................... 7
RF/Analog Library -- Introduction......................................................................................... 9
RF/Analog Library -- Token Descriptions ................................................................................ 10
Appendix A -- Features Common to the Circuit-type Tokens............................................... 98
Appendix B -- Noise Figure Calculations............................................................................. 100
Appendix C -- Amplifier and Active Mixer Characteristics................................................... 120
## Amplifiers and Mixers

<table>
<thead>
<tr>
<th>Abbrev:</th>
<th>Token Name:</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amp-Fixed</td>
<td>Amplifier, Fixed</td>
<td>11</td>
</tr>
<tr>
<td>Amp-TWT</td>
<td>Amplifier, Traveling Wave Tube</td>
<td>15</td>
</tr>
<tr>
<td>Amp-VG</td>
<td>Amplifier with Variable Gain</td>
<td>17</td>
</tr>
<tr>
<td>Attn-Fixed</td>
<td>Attenuator, Fixed</td>
<td>21</td>
</tr>
<tr>
<td>Mix-Act</td>
<td>Mixer, Double-Balanced, Active</td>
<td>45</td>
</tr>
<tr>
<td>Mix-Psv</td>
<td>Mixer, Double-Balanced, Passive</td>
<td>49</td>
</tr>
</tbody>
</table>

## Operational Amplifier Circuits

<table>
<thead>
<tr>
<th>Abbrev:</th>
<th>Token Name:</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Op-Buff</td>
<td>Op-amp Buffer circuit (non-inverting)</td>
<td>54</td>
</tr>
<tr>
<td>Op-Hyst</td>
<td>Op-amp Hysteresis circuit</td>
<td>55</td>
</tr>
<tr>
<td>Op-I-Dmp</td>
<td>Op-amp Integrate and Dump circuit</td>
<td>57</td>
</tr>
<tr>
<td>Op-Invert</td>
<td>Op-amp Inverter, single input circuit</td>
<td>59</td>
</tr>
<tr>
<td>Op-PID</td>
<td>Op-amp PID circuit</td>
<td>60</td>
</tr>
<tr>
<td>Op-PLL1</td>
<td>Op-amp PLL filter, single input circuit</td>
<td>62</td>
</tr>
<tr>
<td>Op-PLL2</td>
<td>Op-amp PLL filter, differential input circuit</td>
<td>64</td>
</tr>
<tr>
<td>Op-Sum3</td>
<td>Op-amp Sum of 3 inputs circuit</td>
<td>66</td>
</tr>
</tbody>
</table>

## RC Circuits

<table>
<thead>
<tr>
<th>Abbrev:</th>
<th>Token Name:</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>RC-Cpump</td>
<td>RC Charge Pump circuit</td>
<td>86</td>
</tr>
<tr>
<td>RC-Diff</td>
<td>RC Differentiator circuit</td>
<td>88</td>
</tr>
<tr>
<td>RC-Hpf</td>
<td>RC High Pass Filter circuit</td>
<td>90</td>
</tr>
<tr>
<td>RC-I-Dmp</td>
<td>RC Integrate and Dump circuit</td>
<td>92</td>
</tr>
<tr>
<td>RC-Lpf</td>
<td>RC Low Pass Filter circuit</td>
<td>94</td>
</tr>
<tr>
<td>RC-PLL</td>
<td>RC PLL Filter circuit</td>
<td>96</td>
</tr>
</tbody>
</table>
LC Circuits

Abbrev: Token Name:
LC-Hpf ........... LC High Pass Filter circuit ................................................................. 33
LC-Lpf ............ LC Low Pass Filter circuit ................................................................. 35
LC Lpfs ........... LC simple Low Pass Filter circuit ....................................................... 37
LC-Quad .......... LC Quadrature tank circuit ............................................................... 39
LC-Resn .......... LC Capacitive-Coupled Resonator circuit ......................................... 41
LC-Tank .......... LC Tank circuit ............................................................................... 43

Power Combiners and Splitters

Abbrev: Token Name:
PCmb 180 ........ Power Combiner: 2-Way, 180-Degree ................................................. 68
PCmb-2 ........... Power Combiner: 2-Way, 0-Degree ....................................................... 69
PCmb-3 ........... Power Combiner: 3-Way, 0-Degree ....................................................... 70
PCmb-4 ........... Power Combiner: 4-Way, 0-Degree ....................................................... 72
PCoupler .......... Power Coupler: 2-Way, 0-Degree ......................................................... 74
PSplit 180 ........ Power Splitter: 2-Way, 180-Degree ....................................................... 76
PSplit-2 ........... Power Splitter: 2-Way, 0-Degree ......................................................... 78
PSplit-3 ........... Power Splitter: 3-Way, 0-Degree ......................................................... 80
PSplit-4 ........... Power Splitter: 4-Way, 0-Degree ......................................................... 82
PSplit 90 .......... Power Splitter: 2-Way, 90-Degree (Hilbert) ......................................... 84

Diode Circuits

Abbrev: Token Name:
D-Anode .......... Diode circuit with input to the Anode .................................................. 23
D-Cath ............ Diode circuit with input to the Cathode ............................................... 25
D-Zen-2 .......... Diode, Zener circuit with back-to-back pair ........................................ 27
D-Zen-An ........ Diode, Zener circuit with input to the Anode ....................................... 29
D-Zen-Ca ........ Diode, Zener circuit with input to the Cathode ..................................... 31
<table>
<thead>
<tr>
<th>Abbrev</th>
<th>Token Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amp-Fixed</td>
<td>Amplifier, Fixed</td>
</tr>
<tr>
<td>Amp-TWT</td>
<td>Amplifier, Traveling Wave Tube</td>
</tr>
<tr>
<td>Amp-VG</td>
<td>Amplifier with Variable Gain</td>
</tr>
<tr>
<td>Attn-Fixed</td>
<td>Attenuator, Fixed</td>
</tr>
<tr>
<td>D-Anode</td>
<td>Diode circuit with input to the Anode</td>
</tr>
<tr>
<td>D-Cath</td>
<td>Diode circuit with input to the Cathode</td>
</tr>
<tr>
<td>D-Zen-2</td>
<td>Diode, Zener circuit with back-to-back pair</td>
</tr>
<tr>
<td>D-Zen-An</td>
<td>Diode, Zener circuit with input to the Anode</td>
</tr>
<tr>
<td>D-Zen-Ca</td>
<td>Diode, Zener circuit with input to the Cathode</td>
</tr>
<tr>
<td>LC-Hpf</td>
<td>LC High Pass Filter circuit</td>
</tr>
<tr>
<td>LC-Lpf</td>
<td>LC Low Pass Filter circuit</td>
</tr>
<tr>
<td>LC Lpfs</td>
<td>LC simple Low Pass Filter circuit</td>
</tr>
<tr>
<td>LC-Quad</td>
<td>LC Quadrature tank circuit</td>
</tr>
<tr>
<td>LC-Resn</td>
<td>LC Capacitive-Coupled Resonator circuit</td>
</tr>
<tr>
<td>LC-Tank</td>
<td>LC Tank circuit</td>
</tr>
<tr>
<td>Mix-Act</td>
<td>Mixer, Double-Balanced, Active</td>
</tr>
<tr>
<td>Mix-Psv</td>
<td>Mixer, Double-Balanced, Passive</td>
</tr>
<tr>
<td>Op-Buff</td>
<td>Op-amp Buffer circuit (non-inverting)</td>
</tr>
<tr>
<td>Op-Hyst</td>
<td>Op-amp Hysteresis circuit</td>
</tr>
<tr>
<td>Op-I-Dmp</td>
<td>Op-amp Integrate and Dump circuit</td>
</tr>
<tr>
<td>Op-Invert</td>
<td>Op-amp Inverter, single input circuit</td>
</tr>
<tr>
<td>Op-PID</td>
<td>Op-amp PID circuit</td>
</tr>
<tr>
<td>Op-PLL1</td>
<td>Op-amp PLL filter, single input circuit</td>
</tr>
<tr>
<td>Op-PLL2</td>
<td>Op-amp PLL filter, differential input circuit</td>
</tr>
<tr>
<td>Op-Sum3</td>
<td>Op-amp Sum of 3 inputs circuit</td>
</tr>
<tr>
<td>Abbrev</td>
<td>Token Name</td>
</tr>
<tr>
<td>---------</td>
<td>------------------------------------------------</td>
</tr>
<tr>
<td>PCmb 180</td>
<td>Power Combiner: 2-Way, 180-Degree</td>
</tr>
<tr>
<td>PCmb-2</td>
<td>Power Combiner: 2-Way, 0-Degree</td>
</tr>
<tr>
<td>PCmb-3</td>
<td>Power Combiner: 3-Way, 0-Degree</td>
</tr>
<tr>
<td>PCmb-4</td>
<td>Power Combiner: 4-Way, 0-Degree</td>
</tr>
<tr>
<td>PCoupler</td>
<td>Power Coupler: 2-Way, 0-Degree</td>
</tr>
<tr>
<td>PSplit 180</td>
<td>Power Splitter: 2-Way, 180-Degree</td>
</tr>
<tr>
<td>PSplit-2</td>
<td>Power Splitter: 2-Way, 0-Degree</td>
</tr>
<tr>
<td>PSplit-3</td>
<td>Power Splitter: 3-Way, 0-Degree</td>
</tr>
<tr>
<td>PSplit-4</td>
<td>Power Splitter: 4-Way, 0-Degree</td>
</tr>
<tr>
<td>PSplit 90</td>
<td>Power Splitter: 2-Way, 90-Degree (Hilbert)</td>
</tr>
<tr>
<td>RC-Cpump</td>
<td>RC Charge Pump circuit</td>
</tr>
<tr>
<td>RC-Diff</td>
<td>RC Differentiator circuit</td>
</tr>
<tr>
<td>RC-Hpf</td>
<td>RC High Pass Filter circuit</td>
</tr>
<tr>
<td>RC-I-Dmp</td>
<td>RC Integrate and Dump circuit</td>
</tr>
<tr>
<td>RC-Lpf</td>
<td>RC Low Pass Filter circuit</td>
</tr>
<tr>
<td>RC-PLL</td>
<td>RC PLL Filter circuit</td>
</tr>
</tbody>
</table>
RF/ANALOG LIBRARY

Introduction
The SystemView RF/Analog Library contains a comprehensive set of tools to aid in the rapid design and simulation of modern RF and analog systems. The SystemView RF/Analog Library supports the important electronic components used in today’s designs, such as amplifiers and attenuators, active and passive mixers, power splitters and combiners, and various RC and LC filters. There is also an assortment of op-amp circuits featuring both positive and negative feedback.

The particulars for each function are detailed in this manual. They are listed in alphabetical order for convenience. For each token, there is a description of its operation and the required user inputs.
**Token Name:** Amplifier, Fixed  
**Abbreviation:** Amp-Fixed  
**Group:** Amplifiers and Mixers

**Synopsis:**
This token models an analog amplifier including its nonlinear characteristics. All power measurements are referenced to a 50-ohm system.

**See Also:**
Amp-VG (Variable Gain Amplifier)

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gain (dB):</td>
<td>GdB</td>
<td>The fixed gain of the amplifier.</td>
</tr>
<tr>
<td>Out IP2 (dBm):</td>
<td>Out IP2</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms $(f_{r1} - f_{r2})$ and $(f_{r2} - f_{r1})$, equal the output power of direct terms $(f_{r1})$ and $(f_{r2})$. As a rule, the 2nd order point is 18 to 20 dB above the Out P1dB compression point.</td>
</tr>
<tr>
<td>Out IP3 (dBm):</td>
<td>Out IP3</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms $(2f_{r1} \pm f_{r2})$, and $(2f_{r2} \pm f_{r1})$, are equal to the output power of the direct terms $(f_{r1})$ and $(f_{r2})$. As a general rule, the 3rd order point is about 10 dB above the Out P1dB compression point.</td>
</tr>
<tr>
<td>Out IP4 (dBm):</td>
<td>Out IP4</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms $(2f_{r1} \pm 2f_{r2})$, are equal to the output power of the direct terms $(f_{r1})$ and $(f_{r2})$.</td>
</tr>
<tr>
<td>Out P1dB (dBm):</td>
<td>Out P1dB</td>
<td>The Out 1 dB compression point is the output RF power for which the output signal is 1 dB less than the small signal gain.</td>
</tr>
</tbody>
</table>
Parameters continued:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise figure (dB):</td>
<td>NF</td>
<td>Noise figure for thermal noise.</td>
</tr>
<tr>
<td>Enable/disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise.</td>
</tr>
</tbody>
</table>

Notes: Refer to Appendix for Amplifier and Active Mixer characteristics.

Token Inputs:
- Signal.

Token Outputs:
- 0: Signal
- 1: Signal, inverted

Discussion:
In addition to the fundamental frequency, this token generates the second and third harmonics. The amplifier is modeled by a polynomial.

Please refer to the appendix, Amplifier and Active Mixer Characteristics, for information on entering the parameter values when only a limited amount of parameter information is known. The block diagram for this token is shown below:

![Block diagram of the token](image-url)
Examples:
The first example file is `rflib\bfsk-b2.svu`. This file is a somewhat detailed binary FSK transmitter and receiver, including BER (bit error rate) measurement. (Note: An application note is available on the SystemView CD.) In this example, several amplifiers are used. Their parameters have been set to model the following amplifiers:

- Power amplifier
- Monolithic amplifier (low power)
- LNA (low noise amplifier)
- FM limiting amplifier.

Another example file is `rflib\dsss-tr2.svu` and (`dsss-ev.svu`). This is a detailed direct sequence spread spectrum system that uses a transmitted reference (to simplify the de-spreading example). A third example file is `rflib\costas-r.svu`. This is a stand-alone Costas loop.

Input Third Order Intercept Point (In IP3) for a typical RF amplifier.
**Token Name:** Amplifier, Traveling Wave Tube  
**Abbreviation:** Amp-TWT  
**Group:** Amplifiers and Mixers

**Synopsis:**  
This token implements a model for a traveling wave tube amplifier (TWTA). The model as described below, depends on 4 parameters that are determined by fitting the model to actual amplifier performance data.

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a_r$</td>
<td>$a$</td>
<td>Small signal AM/AM parameter</td>
</tr>
<tr>
<td>$b_r$</td>
<td>$b$</td>
<td>Large signal AM/AM parameter</td>
</tr>
<tr>
<td>$a_\phi$</td>
<td>$a_\phi$</td>
<td>Small signal AM/PM parameter</td>
</tr>
<tr>
<td>$b_\phi$</td>
<td>$b_\phi$</td>
<td>Large signal AM/PM parameter</td>
</tr>
</tbody>
</table>

The four parameters $a_r, b_r, a_\phi, b_\phi$ pertain to the empirical modeling curve described below.

**Token Inputs:**  
- The signal $x(t)$ to be amplified by the TWTA

**Token Outputs:**  
- The amplified signal $y(t)$

**Discussion:**  
The TWTA is a nonlinear amplifier used extensively on communications satellites. For an input sine wave of the form:

$$x(t) = r(t) \cos(2\pi f_0 t + \psi(t))$$
The output of the TWTA is given by:

\[ y(t) = A[r(t)] \cos(2\pi f_0 t + \psi(t) + \phi[r(t)] \) 

In other words the output amplitude and phase of the TWTA are dependent on the input amplitude r(t).

The model used, is described in [1] as a two parameter model of the form:

\[ A(r) = a_r r / (1 + b_r r^2) \]

\[ \phi(r) = a_\phi r^2 / (1 + b_\phi r^2) \]

The four coefficients are determined by a least square fit to actual measured data. The term \( a_r \) is the small signal linear gain of the TWTA.

**Implementation Note**

The token employs a Hilbert transform filter that has a valid frequency response from .05 fs to .45 fs, where fs is the system sample rate.
Examples:
\rf\lib\TWTA-1.svu

References
Token Name: Amplifier with Variable Gain
Abbreviation: Amp-VG
Group: Amplifiers and Mixers

Synopsis:
An adjustable attenuator precedes the input to the amplifier, (including its nonlinear characteristics). A second input to the token functions as a gain control that is "linear in dB". All power measurements are referenced to 50 ohms.

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Gain (dB):</td>
<td>GdB</td>
<td>The fixed gain of the amplifier.</td>
</tr>
<tr>
<td>Out IP2 (dBm):</td>
<td>Out IP2</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms ((f_{rf2} - f_{rf1})) and ((f_{rf1} - f_{rf2})), are equal to the output power of the direct terms ((f_{rf1})) and ((f_{rf2})). Generally, the 2nd order point is 18 to 20 dB above the Out P1dB compression point.</td>
</tr>
<tr>
<td>Out IP3 (dBm):</td>
<td>Out IP3</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms ((2f_{rf1} \pm f_{rf2})) and ((2f_{rf2} \pm f_{rf1})), are equal to the output power of the direct terms ((f_{rf1})) and ((f_{rf2})). Generally, the 3rd order point is 10 dB above the Out P1dB compression point.</td>
</tr>
<tr>
<td>Out IP4 (dBm):</td>
<td>Out IP4</td>
<td>The output RF power of two tones, for which the output power of the harmonic terms ((2f_{rf1} \pm 2f_{rf2})), are equal to the output power of the direct terms ((f_{rf1})) and ((f_{rf2})).</td>
</tr>
<tr>
<td>Out P1dB (dBm):</td>
<td>Out P1dB</td>
<td>The Out 1 dB compression point is the output RF power for which the output signal is 1 dB less than the small signal gain.</td>
</tr>
</tbody>
</table>
Parameters continued:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise Figure (dB):</td>
<td>NF</td>
<td>Noise figure for thermal noise.</td>
</tr>
<tr>
<td>Attenuator Loss @ 0V (dB):</td>
<td>LdB</td>
<td>Attenuator Loss at 0 volts. The attenuator is resistive, it can have 0 loss, or a large loss (500dB). It cannot have Gain.</td>
</tr>
<tr>
<td>Slope (dB/V):</td>
<td>SdB</td>
<td>Scale factor of gain control.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise.</td>
</tr>
</tbody>
</table>

*Notes: Refer to appendix for Amplifier and Active Mixer Characteristics.*

**Token Inputs:**
- 0: Signal
- 1: Gain Control

**Token Outputs:**
- 0: Signal
- 1: Signal, inverted

**Discussion:**
Besides the fundamental frequency this token will generate harmonics. The block diagram for this token is shown below.

![Block Diagram](image_url)
Typical parameter values for the amplifier are shown below:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Gain (dB)</td>
<td>30 dB</td>
</tr>
<tr>
<td>Atten. Loss @ 0V (dB)</td>
<td>20 dB</td>
</tr>
<tr>
<td>Slope (dB/V)</td>
<td>32 dB/V</td>
</tr>
</tbody>
</table>

The resulting amplifier would operate as follows:

<table>
<thead>
<tr>
<th>Gain Control (volts)</th>
<th>Fixed Gain (dB)</th>
<th>dB Atten. at zero volts</th>
<th>Control Atten. (dB)</th>
<th>Resulting Gain (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>+1.0 volts</td>
<td>30</td>
<td>20</td>
<td>-20</td>
<td>30</td>
</tr>
<tr>
<td>+0.625 volts</td>
<td>30</td>
<td>20</td>
<td>-20</td>
<td>30</td>
</tr>
<tr>
<td>+0.5 volts</td>
<td>30</td>
<td>20</td>
<td>-16</td>
<td>26</td>
</tr>
<tr>
<td>0.0 volts</td>
<td>30</td>
<td>20</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>-0.5 volts</td>
<td>30</td>
<td>20</td>
<td>+16</td>
<td>-6</td>
</tr>
<tr>
<td>-1.0 volts</td>
<td>30</td>
<td>20</td>
<td>+32</td>
<td>-22</td>
</tr>
<tr>
<td>-2.0 volts</td>
<td>30</td>
<td>20</td>
<td>+64</td>
<td>-54</td>
</tr>
</tbody>
</table>

Note that the resulting Gain can never be more than the fixed Gain.

**Examples:**
See the example file `\rflib\vga-pn.svu`. 
Input Third Order Intercept Point (In IP3) for a typical RF amplifier.
Token Name: Attenuator, Fixed
Abbreviation: Attn-Fixed
Group: Amplifiers and Mixers

Synopsis: The attenuator reduces the power level of a signal.

See Also: None

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss (dB);</td>
<td>LdB</td>
<td>The loss in dB is entered as a positive number or zero.</td>
</tr>
<tr>
<td>Enable/disable noise:</td>
<td></td>
<td>This button enables/disables thermal noise. Since the attenuator is passive, the noise figure (NF) value is equal to the loss (LdB) parameter.</td>
</tr>
</tbody>
</table>

Token Inputs:
- The signal x(t) which is to be attenuated.

Token Outputs:
- The attenuated signal y(t).

Discussion:
\[ y(t) = 10^{-\frac{LdB}{20}} x(t) + Noise \]
Example:
The example file `/rflib/bfsk-b2.svu` uses the attenuator to give a filter a loss in the pass-band, and the filter exhibits a noise figure. Since the attenuator is passive, the noise figure (NF) value equals the loss (LdB) parameter.
**Token Name:** Diode Circuit with Input to the Anode  
**Abbreviation:** D-Anode  
**Group:** Diode Circuits

**Synopsis:**  
This circuit simulates one diode as the pass through element and one resistor to ground as a load. The input is applied to the anode, and the output is taken from the cathode. This token allows the user to create various diode models. A typical example is a half-wave rectifier.

**See Also:**  
D-Cath

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss (dB):</td>
<td>LdB</td>
<td>Loss in dB.</td>
</tr>
<tr>
<td>Fwd V-On (v):</td>
<td>Vf</td>
<td>Forward voltage drop.</td>
</tr>
<tr>
<td>Trans Width (v):</td>
<td>dv</td>
<td>Width of region to achieve full turn on.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button enables or disables the thermal noise. The value of the noise figure (NF) is equal to the loss (LdB) parameter.</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- Signal

**Token Outputs:**  
- Output of diode circuit.
Discussion:
The input parameters above refer to the voltage-out versus voltage-in curve for the diode-resistor circuit. The diode output is zero until the signal increases to a positive value, equal to the turn on voltage minus half the transition voltage width (i.e., Vf-dv/2). The diode is fully turned on at the turn on voltage, plus half the transition voltage width (i.e., Vf+dv/2), and thereafter passes the signal with a given loss.

Vf is entered as a positive number. This circuit requires a positive input signal for the diode to be forward biased. Because the output resistor of the circuit is not available to the user, the LdB, Vf, and dv values are entered in iterations until the desired transfer function is achieved.

Note: The output signal of SystemView tokens, including all Diode tokens, is either a zero value (volts) or a positive or negative value. There is no high impedance state. If a filter is connected to the output of a diode token, the filter will be discharged to zero as quickly as it was charged to its signal value regardless of the diode biasing.

Examples:
See example file \rflib\diode.svu. In this example a 1N914 diode is used in two circuits. One simulates a 1K-load resistor, and the other a 50-ohm load.

In the example file \rflib\envp-det.svu, the D-Anode is combined with the Op-Hyst and RC-Cpump to perform RF envelope detection.
Token Name: Diode Circuit with Input to the Cathode
Abbreviation: D-Cath
Group: Diode Circuits

Synopsis:
This circuit simulates one diode as the pass through element and one resistor to ground as the load. The input is applied to the cathode, and the output is taken from the anode of the diode. This token allows the user to create various diode models. A typical example is a half-wave rectifier.

See Also:
D-Anode.

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss (dB):</td>
<td>LdB</td>
<td>Loss.</td>
</tr>
<tr>
<td>Fwd V-On (v):</td>
<td>Vf</td>
<td>Forward voltage drop.</td>
</tr>
<tr>
<td>Trans Width (v):</td>
<td>dv</td>
<td>Width of region to achieve full turn on.</td>
</tr>
<tr>
<td>Enable/Disable noise figure</td>
<td></td>
<td>Enable or disable thermal noise. The value of the noise figure (NF) is equal to the loss (LdB) parameter.</td>
</tr>
</tbody>
</table>

Token Inputs:
• Signal

Token Outputs:
• Output of diode
Discussion:
The input parameters above refer to the voltage out versus voltage in curve for the diode-resistor circuit. The diode output is zero until the signal decreases to a negative value equal to the negative of the turn on voltage plus half the transition voltage width (i.e., $-V_f+dv/2$).

The diode is fully turned on at the negative of the turn on voltage, minus half the transition voltage width (i.e., $-V_f-dv/2$), and thereafter passes the signal with a given loss.

$V_f$ is entered as a positive number. This circuit requires a negative input signal for the diode to be forward biased.

Because the output resistor of the circuit is not available to the user, the LdB, $V_f$, and $dv$ values are entered in iterations until the desired transfer function is achieved.

Note: The output signal of SystemView tokens, including all Diode tokens, is either a zero value (volts) or a positive or negative value. There is no high impedance state. If a filter is connected to the output of a diode token, the filter will be discharged to zero as quickly as it was charged to its signal value regardless of the diode biasing.

Examples:
See example file \rflib\diode.svu. In this example a 1N914 diode is used in two circuits. One circuit simulates a 1K-load resistor, the other a 50-ohm load.
**Token Name:** Diode, Zener Circuit with Back-to-Back Pair  
**Abbreviation:** D-Zen-2  
**Group:** Diode Circuits

**Synopsis:**  
This token models a circuit that has one resistor as a pass-through element and a pair of back-to-back Zener diodes as the load. The input is applied to one end of the pass through resistor. The output is taken from the junction of the opposite end of the resistor, and the ungrounded end of the Zener diode pair. The parameters allow various Zener diode models to be created. A typical use would be a symmetrical clipper.

**See Also:**  
D-Zen-An, D-Zen-Ca

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd V1-On (v):</td>
<td>Vf1</td>
<td>Forward voltage where diode 1 (D1) turns on.</td>
</tr>
<tr>
<td>Rev V1-On (v):</td>
<td>Vz1</td>
<td>Reverse voltage where diode 1 (D1) turns on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Voltage at Iz)</td>
</tr>
<tr>
<td>Rev I-On (mA):</td>
<td>Iz</td>
<td>Reverse current where both diodes turn on.</td>
</tr>
<tr>
<td>Rzener (ohms):</td>
<td>Rz</td>
<td>dV/dI in Zener operation region</td>
</tr>
<tr>
<td>Fwd V2-On (v):</td>
<td>Vf2</td>
<td>Forward voltage where diode 2 (D2) turns on.</td>
</tr>
<tr>
<td>Rev V2-On (v):</td>
<td>Vz2</td>
<td>Reverse voltage where diode 2 (D2) turns on.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Voltage at Iz)</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button enables or disables the thermal noise. The value of the noise figure (NF) is a function of the Zener resistance and the 50-ohm resistor, R0.</td>
</tr>
</tbody>
</table>
**Token Inputs:**
- Signal

**Token Outputs:**
- Signal

**Discussion:**
The input parameters above refer to the Zener diode characteristic curve, which produces current through the diode as a function of the voltage across it (i.e., the I-V curve). The Vf and Vz values bound the output of the Zener diode. An input resistor of 50 Ω is used within the model.

Vf1 and Vf2 are entered as positive numbers.

Vz1 and Vz2 are entered in volts as positive numbers.

Iz is entered in mA as a positive number.

Because the input resistor of the circuit is fixed at 50-ohms, the Rz value is entered as a ratio of the 50-ohm resistor to the actual Zener impedance.

**Examples:**
See example file `\rf\lib\zener.svu`.

---

**RF/Analog Library**
**Token Name:** Diode, Zener Circuit with Input to the Anode  
**Abbreviation:** D-Zen-An  
**Group:** Diode Circuits

** Synopsis:**
This circuit has one resistor as the pass-through element and one Zener diode to ground as the load. The input is applied to the pass-through resistor. The output is taken from the anode of the diode. The parameters allow various Zener diode models to be created. A typical use is a one-sided negative clipper.

**See Also:**
D-Zen-Ca, D-Zen-2

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd V-On (v):</td>
<td>Vf</td>
<td>The voltage at which the Zener diode starts to conduct in the forward direction.</td>
</tr>
<tr>
<td>Rev V-On (v):</td>
<td>Vz</td>
<td>The voltage seen across the Zener diode with Iz flowing through it.</td>
</tr>
<tr>
<td>Rev I-On (mA):</td>
<td>Iz</td>
<td>The test current flowing through the Zener diode that corresponds to Vz.</td>
</tr>
<tr>
<td>Rzener (ohms):</td>
<td>Rz</td>
<td>The internal impedance of the Zener diode that produces the dV/dI in the region of Zener operation.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button enables or disables the thermal noise. The value of the noise figure (NF) is a function of the Zener resistance and the 50-ohm resistor, R0.</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- Signal
Discussion:
The preceding input parameters refer to the Zener diode characteristic curve that produces voltage across the diode, as a function of the current through it (i.e., the I-V curve). The Vf and Vz values bound the output of the reverse Zener diode. An input resistor of 50 Ω is used.

Vf is entered as a positive number. This circuit requires a positive input signal for the diode to be forward biased.

Vz is entered in volts as a positive number. This circuit requires a negative input signal for the diode to operate in the Zener region.

Iz is entered in mA as a positive number.

Because the input resistor of the circuit is fixed at 50 ohms, the Rz value is entered as a ratio of the 50-ohm resistor to the actual Zener impedance.

Examples:
With a forward voltage of 0.6 V, a Zener voltage of 6.8 V, at a current of 20 mA, a Zener resistance of 0.001 Ω, and a sinusoidal input with an amplitude of 10, the negative output is clipped at -6.8 V, while the positive values are clipped at 0.6 V. See example files \rflib\zener.svu and \rflib\diode.svu.
**Token Name:** Diode, Zener Circuit with Input to the Cathode  
**Abbreviation:** D-Zen-Ca  
**Group:** Diode Circuits

**Synopsis:**
This circuit has one resistor as the pass-through element and one Zener diode to ground as the load. The input is applied to the pass-through resistor. The output is taken from the cathode of the diode. The parameters allow various Zener diode models to be created. A typical use is a one-sided positive clipper.

**See Also:**
D-Zen-An, D-Zen-2

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fwd V-On (v):</td>
<td>( V_f )</td>
<td>The voltage at which the Zener diode starts to conduct in the forward direction.</td>
</tr>
<tr>
<td>Rev V-On (v):</td>
<td>( V_z )</td>
<td>The voltage seen across the Zener diode with ( I_z ) flowing through it.</td>
</tr>
<tr>
<td>Rev I-On (mA):</td>
<td>( I_z )</td>
<td>The test current flowing through the Zener diode that produces ( V_z ).</td>
</tr>
<tr>
<td>Rzener (ohms):</td>
<td>( R_z )</td>
<td>The internal impedance of the Zener diode that produces the ( dV/dI ) in the region of Zener operation.</td>
</tr>
</tbody>
</table>

Enable/Disable noise figure:
This button enables or disables the thermal noise. The value of the noise figure (NF) is a function of the Zener resistance and the 50-ohm resistor, \( R_0 \).

**Token Inputs:**
- Signal

**Token Outputs:**
- Output of diode
Discussion:
The input parameters above refer to the Zener diode characteristic curve, which produces voltage across the diode as a function of the current through it (i.e., the I-V curve). The Vf and Vz values bound the output of the Zener diode. An input resistor of 50 Ω is used.

Vf is entered as a positive number. This circuit requires a negative input signal for the diode to be forward biased.

Vz is entered in volts as a positive number. This circuit requires a positive input signal for the diode to operate in the Zener region.

Iz is entered in mA as a positive number.

Because the input resistor of the circuit is fixed at 50-ohms, the Rz value is entered as a ratio of the 50-ohm resistor to the actual Zener impedance.

Examples:
With a forward voltage of 0.6 V, a Zener voltage of 6.8 V, at a current of 20 mA, a Zener resistance of .001 Ω, and a sinusoidal input with an amplitude of 10, the positive output is clipped at 6.8 V, while the negative values are clipped at -0.6 V. See example file \rflib\zener.svu.
Token Name: LC High Pass Filter Circuit  
Abbreviation: LC-Hpf  
Group: LC Circuits

Synopsis:  
This token models LC high pass filters up to 7 poles.

See Also: None

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors (source and load)</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2, C3</td>
<td>4 capacitors</td>
</tr>
<tr>
<td>Inductors</td>
<td>L0, L1, L2</td>
<td>3 inductors</td>
</tr>
<tr>
<td>Inductor Q</td>
<td>Q0, Q1, Q2</td>
<td>Quality factors of the 3 inductors</td>
</tr>
</tbody>
</table>

Token Inputs:  
• Signal

Token Outputs:  
• Signal

Discussion:  
The inductor quality factor Q corresponding to an inductor L is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \frac{1 + Q^2}{Q}$$

Where $f$ is the cut-off frequency.

This filter has a 6 dB loss in the passband when the external termination resistors R0 and R1 are equal. This loss occurs because the external termination resistors are included as part of the model. To overcome the loss, use an operator library token after the filter, and set its linear gain to 2.
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None

References:
Token Name: LC Low Pass Filter Circuit
Abbreviation: LC-Lpf
Group: LC Circuits

Synopsis:
This token models LC low pass filters up to 7 poles, including elliptic filters.

See Also:
LC-Lpfs

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors (source and load)</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2, C3, C4, C5, C6</td>
<td>7 capacitors</td>
</tr>
<tr>
<td>Inductors</td>
<td>L0, L1, L2</td>
<td>3 inductors</td>
</tr>
<tr>
<td>Inductor Q</td>
<td>Q0, Q1, Q2</td>
<td>Quality factors of the 3 inductors</td>
</tr>
</tbody>
</table>

Token Inputs:
- Signal

Token Outputs:
- Signal

Discussion:
The inductor quality factor $Q$ corresponding to an inductor $L$ is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \left(1 + \frac{Q^2}{Q}\right)$$

Where $f$ is the cutoff frequency.
This filter has a 6 dB loss in the passband when the resistors R0 and R1 are equal to each other. This loss occurs because the external termination resistors R0 and R1 are included as part of the filter model. To overcome this loss, use an operator library token after the filter, and set its linear gain to 2.

The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

![Circuit Diagram](image)

**Examples:**
See example file `\rflib\costas-r.svu`. In this example a filter is used at each of the two mixer outputs to smooth the I and Q data for viewing.

**References:**
**Token Name:** LC simple Low Pass Filter Circuit

**Abbreviation:** LC Lpfs

**Group:** LC Circuits

**Synopsis:**
This token models various one or two pole low pass filters that may exhibit peaking.

**See Also:**
LC-Lpf

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
<tr>
<td>Inductor</td>
<td>L0</td>
<td>1 inductor</td>
</tr>
<tr>
<td>Quality Factor</td>
<td>Q0</td>
<td>Quality factor of the inductor</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- Signal

**Discussion:**
The inductor quality factor $Q$ corresponding to an inductor $L$ is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \left( \frac{1 + Q^2}{Q} \right)$$

Where $f$ is the cutoff frequency.
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
Token Name: LC Quadrature Tank Circuit
Abbreviation: LC-Quad
Group: LC Circuits

Synopsis:
This token models the classic FM quadrature detector. The input to this phase-shift network could be a sine wave, but it is usually a FM square wave from a limiter amplifier. The output from the phase-shift network will be a sine wave shifted almost 90 degrees from the input (the parallel tuned circuit will filter out most of the square-wave harmonics). At frequencies below the center frequency, the phase shift will be increased, and at higher frequencies, the shift will be decreased. Normally the input and output of this circuit are applied to an analog multiplier, and then a low-pass filter to complete the FM detector. Sometimes, an exclusive-OR gate is used in place of the analog multiplier.

See Also:
LC-Tank

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistor</td>
<td>R0</td>
<td>1 resistor</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1</td>
<td>2 capacitors</td>
</tr>
<tr>
<td>Inductor</td>
<td>L0</td>
<td>1 inductor</td>
</tr>
<tr>
<td>Quality Factor</td>
<td>Q0</td>
<td>Quality factor of the inductor</td>
</tr>
</tbody>
</table>

Token Inputs:
- Signal

Token Outputs:
- Signal
**Discussion:**
The inductor quality factor $Q$ corresponding to an inductor $L$ is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \left(1 + \frac{Q^2}{Q}\right)$$

Where $f$ is the cut-off frequency.

The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

![Circuit Diagram]

**Examples:**
In the example file `\rflib\bfsk-b4.svu`, the LC-Quad circuit is used together with an analog multiplier as a demodulator in a binary FSK (frequency shift keying) transmitter/receiver system.
Token Name: LC Capacitive-Coupled Resonator Circuit  
Abbreviation: LC-Resn  
Group: LC Circuits

Synopsis:  
This token models an LC bandpass filter. The two-coupled resonators produce a 4-pole narrow-band filter.

See Also:  
LC Quad, LC Tank

Parameters:  
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2</td>
<td>3 capacitors</td>
</tr>
<tr>
<td>Inductors</td>
<td>L0, L1</td>
<td>2 inductors</td>
</tr>
<tr>
<td>Inductor Q</td>
<td>Q0, Q1</td>
<td>The quality factor (Q)</td>
</tr>
</tbody>
</table>

Token Inputs:  
- Signal

Token Outputs:  
- Signal

Discussion:  
The inductor quality factor Q corresponding to an inductor L is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \frac{1 + Q^2}{Q}$$

Where $f$ is the frequency at resonance.
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
See example file \rflib\split90.svu. In this example two mixers are used as an I and Q demodulator. A coupled resonator is used preceding the 2-way zero degree splitter.

References:
Index: LC bandpass filters, narrow band couplers.
**Token Name:** LC Tank Circuit  
**Abbreviation:** LC-Tank  
**Group:** LC Circuits

**Synopsis:**  
This token models an LC tank circuit. This circuit model has one inductor, two capacitors, and two resistors.

**See Also:**  
LC Quad

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1</td>
<td>2 capacitors</td>
</tr>
<tr>
<td>Inductor</td>
<td>L0</td>
<td>1 inductor</td>
</tr>
<tr>
<td>Quality Factor</td>
<td>Q</td>
<td>Quality factor of the inductor</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- Signal

**Token Outputs:**  
- Signal

**Discussion:**  
The inductor quality factor $Q$ corresponding to an inductor $L$ is translated into an equivalent shunt resistor $R_Q$ by the formula:

$$R_Q = 2\pi f L \left(1 + \frac{Q^2}{Q} \right)$$

Where $f$ is the cut-off frequency.
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
Token Name: Mixer, Double-Balanced, Active  
Abbreviation: Mix-Act  
Group: Amplifiers and Mixers

Synopsis:  
This token models a semiconductor active double-balanced mixer. The three mixer ports operate as if in a 50-ohm environment.

See Also:  
Mix-Psv (Passive mixer)

Parameters:
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO Min Pwr (dBm):</td>
<td>LO Min.</td>
<td>Above this minimum LO power, the mixer shows no change in gain, harmonics, or LO leakage generated, regardless of changes in LO power. The LO input circuit consists of a limiting amplifier that gradually comes out of saturation at about 4 dB below the LO Min value. The LO input responds to the duty cycle, and the voltage offset of the applied LO, that in turn affects the mixer’s output.</td>
</tr>
<tr>
<td>In P1dB (dBm):</td>
<td>In P1dB</td>
<td>The In 1 dB compression point is the RF input power for which the SSB output signal $f_{if}$ power is 1 dB below the value set by the conversion gain.</td>
</tr>
<tr>
<td>In IP3 (dBm):</td>
<td>In IP3</td>
<td>The input RF power of two tones, for which the output power of the harmonic terms $(2f_{rf1} \pm f_{rf2}) \pm f_{lo}$ and $(2f_{rf2} \pm f_{rf1}) \pm f_{lo}$, are equal to the output power of the direct terms $(f_{rf1} \pm f_{lo})$ and $(f_{rf2} \pm f_{lo})$. It is usually about 10 dB above the In 1 dB compression point. (See Figure 1.)</td>
</tr>
</tbody>
</table>
### Parameters (continued):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convr Gain (dB):</td>
<td>GdB</td>
<td>The Conversion Gain parameter is the gain in power, of the desired single side band (SSB) power output of the mixer, relative to RF power input. When the applied LO input power is set above the LO Min value.</td>
</tr>
<tr>
<td>RF Isolation (dBc):</td>
<td></td>
<td>The RF isolation is the power loss of the RF signal as seen at the SSB output of the mixer relative to the RF power at the input.</td>
</tr>
<tr>
<td>LO Leakage (dBm):</td>
<td></td>
<td>The LO Leakage is the power (in dBm) of the LO signal, as seen at the output of the mixer, when the LO power is greater than the LO Min Pwr value. When the LO input power is less than the LO Min Pwr value, the output amplitude of the mixer (all spurs including the LO leakage) will fall off relative to the LO power at the input.</td>
</tr>
<tr>
<td>In IP2 (dBm):</td>
<td>In IP2</td>
<td>The input RF power of two tones, for which the output power of the harmonic terms ((f_{rf1} - f_{rf2}) \pm f_{lo}) and ((f_{rf2} - f_{rf1}) \pm f_{lo}), are equal to the output power of the direct terms ((f_{rf1} \pm f_{lo})) and ((f_{rf2} \pm f_{lo})). It is usually about 18 to 20 dB above the In 1 dB compression point. (See Figure 1).</td>
</tr>
<tr>
<td>DC Offset (v):</td>
<td></td>
<td>This offset value is added to the mixer output. It is a fixed value and stays in effect even if the RF and LO inputs are zero.</td>
</tr>
<tr>
<td>Noise figure (dB):</td>
<td>NF</td>
<td>Since this mixer is an active part, the value of the noise figure is independent of the Convr Gain parameter.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button allows the choice of added thermal noise (enabled) or not (disabled).</td>
</tr>
</tbody>
</table>

**Notes:** Refer to the appendix for Amplifier and Mixer characteristics.
**Token Inputs:**
- 0: RF signal.
- 1: LO signal.

**Token Outputs:**
- 0: IF signal.
- 1: IF signal, inverted. (Output times -1.)

**Discussion:**
The mixer is one of the devices at the heart of a receiver design. This mixer is designed to allow the user to directly enter catalog type parameter data. Because of non-linearity, not only does the desired signal appear at the output, but an array of harmonic products will appear as well. This model allows the exact specification of the third harmonic product, which is the dominant spur plus the 2-tone Input IP3. The model produces harmonics as follows:

- **RF harmonics:** 1, 2, 3, 4, and 5 only (for small signals)
- **LO harmonics:** 1, 3, 5, 7, 9, ...etc.

As described earlier in the parameter table, there will be a fixed amount of LO leakage at the mixer output over a large range of LO input power levels. This is due to the limiting-amplifier model that is used at the LO input port of the mixer. A typical power level for this leakage is -30 dBm. However, the user may find it necessary to use a very small amount of leakage (about -90 dBm) if the system has been frequency scaled to reduce the simulation time. This occurs when an IF output filter is unable to separate the IF center frequency from the relatively close LO leakage frequency. The frequency-scaled example file `\rf\lib\bfsk-b2.svu`, with two active mixers, takes advantage of using a small power lever for the leakage parameter.
Please refer to the appendix for *Amplifier and Active Mixer Characteristics*, for information on entering the parameter values when only a limited amount of parameter information is known.

**Figure 1:** A typical active mixer Input Third Order Intercept Point. (In IP3)

**Examples:**
In the example file `\rflib\bfsk-b2.svu` two active mixers are used in a binary frequency shift keying (FSK) transmitter/receiver system, see example files `\rflib\mix-pn.svu` and `\rflib\mix-sine.svu`.  

48

*RF/Analog Library*
**Token Name:** Mixer, Double-Balanced, Passive  
**Abbreviation:** Mix-Psv  
**Group:** Amplifiers and Mixers

**Synopsis:**  
This token models the classic diode-ring double-balanced mixer. All three of the mixer ports operate as if in a 50-ohm environment.

**See Also:** Mix-Act (Active mixer)

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO Power (dBm):</td>
<td></td>
<td>The class of mixer. The expected LO power applied to the mixer.</td>
</tr>
<tr>
<td>In P1dB (dBm):</td>
<td>In P1dB</td>
<td>The In 1 dB compression point is the RF input power, for which the single side band (SSB) output signal f_{if} power is 1 dB below the value set by the conversion loss. The In P1dB is usually 6 dB below the LO power class of the mixer.</td>
</tr>
</tbody>
</table>
| In IP3 (dBm):     | In IP3 | The input RF power of two tones, for which the output power of the harmonic terms \((2f_{rf1} - f_{rf2}) \pm f_{lo}\) and 
\((2f_{rf2} - f_{rf1}) \pm f_{lo}\), are equal to the output power of the direct terms 
\((f_{rf1} - f_{lo})\) and \((f_{rf2} - f_{lo})\). The In IP3 is usually about 10 dBm above the In 1dB compression point for higher frequencies, and about 15 dBm above the In 1dB compression point for lower frequencies. (See Figure 1.) |
| Convr Loss (dB):  | LdB    | The Conversion Loss is the loss of power of the desired SSB mixer output relative to the RF input power. |
### Parameters (continued):

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>RF Isolation (dBc):</td>
<td></td>
<td>The RF isolation is the power loss of the RF signal, as seen at the SSB output of the mixer, relative to the RF power at the input.</td>
</tr>
<tr>
<td>LO Isolation (dBc):</td>
<td></td>
<td>The LO isolation is the power loss of the LO signal, as seen at the output of the mixer, relative to the LO power at the input.</td>
</tr>
<tr>
<td>3rd Order Harm (dBc):</td>
<td></td>
<td>The power level of the 3 x 1 harmonic $3f_{lo} - f_{if}$ at the mixer output with respect to power level of the desired SSB signal at $f_{if}$. This is usually the dominant harmonic in a mixer.</td>
</tr>
<tr>
<td>DC Offset (v):</td>
<td></td>
<td>This offset value is added to the mixer output. It is a fixed value and stays in effect even if the RF and LO inputs are zero.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button allows the choice of added thermal noise (enabled) or not (disabled). Since this mixer is a passive part, the value of the noise figure (NF) is modeled as the same numerical value as the Convr Loss (LdB) parameter. (RF catalogs indicate that a passive mixer’s noise figure is generally between 0.5 and 1.0 dB of the conversion loss performance and therefore is not measured on a production testing basis.)</td>
</tr>
</tbody>
</table>

**Notes:** Refer to the appendix for Amplifier and Active Mixer Characteristics.

**Token Inputs:**
- 0: RF signal.
- 1: LO signal.

**Token Outputs:**
- 0: IF signal.
- 1: IF signal, inverted.
Discussion:
The mixer is one of the devices at the heart of a receiver design. This mixer is designed to allow the user to directly enter catalog type parameter data. Because of non-linearity, not only does the desired signal appear at the output, but an array of harmonic products as well. This model allows the exact specification of the third harmonic product, which is the dominant spur plus the 2-tone Input IP3. The model produces all odd harmonics of the LO signal and all harmonics to the 5th order of the RF signal.

Figure 1: A typical passive mixer Third Order Intercept Point. (In IP3).

The block diagram for this token is shown below.
Examples:
See example file \rflib\costas-r.svu. In this example two passive mixers are used as I and Q demodulators, while a third passive mixer is used as a phase detector to close the loop. Also, see example files \rflib\mix-pn.svu and \rflib\mix-sine.svu.

Example of Mixer Spurs:
Figure 2 shows the output spectrum of the SystemView passive mixer in a test system. Table 1 lists the mixer parameters used for the test along with the specified test signals. The parameters are very close to the catalog values of the MINI-CIRCUITS™ SRA-1-1 mixer.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>LO Power (dBm):</td>
<td>7</td>
</tr>
<tr>
<td>In P1dB (dBm):</td>
<td>1</td>
</tr>
<tr>
<td>In IP3 (dBm):</td>
<td>16</td>
</tr>
<tr>
<td>Convr Loss (dB):</td>
<td>5</td>
</tr>
<tr>
<td>RF Isolation (dB):</td>
<td>46</td>
</tr>
<tr>
<td>LO Isolation (dB):</td>
<td>60</td>
</tr>
<tr>
<td>3rd Order Harm (dBc):</td>
<td>12</td>
</tr>
<tr>
<td>DC Offset (v):</td>
<td>0</td>
</tr>
<tr>
<td>Noise Figure:</td>
<td>Enabled</td>
</tr>
<tr>
<td>RF input (sine wave):</td>
<td>12.5 MHz at -14.0 dBm</td>
</tr>
<tr>
<td>LO input (sine wave):</td>
<td>10.0 MHz at +7.0 dBm</td>
</tr>
</tbody>
</table>

Table 1: Parameters used for the mixer test.
In Figure 2, the amplitude of the main difference IF frequency, is -19 dBm at 2.5 MHz (A). The main sum frequency has this same amplitude at 22.5 MHz (B). The 3 x 1 harmonic is at 17.5 MHz (C) with a -31 dBm power level, which is 12 dB below the IF term. In addition to the other spurs due to even and odd order harmonics, the LO (D) and RF (E) leakage are visible. The default values of isolation are used here to produce a -47 dBm spur at the LO frequency and a -60 dBm spur at the RF frequency.

\[
\text{RF spur: } -14 \text{ dBm input} -46 \text{ dB} = -60 \text{ dBm} \\
\text{LO spur: } +7 \text{ dBm input} -60 \text{ dB} = -53 \text{ dBm}
\]

The spectrum shows the LO spur is 6 dB higher than the specified value (-53 dBm) because of some unavoidable spur interaction. As the RF input amplitude is reduced, the spectrum spur approaches the theoretical value.

**Note:** When measurements of this type are made, all frequencies involved must be integer multiples of the FFT resolution. In this example the resolution is 25 KHz as noted on the plot. The FFT resolution is controlled in the SystemView Time Specification window, and is displayed on the lower right side of the form. The resolution is the reciprocal of the system run time.
**Token Name:** Op-amp Buffer Circuit (Non-inverting)  
**Abbreviation:** Op-Buff  
**Group:** Operational Amplifier Circuits

**Synopsis:** This models a one-input, non-inverting, buffer operational amplifier circuit.

**See Also:** None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:** Signal  
**Token Outputs:** Signal

**Discussion:** The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Gain at DC; \( V_{out} = V_{in} \left( \frac{R_0 + R_1}{R_1} \right) \)

**Examples:** None.
**Token Name:** Op-amp Hysteresis Circuit  
**Abbreviation:** Op-Hyst  
**Group:** Operational Amplifier Circuits

**Synopsis:**  
This token models an op-amp that has positive feedback (hysteretic comparator). The hysteresis feature allows several non-linear circuits to be modeled including the Schmitt trigger circuit.

**See Also:**  
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Input Res. (ohms):</td>
<td>R0</td>
<td>The input signal is applied through this resistor to the plus input of the op-amp.</td>
</tr>
<tr>
<td>Feedback Res. (ohms):</td>
<td>R1</td>
<td>This resistor is connected between the circuit’s output junction and the op-amp’s plus input.</td>
</tr>
<tr>
<td>Output Res. (ohms):</td>
<td>R2</td>
<td>This resistor is located between the output of the op-amp (a zero impedance output) and the output junction of the circuit.</td>
</tr>
<tr>
<td>OpAmp Max (volts):</td>
<td></td>
<td>The maximum positive voltage at the output of the op-amp (positive clamping voltage).</td>
</tr>
<tr>
<td>OpAmp Min (volts):</td>
<td></td>
<td>The maximum negative voltage at the output of the op-amp (negative clamping voltage).</td>
</tr>
</tbody>
</table>

**Token Inputs:**

- 0: Signal

55  
*RF/Analog Library*
• 1: Reference

**Token Outputs:**
• 0: Op-Amp
• 1: R1-R2 Junction

**Discussion:**
When only two of the circuit’s resistors are used (R2 = 0), it can use hysteresis to make a clean comparator decision on a noisy input signal. With all 3 resistors in use, other non-linear effects can be modeled.

The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

![Circuit Diagram](image)

**Examples:**
In the example file `\rflic\chaos.svu`, this circuit and several other op-amp circuits are connected together to generate a random signal.
In the example file `\rflic\envp-det.svu`, the D-Anode is combined with the Op-Hyst and RC-Cpump to perform RF envelope detection.
**Token Name:** Op-amp Integrate and Dump Circuit  
**Abbreviation:** Op-I-Dmp  
**Group:** Operational Amplifier Circuits

**Synopsis:**  
This token will model an active integrate and dump circuit. The dumping switch has a provision for both on-resistance and off-condition-leakage.

**See Also:**  
RC-I-Dmp

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2,</td>
<td>3 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: Signal  
- 1: Control

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. When entering parameters (R0, R1, R2 and C0) to make the dump time very fast, check the Bode plot (dump mode) in the design window. A very fast dump mode leads to a very high frequency circuit that will require an even higher system-sampling rate to avoid unwanted oscillations. Notice that this op-amp circuit inverts the signal that is applied to it. When in the integrate mode, a negative input signal produces a positive-going ramp at the output. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
See example file \rflib\op-i-dmp.svu. In this example, the Op-I-Dmp circuit is fed by a zero-to-positive PN source and some noise. The control signal is a square wave clocked at the PN rate. The circuit’s output shows a linear ramp of the integrator as well as the finite dump time. The RC-I-Dmp token is also shown for comparison.
**Token Name:** Op-amp Inverter, Single Input Circuit  
**Abbreviation:** Op-Invert  
**Group:** Operational Amplifier Circuits

**Synopsis:** This token models a one-input inverting op-amp circuit.

**See Also:** Op-Sum3

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1</td>
<td>2 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:** Signal  
**Token Outputs:** Signal

**Discussion:** Instructions on parameter entry for RF library tokens are in the appendix.

Gain at DC: \[ V_{out} = -V_{in} \left( \frac{R1}{R0} \right) \]

**Examples:** In the example file \rflib\chaos.svu, this circuit and several other different op-amp circuits are connected together to generate a random signal.
**Token Name:** Op-amp PID Circuit  
**Abbreviation:** Op-PID  
**Group:** Operational Amplifier Circuits

**Synopsis:**
This token models the classic active Proportional-Integral-Derivative loop filter that has 2 or 3 breakpoints. Besides the signal input, there is a 2nd input to the circuit for a reference voltage.

**See Also:**
Op-PLL1, Op-PLL2

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2, R3</td>
<td>4 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2</td>
<td>3 capacitors</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: Signal
- 1: Reference

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
See example file \rflib\pid-op.svu. In this example, an input pulse disturbs a system. The system recovers in the shortest amount of time possible without any overshoot of the signal. Changing any of the PID parameters of the example system will result in ringing, overshoot, or sluggish recovery.
**Token Name:** Op-amp PLL filter, Single Input Circuit  
**Abbreviation:** Op-PLL1  
**Group:** Operational Amplifier Circuits

**Synopsis:**  
This token models the classic active, one input, and integrating R-C phase lock loop filter.

**See Also:**  
Op-PLL2, RC-PLL

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2, R3, R4</td>
<td>5 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2</td>
<td>3 capacitors</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- Signal

**Token Outputs:**  
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
**Token Name:** Op-amp PLL filter, Differential Input Circuit  
**Abbreviation:** Op-PLL2  
**Group:** Operational Amplifier Circuits

**Synopsis:**  
This token models an active, differential-input, Phase Lock Loop (PLL) filter and may be used together with the Phase/Frequency Detector found in the Logic Library.

**See Also:**  
RC-Cpump

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R3, R4, R5,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R6, R7, R8,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R9</td>
<td>10 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>4 capacitors</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: Input 0
- 1: Input 1

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
In the example file `\rf\lib\op-pll2.svu`, two PN sources serve as the input to the differential filter. Normally, the two sources would be the 2 outputs of a digital phase/frequency detector (see the Logic library). This type of filter is commonly used in a phase locked loop (PLL).
**Token Name:** Op-amp Sum of 3 Inputs Circuit  
**Abbreviation:** Op-Sum3  
**Group:** Operational Amplifier Circuits

**Synopsis:**  
This token models an inverting, 3-input summing operational amplifier. Fewer than 3 inputs may be used if desired.

**See Also:**  
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2, R3</td>
<td>4 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
<tr>
<td>Limit (±v)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: Input 0
- 1: Input 1
- 2: Input 2

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Gain at DC: \[ V_{out} = -R_3 \left( \frac{V_{in0}}{R_0} + \frac{V_{in1}}{R_1} + \frac{V_{in2}}{R_2} \right) \]

Examples:
In the example file `\rflib\chaos.svu`, this circuit and several other different op-amp circuits are connected together to generate a random signal.
**Token Name:** Power Combiner: 2-Way, 180-Degree  
**Abbreviation:** PCmb 180  
**Group:** Splitters and Combiners

**Synopsis:**
The token calculates the difference of two input signals, and models a 2-way combiner, 0 degrees one-way and 180 degrees the other. It has a theoretical insertion loss of 3.0 dB. Additional loss, usually 0.5 dB may be specified.

**See Also:** None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 3 dB:</td>
<td>LdB</td>
<td>Insertion loss in dB above 3 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This enables/disables thermal noise. Since this is a passive part, the noise figure (NF) value equals the loss (LdB) parameter plus 3 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: 0 Degree input
- 1: 180 Degree input

**Token Outputs:**
- Output

**Discussion:**
The output is the difference of the two input channels, reduced by the additional insertion loss above 3 dB, and enhanced by random thermal noise.
Token Name: Power Combiner: 2-Way, 0-Degree
Abbreviation: PCmb-2
Group: Splitters and Combiners

Synopsis:
The token combines two inputs to a single output, each zero degrees. It has a theoretical insertion loss of 3 dB. Additional loss of 0.5 dB may be specified.

See Also: None

Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 3 dB:</td>
<td>LdB</td>
<td>Insertion loss in dB above 3dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>The button enables/disables thermal noise. Since it is passive, the noise figure (NF) value equals the loss (LdB) parameter plus 3 dB.</td>
</tr>
</tbody>
</table>

Token Inputs:
- First signal
- Second signal

Token Outputs:
- Output

Discussion: The output channel contains total power of two input channels, reduced by additional insertion loss over 3 dB. Random thermal noise can be enabled or disabled.
Token Name: Power Combiner: 3-Way, 0-Degree
Abbreviation: PCmb-3
Group: Splitters and Combiners

Synopsis:
This token combines three inputs into a single output, zero degrees each way. This part has a theoretical insertion loss of 4.8 dB. An additional loss may be specified, typically 0.5 dB.

See Also:
None

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 4.8 dB:</td>
<td>$L_{dB}$</td>
<td>Insertion loss in dB above 4.8 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button enables or disables the thermal noise. Since this is a passive part, the value of the noise figure (NF) is equal to the loss ($L_{dB}$) parameter plus 4.8 dB.</td>
</tr>
</tbody>
</table>

Token Inputs:
- First signal
- Second signal
- Third signal

Token Outputs:
- Output
**Discussion:**
The output channel contains the total power of the three input channels, reduced by the additional insertion loss above 4.8 dB, and enhanced by random thermal noise.

![Diagram](image)

**Examples:** None
**Token Name:** Power Combiner: 4-Way, 0-Degree  
**Abbreviation:** PCmb-4  
**Group:** Splitters and Combiners

**Synopsis:**  
This token combines four inputs into a single output, zero degrees each way. This part has a theoretical insertion loss of 6 dB. An additional loss may be specified, typically 0.5 dB.

**See Also:**  
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 6 dB:</td>
<td>LdB</td>
<td>Insertion loss in dB above 6 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>This button enables or disables the thermal noise. Since this is a passive part, the value of the noise figure (NF) is equal to the loss (dB) parameter plus 6 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- First signal  
- Second signal  
- Third signal  
- Fourth signal

**Token Outputs:**  
- Output
**Discussion:**
The output channel contains the total power of the four input channels, reduced by the additional insertion loss above 6.0 dB, and enhanced by random thermal noise.

![Diagram of signal flow](image)

**Examples:**
None
**Token Name:** Power Coupler: 2-Way, 0-Degree  
**Abbreviation:** PCoupler  
**Group:** Splitters and Combiners

**Synopsis:**  
This token splits a signal into two unequal parts, zero degrees each, with unequal outputs. The signal loss (dB) is relative to the input level. Some commonly used parameter values are shown below:

<table>
<thead>
<tr>
<th>Mainline (direct) loss (dB)</th>
<th>Coupled (tapped) loss (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.2</td>
<td>20.5</td>
</tr>
<tr>
<td>0.5</td>
<td>19.5</td>
</tr>
<tr>
<td>1.0</td>
<td>10.0</td>
</tr>
<tr>
<td>1.7</td>
<td>6.5</td>
</tr>
</tbody>
</table>

**See Also:** None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Out 1 Loss (dB):</td>
<td>LdB1</td>
<td>Mainline output loss in dB relative to input.</td>
</tr>
<tr>
<td>Out 2 Loss (dB):</td>
<td>LdB2</td>
<td>Coupled output loss in dB relative to input.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. Since this is passive, the noise figure (NF) value is equal to the appropriate loss (LdBx) parameter.</td>
</tr>
</tbody>
</table>

**Token Inputs:**

- Signal

**Token Outputs:**

- 0: Mainline (direct) output channel
- 1: Coupled (tapped) output channel
**Discussion:**
Each output channel contains the power of the input channel, reduced by the given losses, and enhanced by random thermal noise. The SystemView Power Coupler is not a directional coupler and therefore does not support directivity.

**Examples:**
None
**Token Name:** Power Splitter: 2-Way, 180-Degree  
**Abbreviation:** PSplit 180  
**Group:** Splitters and Combiners

**Synopsis:**
This token splits a signal into two equal parts and shifts the phase of the second output by 180 degrees. This part has a theoretical insertion loss of 3 dB. An additional loss may be specified, typically 0.5 dB.

**See Also:**
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 3 dB (dB)</td>
<td>LdB</td>
<td>Insertion loss in dB above 3 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. Since this is a passive part, the value of the noise figure (NF) is equal to the loss (LdB) parameter plus 3 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- 0: 0 Degree output
- 1: 180 Degree output
**Discussion:**
Each output channel contains one-half the power of the input channel (accounting for an initial loss of 3 dB), reduced by the insertion loss, and enhanced by random thermal noise. The output of the second channel is shifted in phase by 180 degrees.

**Examples:**
See the `\rflib\split180.svu` example file.
**Token Name:** Power Splitter: 2-Way, 0-Degree  
**Abbreviation:** PSplit-2  
**Group:** Splitter and Combiners

**Synopsis:**
The token splits a signal into two equal parts, each zero degrees, and has a theoretical insertion loss of 3.0 dB. Additional loss of 0.5 dB may be specified.

**See Also:** None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 3 dB (dB)</td>
<td>LdB</td>
<td>Insertion loss in dB above 3 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. Since this is passive, the value of the noise figure (NF) is equal to the loss (LdB) parameter plus 3 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- 0: Output 0, 0 degrees
- 1: Output 1, 0 degrees
Discussion:
Each output channel has half the input channel power, accounting for an initial loss of 3 dB reduced by insertion loss and enhanced by random thermal noise.

Examples:
See costas-r.svu example file, a splitter is used to feed a pair of mixers.
**Token Name:** Power Splitter: 3-Way, 0-Degree  
**Abbreviation:** PSplit-3  
**Group:** Splitters and Combiners  

**Synopsis:**  
This token splits a signal into three equal parts, zero degrees each way. This part has a theoretical insertion loss of 4.8 dB. An additional loss may be specified, typically 0.5 dB.  

**See Also:**  
None  

**Parameters:**  
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 4.8 dB (dB)</td>
<td>LdB</td>
<td>Insertion loss in dB above 4.8 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. Since this is a passive part, the value of the noise figure (NF) is equal to the loss (LdB) parameter plus 4.8 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- Signal  

**Token Outputs:**  
- 0: Output 0 0 degrees  
- 1: Output 1 0 degrees  
- 2: Output 2 0 degrees
**Discussion:**
Each output channel contains one-third the power of the input channel (accounting for an initial loss of 4.8 dB), reduced by the insertion loss, and enhanced by random thermal noise.

**Examples:**
None
**Token Name:** Power Splitter: 4-Way, 0-Degree

**Abbreviation:** PSplit-4

**Group:** Splitters and Combiners

**Synopsis:**
This token splits a signal into four equal parts, zero degrees each way. This part has a theoretical insertion loss of 6 dB. An additional loss may be specified, typically 0.5 dB.

**See Also:**
None

**Parameters:**
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 6 dB (dB):</td>
<td>LdB</td>
<td>Insertion loss in dB above 6 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. Since this is passive, the value of the noise figure (NF) is equal to the loss (LdB) parameter plus 6 dB.</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- 0: Output 0 0 degrees
- 1: Output 1 0 degrees
- 2: Output 2 0 degrees
- 3: Output 3 0 degrees
Discussion:
Each output channel contains one-fourth the power of the input channel (accounting for an initial loss of 6 dB), reduced by the insertion loss, and enhanced by random thermal noise.

Examples:
None
Token Name: Power Splitter: 2-Way, 90-Degree (Hilbert)
Abbreviation: PSplit 90
Group: Splitters and Combiners

Synopsis:
This token splits a signal into two equal parts and shifts the phase of the second output by 90 degrees. This part has a theoretical insertion loss of 3 dB. An additional loss may be specified, typically 0.5 dB.

See Also:
None

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loss above 3 dB (dB)</td>
<td>LdB</td>
<td>Insertion loss in dB above 3 dB.</td>
</tr>
<tr>
<td>Enable/Disable noise figure:</td>
<td></td>
<td>Enable or disable thermal noise. This is a passive part, the value of the noise figure (NF) is equal to the loss (LdB) parameter plus 3 dB.</td>
</tr>
</tbody>
</table>

Token Inputs:
- Signal

Token Outputs:
- 0: 0 Degree output
- 1: 90 Degree output
Discussion:
Each output channel contains one-half the power of the input channel (accounting for an initial loss of 3 dB), reduced by the insertion loss, and enhanced by random thermal noise. The output of the second channel is shifted in phase by 90 degrees, relative to the first channel.

Because the model is based on the Hilbert Transform (a digital signal processing (DSP) function) there are some frequency and amplitude limitations at the high and low frequencies relative to the system sample rate.

Examples:
See example file split90.svu. In this example, the LO sine wave is split into 2 signals, 90 degrees apart.
Token Name: RC Charge Pump Circuit
Abbreviation: RC-Cpump
Group: RC Circuits

Synopsis:
This token models an RC charge pump circuit that is commonly used in a phase locked loop (PLL).

See Also:
Op-PLL2

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2, R3, R4, R5, R6</td>
<td>7 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1</td>
<td>2 capacitors</td>
</tr>
</tbody>
</table>

Token Inputs:
- 0: Signal Input 0. (Analog Up)
- 1: Signal Input 1. (Analog Down)
- 2: Control 0 (Controls the 0: Signal Input 0)
- 3: Control 1 (Controls the 1: Signal Input 1)

Token Outputs:
- Signal

Discussion:
The circuit diagram for the RC Charge Pump token shows that normally the two switches are held open, and occasionally one of the switches is ordered to close momentarily, changing the voltage level on the integrating capacitor.

The four resistors around the charge pump switches; allow modeling of the output leakage when both switches are open, and modeling of the output
voltage when both switches are closed. The Logic library has a digital phase/frequency detector that may be used to drive the charge pump. Instructions on parameter entry for RF library tokens are in the appendix.

**Examples:**

In the example file `rflib\cpump.svu`, two PN source tokens serve as the control inputs to the charge pump. Normally, the sources would be the outputs of a digital phase/frequency detector. This type of filter is commonly used in a phase locked loop (PLL). Refer to AN120 and AN126A. The response of the Op-PLL2 (differential input filter) is shown, for comparison. In the example file `rflib\envp-det.svu`, the D-Anode is combined with the Op-Hyst and RC-Cpump to perform RF envelope detection.
**Token Name:** RC Differentiator Circuit  
**Abbreviation:** RC-Diff  
**Group:** RC Circuits

**Synopsis:**  
This token models various high pass filters such as a resistor-capacitor differentiator.

**See Also:**  
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2</td>
<td>3 resistors</td>
</tr>
<tr>
<td>Capacitor</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
**Token Name:** RC High Pass Filter Circuit  
**Abbreviation:** RC-Hpf  
**Group:** RC Circuits

**Synopsis:**  
This token models RC high pass filters up to 4 poles.

**See Also:**  
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>R3, R4</td>
<td>5 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2,</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C3</td>
<td>4 capacitors</td>
</tr>
</tbody>
</table>

**Token Inputs:**  
- Signal

**Token Outputs:**  
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
**Token Name:** RC Integrate and Dump Circuit  
**Abbreviation:** RC-I-Dmp  
**Group:** RC Circuits

**Synopsis:**
This token will model a passive RC integrate and dump circuit. The input signal is applied to the pull-up resistor. The capacitor-dumping switch has an on-resistance (dumping resistor). When the switch control input goes below the threshold parameter, the dumping switch closes. When the control input is above the threshold, the capacitor is charged up through the pull-up resistor.

**See Also:**
Op-I-Dmp

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2</td>
<td>3 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0</td>
<td>1 capacitor</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- 0: Signal
- 1: Control

**Token Outputs:**
- Signal
**Discussion:**
The following is the circuit diagram for this token. When entering parameters (R0, R1, R2, and C0) that make the dump time very fast, be sure to check the Bode plot (dump mode) in the design window. A very fast dump mode leads to a very high frequency circuit that will require an even higher system-sampling rate to avoid unwanted oscillations. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

![Circuit Diagram](image)

**Examples:**
See example file `\rflib\op-i-dmp.svu`. In this example, the RC-I-Dmp circuit is fed by a zero-to-positive PN source and some noise. The control signal is a square wave clocked at the PN rate. The circuit’s output shows both the positive-going non-linear ramp of the integrator and the finite dump time.

Another use of this circuit would be in simulating an open-collector logic gate feeding an RC circuit to delay a logic signal. In this case, the input signal could be supplied by a *step function* token set to a positive voltage.
Token Name: RC Low Pass Filter Circuit
Abbreviation: RC-Lpf
Group: RC Circuits

Synopsis:
This token models RC low pass filters up to 4 poles.

See Also:
None

Parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>R0, R1, R2, R3, R4</td>
<td>5 resistors</td>
</tr>
<tr>
<td>Capacitors</td>
<td>C0, C1, C2, C3</td>
<td>4 capacitors</td>
</tr>
</tbody>
</table>

Token Inputs:
- Signal

Token Outputs:
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

Examples:
None
**Token Name:** RC PLL Filter Circuit  
**Abbreviation:** RC-PLL  
**Group:** RC Circuits

**Synopsis:**
This token models the classic “lag” RC loop filter with two or three breakpoints. When used as a 2-breakpoint filter ($C_1 = 0.0$), this low pass filter reverts to a constant loss function at the second break point.

**See Also:**
None

**Parameters:**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resistors</td>
<td>$R_0, R_1, R_2$</td>
<td>3 resistors</td>
</tr>
<tr>
<td>Capacitor</td>
<td>$C_0, C_1$</td>
<td>2 capacitors</td>
</tr>
</tbody>
</table>

**Token Inputs:**
- Signal

**Token Outputs:**
- Signal
Discussion:
The following is the circuit diagram for this token. Instructions on parameter entry for a selected RF library circuit token are provided in the appendix.

![Circuit Diagram]

Examples:
See example file `\rflib\costas-r.svu`. In this example, the RC-PLL filter is used as the loop filter.
Appendix A: Features Common to all of the Circuit-type Tokens

The RF/Analog Library includes a number of tokens that model component-level circuits. Some of these tokens include the RC, LC, and op-amp tokens.

Each of these tokens contains a schematic window for entering circuit parameters. These parameters may be “typical values”, or they can be a very small or a very large value to cause the particular schematic component to be a shorted-out component or an open circuit. After defining these parameters, you can view the results in the s- or z-domain. You may also view the results in interactive Bode or Root Locus plot windows and then return to the schematic window to revise your circuit parameters. These features allow you to determine optimum circuit parameters in a quick iterative fashion before executing your entire simulation.

RF/Analog Circuit Token Definition

Launch an RF/Analog Library generic token from the token Reservoir. Double click the new generic token to access the RF/Analog token library. A circuit token is selected by double clicking any of the circuit tokens in the library or by clicking the token and then clicking the Parameters button.

An example schematic window, in Figure A.1, has the following features:

- A two-dimensional schematic window where circuit parameters can be defined.
- A Laplace button, located below the schematic window, allows viewing of the results of the parameters defined in the s-domain.
- A z-Domain button, located below the schematic window, allows viewing the results of the parameters defined in the s-domain.
- A Bode Plot button, located below the schematic window, allows viewing of an interactive Bode plot display of frequency, and/or
phase on a linear, or logarithmic frequency scale. (Ctrl Key + drag mouse to zoom).

- A Root Locus Plot button, located below the circuit design area, allows viewing of an interactive Root Locus plot display. (Ctrl Key + drag mouse to zoom).

![Figure A.1: Example RF/Analog circuit token schematic window.](image)

**Noise Figure Calculation**

Eagleware-Elanix Application note AN110 contained in SystemView provides noise figure calculations.
Appendix B: Noise figure Calculation

Introduction
An RF system is a collection of various filter, amplifier, and mixer processing blocks. These blocks either have gain or loss, but in either case they contribute noise to the output of a system. Although the overall function of a given system must remain unchanged, there are some design tradeoffs that can be made to lower the noise present at the output of the system. The gain/loss and noise figure of each block combine in a rather complicated manner, making the calculation of the results of the trade-off a tedious, error prone task. A graphical computer simulation using SystemView by ELANIX is described that will allow the design engineer to quickly compare the noise figures of differing RF receiver topologies. Thermal noise, noise figure, and noise figure software testing will be discussed in detail, but first the noise figure of an example receiver system will be simulated.

Terminology
In this application note, noise factor (F) refers to the linear value. Noise Figure (NF) refers to the dB value. A method of converting between the two formats is shown in Table 1.

<table>
<thead>
<tr>
<th>Given: noise figure (NF) = 8.0 dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise factor (F) = 10(^{\frac{8.00 \text{ dB}}{10}}) = 6.310 (linear)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Given: noise factor (F) = 6.310 (linear)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise figure (NF) = 10 \log_{10} (6.310) = 8.0 dB</td>
</tr>
</tbody>
</table>

Table 1.

The above method may also be used for converting the gain of a block between the two formats.

Table 2 shows the conversion when there is negative gain (a loss).
**Table 2.**

**Noise Figure Simulation of an RF Receiver System**

Only 6 types of tokens are required to simulate the noise figure of an RF processing system. Four tokens are from the main library:

- *Thermal Noise source*
- *Sinusoid source*
- *Adder*
- *Sink*

The other two tokens are from the SystemView RF library:

- *Amplifier*
- *Attenuator*

In Figure 1, two almost identical RF systems are run in parallel and the signal + noise input is compared with each of the outputs. The sum of the two source tokens represents the signal + noise input to each of the two systems. In the top system, there is only one input filter. In the bottom system, the input filter has been split into two sections, each with half the attenuation of the original filter. The top and bottom systems in have the same overall gain, but the losses are distributed differently.

The results shown in Figure 2 are typical of a simulation run, and show the result of splitting the input filter. Because each token introduces its own noise, each simulation run will have slightly different output values, within about 0.2 dB. The bottom system produces about a 2.6 dB improvement in the signal to noise ratio, showing the importance of a receiver having a low loss front end. (Of course, with the simpler filter, the input amplifier is less immune to out of band interference.)
Figure 1. Two RF processing systems, with identical gain and loss, used to compare component-generated noise.
Figure 2. These are the plots of each of the three sinks in Figure 1. The plots are obtained by using the Power Spectrum (dBm in 50 ohms) calculator.
Figure 3. The results of using the Statistics button in Figure 2.
The noise figure of the top and bottom systems are obtained by using the Plot Statistics (Figure 3) as follows.

For \textbf{w3 (Figure 3)}

The noise floor is shown as:
Mean: \(-1.363e+2\) or \(-136.3\) dBm
The signal is shown as:
Max: \(-5.995e+1\) or \(-59.95\) dBm
Subtracting we get:
\(S_{in}/N_{in} = -59.95 - (-136.3) = 76.35\) dB

For \textbf{w4 (Figure 3)}

The noise floor is shown as:
Mean: \(-1.033e+2\) or \(-103.3\) dBm
The signal is shown as:
Max: \(-3.895e+1\) or \(-38.95\) dBm
Subtracting we get:
\(S_{top}/N_{top} = -38.95 - (-103.3) = 64.35\) dB

For \textbf{w5 (Figure 3)}

The noise floor is shown as:
Mean: \(-1.059e+2\) or \(-105.9\) dBm
The signal is shown as:
Max: \(-3.895e+1\) or \(-38.95\) dBm
Subtracting we get:
\(S_{bot}/N_{bot} = -38.95 - (-105.9) = 66.95\) dB
For power measurements the noise factor formula is:

\[ NF = 10 \log_{10} \left( \frac{S_i}{N_i} \right) / \left( \frac{S_o}{N_o} \right) \text{ dB} \]

Since we are using dB values, the four linear parameters in the formula are subtracted instead of divided.

The noise figure (NF) of the top system is:

\[ S_{in}/N_{in} - S_{top}/N_{top} = 76.35 - 64.35 = 12.00 \text{ dB} \]

The noise figure (NF) of the bottom system is:

\[ S_{in}/N_{in} - S_{bot}/N_{bot} = 76.35 - 66.95 = 9.40 \text{ dB} \]

Comparing the signal to noise ratios of the top and bottom systems:

\[ 12.00 - 9.40 = 2.60 \text{ dB} \]

Each of the above calculations is within 0.2 dB of the hand-calculated values.
The longhand calculation for the top system with one -8 dB input filter:

\[
F_{\text{top\_system}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \frac{F_4 - 1}{G_1G_2G_3} + \frac{F_5 - 1}{G_1G_2G_3G_4}
\]

\[
= 6.310 + 6.297 + 2.539 + 0.040 + 0.423 = 15.609
\]
(linear)

Or \(\text{NF}_{\text{top\_system}} = 10 \log_{10}(15.609) = 11.934\) dB

The longhand calculation for the bottom system with two -4 dB input filters:

\[
F_{\text{bot\_system}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1G_2} + \frac{F_4 - 1}{G_1G_2G_3} + \frac{F_5 - 1}{G_1G_2G_3G_4} + \frac{F_6 - 1}{G_1G_2G_3G_4G_5}
\]

\[
= 2.512 + 2.500 + 0.3799 + 2.533 + 0.3963 + 0.4222 = 8.387 \text{ (linear)}
\]

Or \(\text{NF}_{\text{bot\_system}} = 10 \log_{10}(8.387) = 9.236\) dB

Comparing the signal to noise ratios of the top and bottom systems:

\[11.934 - 9.236 = 2.698\text{ dB}\]

**Using SystemView for Noise Figure Simulation**

In SystemView either of two *Source* tokens may be used to generate this noise:

The *Gaussian* noise source token may be set to 4.14 e-21 watts per Hz with the *Density in 50 ohms* feature enabled.

Or

The *Thermal* noise source token may be set to 50 ohms resistance with a temperature of 300 deg K.
With either noise source, there is another option you may want to use. The random seed may be fixed as was done for the plots in this application note. Select the following:

Preferences
  Customize
    Numeric & Run Time
      √ Fix Random Seed: 12345

When viewing signals and noise in SystemView, the following guidelines may be used:
1. For signals or the carrier, use round numbers rather than a fractional value (15.0 MHz rather than 15.1234 MHz).
2. Set the number of samples to a power of two number. The Auto Scale Set for FFT button is helpful in doing this in the Define System Time window.
3. Set the frequency Bandwidth by setting the Freq. Res. (Hz) in the Define System Time window. Set this frequency to a round number rather than a fractional value. (This is the bandwidth referred to in the Noise Power equation that is discussed in the section on Thermal Noise at the end of this application note.)
4. Performing steps 2 and 3 will cause the system Sample Rate to be automatically set to a power of two number. This in turn will prevent FFT bin splitting during the simulation and result in better-looking plots that have the power at the various frequencies concentrated at the spectral lines.
5. The first plot generated in SystemView is in the time domain. To view the signal (and noise) power in the frequency domain use the sink calculator to select Power Spectrum (dBm in 50 ohms). For signals that are not noise-like (sine waves, etc.) the amplitude of the plotted power level is exactly equal to the true power. When viewing the grass-like structure of the noise power each data point is plotted at the exact true power level.
Note:
If the grass-like structure of the noise power is averaged using either the Statistics button (on the plot window’s top toolbar) or the moving average function (found in the Sink Calculator, Operators tab), the calculated or displayed value will be about 2.5 dB less than the actual power. Also, the integrating property of human eyesight has the same effect of making the noise power look as if it is a couple of dB lower. This is due to the mathematics of random numbers and logs. The log of an average is not necessarily equal to the average of a log.

For a random variable $x$, and any function $f(x)$ it does not necessarily follow that,

$$E[f(x)] = f(E[x])$$

In this case, $f(x) = 10 \log_{10}(x)$. This subject of log vs. linear is described in great mathematical detail in Ref. 1.

The following two examples will show this 2.5 dB difference. Since we are dealing with noise, the results show some statistical variation.

A. The Thermal noise source token is set to 50 ohms resistance with a temperature of 300 deg K and connected to a sink. This is equivalent to a noise power of $-173.83$ dBm. In the Define System Time window, the number of samples is set to 8192, then the frequency resolution is set to 1 Hz (bandwidth in the noise formula). Run the system, and do a Power Spectrum (dBm in 50 ohms). Using the Statistics button, the resulting FFT plot will show the noise power to be $-176.3$ dBm, which is 2.47 dB lower than the source.

B. The same Thermal noise source is used, but the frequency resolution is set to 10 kHz (noise bandwidth). This is equivalent to a noise power of $-133.83$ dBm.

$$10 \log_{10}(10e3) = +40 \text{ dBm}$$

$$-173.83 \text{ dBm} + 40 \text{ dB} = -133.83 \text{ dBm}$$
The statistics of the resulting FFT plot will show the noise power in the 10 kHz bandwidth to be -136.33 dBm, which is 2.5 dB lower than the calculated value. Notice that the wider bandwidth of 10 kHz produces more noise power than the 1 Hz bandwidth.

**Thermal Noise**

Thermal noise is generated by the random motion of free electrons in any conducting medium whose temperature is above absolute zero. The physical model for thermal noise (or Johnson noise) is a noise voltage generator in series with a noiseless resistor.

The open-circuit RMS voltage of the network is defined (Ref. 2, 3, and 4) by the equation:

\[(E_{\text{RMS}})^2 = 4KTBR\]

where:

- \(K\) = Boltzman’s constant, 1.38 x 10\(^{-23}\) Joule/deg K
  - Or W/(deg K \cdot Hz)
- \(T\) = Absolute Temperature, (deg C + 273)
- \(B\) = Bandwidth, Hz
- \(R\) = Resistance, ohms

To find the noise power generated by a single 50-ohm resistor, we shall use the condition of maximum power transfer in circuits, when the source impedance equals the load impedance as shown in Figure 4.
The current in this circuit is: $I = \frac{E}{2R}$

Therefore, the thermal noise input power to the load is:

$$P_{\text{thermal-noise}} = I^2 \cdot R = \left[ \frac{E^2}{(2R)^2} \right] \cdot R = \frac{E^2}{4R}$$

Substituting,

$$P_{\text{thermal-noise}} = \frac{4KTB^2}{4R} = KTB \text{ (Watts)}$$

Notice that the resistance $R$ has dropped out of the equation yielding the conventional equation for the maximum noise power.

Using a $T$ of 300 (27 deg C or 80.6 deg F) and a 1 Hz bandwidth we get:

$$P_{\text{thermal-noise}} = 1.38 \times 10^{-23} \times 300 \times 1 = 4.14 \times 10^{-21} \text{ (watts)}$$
This power may be converting to dB referenced to 1 watt,
\[ 10 \log_{10} (4.14 \times 10^{-21}) = -203.83 \text{ dB (watts)} \]

And then converted to dBm referenced to 1 milliwatt:
\[ 10 \log_{10}(1000) = +30 \text{ dBm} \]
\[ -203.83 \text{ dB} + 30 \text{ dB} = -173.83 \text{ dBm (milliwatts)} \]

**Noise Figure**
All devices such as amplifiers, mixers, filters, and attenuators, produce thermal noise, and the output of these devices will contain a higher percentage of noise when compared to the input signal. The amount of noise added to the output determines the lowest signal amplitude that can be seen or recovered from the device. Noise Figure (NF) in dB and the corresponding linear noise factor (F) are used as a useful measurement of device performance. For power measurements the formulas are:

\[
F = \frac{S_i / N_i}{S_o / N_o} \text{ linear}
\]
\[
NF = 10 \log_{10} \left( \frac{S_i / N_i}{S_o / N_o} \right) \text{ dB}
\]

*Where the four linear values are:

S\textsubscript{i} = input signal voltage, linear

N\textsubscript{i} = input thermal noise voltage, linear

S\textsubscript{o} = output signal voltage

(S\textsubscript{i} \cdot \text{linear gain of device})

N\textsubscript{o} = output thermal noise voltage

(N\textsubscript{i} \cdot \text{linear gain of device}) + (added noise)

(For voltage measurements the 10 \log_{10} factor is replaced with a 20 \log_{10} factor.)
Cascaded Noise Figure

When several devices are cascaded in a system the total system noise figure is calculated as follows:

\[ F_{\text{system}} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots \]

In the equation above, \( F \) and \( G \) are the linear representations of noise figure and gain. Notice that the gain of the last block does not enter into the calculation. For a passive lossy element, such as an L-C filter, the noise figure is equal to the loss. Also, for that passive lossy element, the reciprocal of the loss is used for its gain. (Gain = 1 / loss)

Testing the accuracy of Noise Figure Software

The following system (Figure 5) is useful to test the accuracy of noise figure software. The system’s Freq. Res. (bandwidth) is 10 kHz. A small signal and thermal noise are added together and are used as the input to the top chain of 5 attenuators, and the bottom chain of 5 amplifiers.

Each of the 5 attenuators has a loss of 5 dB (and therefore a 5 dB noise figure). This results in a hand calculated cascaded loss of 25 dB and a noise figure of 25 dB, using the cascaded noise figure equation.

Each of the 5 amplifiers has a gain of 5 dB with a 5 dB noise figure. This results in a hand calculated cascaded gain of 25 dB and a noise figure of 6.18 dB, again using the cascaded noise figure equation.

Figure 6 shows the plots of the signal + noise at the input, and both outputs of the system. In Figure 7, the Statistics button displays the calculated information of Figure 6. As shown in Table 3, the plot calculations are very close to the hand-calculated values. Remember, the two systems are being fed with random noise.
The noise figure of the top and bottom systems are obtained by using the Plot Statistics (Figure 7) as follows.

**For w3 (Figure 7)**
The noise floor is shown as:
Mean: -1.363e+2 or -136.3 dBm
The signal is shown as:
Max: -5.994e+1 or -59.94 dBm
Subtracting we get:
\[ \text{S}_{\text{in}}/\text{N}_{\text{in}} = -59.94 - (-136.3) = 76.36 \text{ dB} \]

**For w4 (Figure 7)**
The noise floor is shown as:
Mean: -1.363e+2 or -136.3 dBm
The signal is shown as:
Max: -8.492e+1 or -84.92 dBm
Subtracting we get:
\[ \text{S}_{\text{top}}/\text{N}_{\text{top}} = -84.92 - (-136.3) = 51.38 \text{ dB} \]

**For w5 (Figure 7)**
The noise floor is shown as:
Mean: -1.052e+2 or -105.2 dBm
The signal is shown as:
Max: -3.495e+1 or -34.95 dBm
Subtracting we get:
\[ \text{S}_{\text{bot}}/\text{N}_{\text{bot}} = -34.95 - (-105.2) = 70.25 \text{ dB} \]

For power measurements the noise factor formula is:

<table>
<thead>
<tr>
<th>Attenuators</th>
<th>Noise Figure</th>
<th>Noise Figure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Attenuators</td>
<td>24.98 dB</td>
<td>25.00 dB</td>
</tr>
<tr>
<td>5 Amplifiers</td>
<td>6.11 dB</td>
<td>6.18 dB</td>
</tr>
</tbody>
</table>

Table 3.
\[ NF = 10 \log_{10} \left( \frac{S_i}{N_i} \right) / \left( \frac{S_o}{N_o} \right) \text{ dB} \]

Since we are using dB values, the four linear parameters in the formula are subtracted instead of divided.

The noise figure (NF) of the top system is:

\[
\frac{S_{in}}{N_{in}} - \frac{S_{top}}{N_{top}} = 76.36 - 51.38 = 24.98 \text{ dB}
\]

(Veres the hand-calculated 25.00 dB)

The noise figure (NF) of the bottom system is:

\[
\frac{S_{in}}{N_{in}} - \frac{S_{bot}}{N_{bot}} = 76.36 - 70.25 = 6.11 \text{ dB}
\]

(Veres the hand-calculated 6.18 dB)

Each of the above calculations is within 0.1 dB of the hand-calculated values.
Figure 5. A system to test the accuracy of the noise figure calculations.
Figure 6. The Power Spectrum plots (dBm in 50 ohms) of each of the three sinks in Figure 5.
Figure 7. The results of using the Statistics button in Figure 6.

Calculating the Required Noise Figure of a Receiver
This topic is beyond the scope of this application note. However, Ref. 5 and 6 contain some information on this subject. Calculating a receiver's required noise figure involves knowing at least the following:

The receiver sensitivity at a given input signal amplitude.

The bandwidth of the receiver.

The filter noise bandwidth, that depends on the number of filter stages.
Summary
The graphical software simulation of an RF system using tokens to represent the various gains and losses with their appropriate noise figure parameters has been shown to be an effective way for the system designer to experiment with a receiver's gain distribution to reduce the amount of noise at the output of a system.

References


Appendix C: Amplifier and Active Mixer Characteristics

This appendix is organized as follows:

C-1. Discussion of Input/Output Referenced Parameters for Amplifiers and Active Mixers

Examples of parameter calculations for amplifiers and active mixers:

C-2. Amplifier Calculation Given: In IP3 (Input 3rd Order Intercept)
C-3. Amplifier Calculation Given: In P1dB (Input Power @ 1dB Gain Compression)
C-4. Amplifier Calculation Given: Out IP3 (Output 3rd Order Intercept)
C-5. Amplifier Calculation Given: Out P1dB (Output Power @ 1dB Gain Compression)

C-6. Mixer Calculation Given: In IP3 (Input 3rd Order Intercept)
C-7. Mixer Calculation Given: In P1dB (Input Power @ 1dB Gain Compression)
C-8. Mixer Calculation Given: Out IP3 (Output 3rd Order Intercept)
C-9. Mixer Calculation Given: Out P1dB (Output Power @ 1dB Gain Compression)

C-10. Notes Specific to Amplifiers
C-11. Notes Specific to Active Mixers
C-12. Notes Specific to the Passive Mixer
C-1. Input/Output Referenced Parameters for Amplifiers and Active Mixers

Introduction
Amplifier and mixer data sheets usually do not list all of the parameter values that SystemView requires to model a particular part. This appendix is intended to serve as a guide to calculate the missing parameters. The calculations are based on some general rules-of-thumb of the relationship of the power levels in dB of the various parameters. Firm values in dB are used in the examples for these relationships. Since they are rules-of-thumb, the dB values may be different for a particular component being simulated (perhaps by +/- 4 dB). See Table 1 for abbreviations used in SystemView.

<table>
<thead>
<tr>
<th>Abbrev.</th>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GdB</td>
<td>Gain of the part</td>
<td>10.0 dB</td>
</tr>
<tr>
<td>Out IP2</td>
<td>Output 2nd Order Intercept</td>
<td>20.0 dBm</td>
</tr>
<tr>
<td>Out IP3</td>
<td>Output 3rd Order Intercept</td>
<td>10.0 dBm</td>
</tr>
<tr>
<td>Out P1dB</td>
<td>Output Power @ 1dB Gain Compression</td>
<td>0.0 dBm</td>
</tr>
<tr>
<td>In IP2</td>
<td>Input 2nd Order Intercept</td>
<td>10.0 dBm</td>
</tr>
<tr>
<td>In IP3</td>
<td>Input 3rd Order Intercept</td>
<td>0.0 dBm</td>
</tr>
<tr>
<td>In P1dB</td>
<td>Input Power @ 1dB Gain Compression</td>
<td>-9.0 dBm</td>
</tr>
</tbody>
</table>

Table 1: Abbreviations along with typical values for an amplifier or active mixer.

Note the GdB-1dB difference, between the Out P1dB and the In P1dB values.

In SystemView, relevant amplifier parameters are referenced to the output of the device (Table 2). However, some amplifier data sheets have the parameters referenced to the input signal. This appendix shows how to convert the parameters for either of the reference conditions to the required value.

<table>
<thead>
<tr>
<th>Token</th>
<th>Out P1dB</th>
<th>Out IP3</th>
<th>Out IP2</th>
<th>Out IP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amp-Fixed</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Amp-VG</td>
<td>X</td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 2: Output referenced parameters.

Note: The “X” indicates the token parameter may be user defined.
For mixers, the reference point is different than the amplifiers. In SystemView, all relevant mixer parameters are referenced to the input of the device (Table 3). Sometimes, mixer data sheets have these parameters referenced to the output signal. This appendix will show how to convert the required parameters for either of these referenced conditions.

<table>
<thead>
<tr>
<th>Token</th>
<th>In P1dB</th>
<th>In IP3</th>
<th>In IP2</th>
<th>In IP4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mix-Active</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>100 dBm</td>
</tr>
<tr>
<td>Mix-Passive</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table 3:** Input referenced parameters.

Examples of parameter calculations for amplifiers and active mixers are presented on the following pages.
C-2. Amplifier Calculation Given: In IP3
(Input 3rd Order Intercept)

This input referenced parameter may be converted to an output-referenced parameter for SystemView by using a simple relationship.

Given:  

\[ \text{GdB} = 10.0 \text{ dB} \]
\[ \text{In IP3} = 0.0 \text{ dBm} \]

\[ \text{Out IP3} = \text{In IP3} + \text{GdB} \]
\[ = 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm} \]

General rule for amplifier parameters:

The Out IP2 is 10 dB greater than the Out IP3.  (Rule 1)

The Out P1dB is 10 dB less than the Out IP3.  (Rule 2)

Therefore,

\[ \text{Out IP2} = \text{Out IP3} + 10 \text{ dB} \]
\[ = 10.0 \text{ dBm} + 10 \text{ dB} = 20.0 \text{ dBm} \]

\[ \text{Out P1dB} = \text{Out IP3} - 10 \text{ dB} \]
\[ = 10.0 \text{ dBm} - 10 \text{ dB} = 0.0 \text{ dBm} \]

Although not necessary for SystemView, another calculation is:

\[ \text{In P1dB} = \text{In IP3} - \text{GdB} + 1 \text{ dB} \]
\[ = 0.0 \text{ dBm} - 10 \text{ dB} + 1 \text{ dB} = -9.0 \text{ dBm} \]
C-3. Amplifier Calculation Given: In P1dB
(Input Power @ 1dB Gain Compression)

This input referenced parameter may be converted to an output-referenced parameter for SystemView by using this simple relationship.

Given:

\[ G_{dB} = 10.0 \, \text{db} \]
\[ \text{In P1dB} = -9.0 \, \text{dBm} \]
\[ \text{Out P1dB} = \text{In P1dB} + G_{dB} - 1 \, \text{dB} \]
\[ = -9.0 \, \text{dBm} + 10 \, \text{dB} - 1 \, \text{dB} = 0.0 \, \text{dBm} \]

General rule for amplifier parameters:

The Out IP2 is 20 dB greater than the Out P1dB.
(Inverse of Rule 2)

The Out IP3 is 10 dB greater than the Out P1dB.
(Rule 1 and Rule 2 combined)

Therefore:

\[ \text{Out IP2} = \text{Out P1dB} + 20 \, \text{dB} \]
\[ = 0.0 \, \text{dBm} + 20 \, \text{dB} = 20.0 \, \text{dBm} \]

\[ \text{Out IP3} = \text{Out P1dB} + 10 \, \text{dB} \]
\[ = 0.0 \, \text{dBm} + 10 \, \text{dB} = 10.0 \, \text{dBm} \]

Although not necessary for SystemView, another calculation is:

\[ \text{In IP3} = \text{Out IP3} - G_{dB} \]
\[ = 10.0 \, \text{dBm} - 10.0 \, \text{dB} = 0.0 \, \text{dBm} \]
C-4. Amplifier Calculation Given: Out IP3
(Output 3rd Order Intercept)

This is the default mode for SystemView amplifier parameters.

Given:      GdB  = 10.0 dB
            Out IP3  = 10.0 dBm

General rule for amplifier parameters:

The Out IP2 is 10 dB greater than the Out IP3.
    (Inverse of Rule 1)

The Out P1dB is 10 dB less than the Out IP3.
    (Inverse of Rule 2)

Therefore,

Out IP2  = Out IP3  + 10 dB
         = 10.0 dBm + 10 dB  = 20.0 dBm

Out P1dB  = Out IP3  - 10 dB
           = 10.0 dBm - 10 dB  = 0.0 dBm

Although not necessary for SystemView, two other calculations are:

In IP3  = Out IP3  - GdB
        = 10.0 dBm - 10.0 dBm = 0.0 dBm

In P1dB = In IP3  - G dB +1dB
        = 0.0 dBm - 10.0 dB +1 dB = -9.0dB
C-5. Amplifier Calculation Given: Out P1dB
(Output Power @ 1dB Gain Compression)

This is the default mode for SystemView amplifier parameters.

Given: \( G_{dB} = 10.0 \, \text{dB} \)
\( \text{Out P1dB} = 0.0 \, \text{dBm} \)

General rule for amplifier parameters:

The Out IP3 is 10 dB greater than the Out P1dB.
(Inverse of Rule 1)

The Out IP2 is 20 dB greater than the Out P1dB.
(Rule 1 and 2 combined)

Therefore,

\[
\text{Out IP3} = \text{Out P1dB} + 10 \, \text{dB} \\
= 0.0 \, \text{dBm} + 10 \, \text{dB} = 10.0 \, \text{dBm}
\]

\[
\text{Out IP2} = \text{Out P1dB} + 20 \, \text{dB} \\
= 0.0 \, \text{dBm} + 20 \, \text{dB} = 20.0 \, \text{dBm}
\]

Although not necessary for SystemView, two other calculations are:

\[
\text{In IP3} = \text{Out IP3} - G_{dB} \\
= 10.0 \, \text{dBm} - 10.0 \, \text{dBm} = 0.0 \, \text{dBm}
\]

\[
\text{In P1dB} = \text{In IP3} - G_{dB} + 1 \, \text{dB} \\
= 0.0 \, \text{dBm} - 10 \, \text{dB} + 1 \, \text{dB} = -9.0 \, \text{dBm}
\]

126
RF/Analog Library
**C-6. Mixer Calculation Given: In IP3**

(Input 3rd Order Intercept)

This is the default mode for SystemView mixer parameters.

Given: \[ \text{GdB} = 10.0 \text{ dB} \]
\[ \text{In IP3} = 0.0 \text{ dBm} \]

General rule for mixer parameters:

The In IP2 is 10 dB greater than the In IP3. (Rule 3)

The In P1dB is (GdB –1dB) less than the In IP3. (Rule 4)

Therefore:

\[ \text{In IP2} = \text{In IP3} + 10 \text{ dB} \]
\[ = 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm} \]

\[ \text{In P1dB} = \text{In IP3} - (10 \text{ dB} - 1 \text{ dB}) \]
\[ = 0.0 \text{ dBm} - 9 \text{ dB} = -9.0 \text{ dBm} \]

Although not necessary for SystemView, another calculation is:

\[ \text{Out IP3} = \text{In IP3} + \text{GdB} \]
\[ = 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm} \]

\[ \text{Out P1dB} = \text{Out IP3} - 10 \text{ dB} \]
\[ = 10.0 \text{ dBm} - 10 \text{ dB} = 0.0 \text{ dBm} \]
C-7. Mixer Calculation Given: In P1dB
(Input Power @ 1dB Gain Compression)

This is the default mode for SystemView mixer parameters.

Given: GdB = 10.0 dB
In P1dB = -9.0 dBm

General rule for mixer parameters:

The In IP3 is (G dB –1 dB) greater than the In P1dB.
   (Inverse of Rule 4)

The In IP2 is 10 dB greater than the In IP3.
   (Rule 3)

Therefore,

\[\text{In IP3} = \text{In P1dB} + (G \text{ dB} - 1 \text{ dB})\]
\[= -9.0 \text{ dBm} + (10 \text{ dB} - 1 \text{ dB}) = 0.0 \text{ dBm}\]

\[\text{In IP2} = \text{In IP3} + 10 \text{ dB}\]
\[= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}\]

Although not necessary for SystemView, two other calculations are:

\[\text{Out P1dB} = \text{In P1dB} + \text{GdB} - 1 \text{ dB}\]
\[= -9.0 \text{ dBm} + 10 \text{ dB} - 1 \text{ dB} = 0.0 \text{ dBm}\]

\[\text{Out IP3} = \text{Out P1dB} + 10 \text{ dB}\]
\[= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}\]
C-8. Mixer Calculation Given: Out IP3
(Output 3rd Order Intercept)

This output-referenced parameter may be converted to an input referenced parameter for SystemView by using this simple relationship:

Given: \( GdB = 10.0 \text{ dB} \)
Out IP3 = 10.0 dBm

\[
\text{In IP3} = \text{Out IP3} - GdB \\
= 10.0 \text{ dBm} - 10 \text{ dB} = 0.0 \text{ dBm}
\]

General rule for mixer parameters:

The In P1dB is \((G \text{ dB} - 1 \text{ dB})\) less than the In IP3. (Rule 4)

The In IP2 is 10 dB greater than the In IP3. (Rule 3)

Therefore,

\[
\text{In P1dB} = \text{In IP3} - (G \text{ dB} - 1 \text{ dB}) \\
= 0.0 \text{ dBm} - (10 \text{ dB} - 1 \text{ dB}) = -9.0 \text{ dBm}
\]

\[
\text{In IP2} = \text{In IP3} + 10 \text{ dB} \\
= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}
\]

Although not necessary for SystemView, two other calculations are:

\[
\text{Out P1dB} = \text{Out IP3} - 10 \text{ dB} \\
= 10.0 \text{ dBm} - 10 \text{ dB} = 0.0 \text{ dBm}
\]

\[
\text{Out IP3} = \text{Out P1dB} + 10 \text{ dB} \\
= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}
\]
C-9. Mixer Calculation Given: Out P1dB
(Output Power @ 1dB Gain Compression)

This output-referenced parameter may be converted to an input referenced parameter for SystemView by using this simple relationship:

Given: \( G_{dB} = 10.0 \text{ dB} \)
Out P1dB = 0.0 dBm

\[
\text{In P1dB} = \text{Out P1dB} - G_{dB} + 1 \text{ dB} \\
= 0.0 \text{ dBm} - 10 \text{ dB} + 1 \text{ dB} = -9.0 \text{ dBm}
\]

General rule for mixer parameters:

The In IP3 is \((G \text{ dB} - 1 \text{ dB})\) greater than the In P1dB.
(Inverse of Rule 4)

The In IP2 is 10 dB greater than the In IP3.
(Rule 3)

Therefore,

\[
\text{In IP3} = \text{In P1dB} + (G \text{ dB} - 1 \text{ dB}) \\
= -9.0 \text{ dBm} + (10 \text{ dB} - 1 \text{ dB}) = 0.0 \text{ dBm}
\]

\[
\text{In IP2} = \text{In IP3} + 10 \text{ dB} \\
= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}
\]

Although not necessary for SystemView, another calculation is:

\[
\text{Out IP3} = \text{Out P1dB} + 10 \text{ dB} \\
= 0.0 \text{ dBm} + 10 \text{ dB} = 10.0 \text{ dBm}
\]
C-10. Notes Specific to Amplifiers

- Since the Out IP4 of an amplifier is usually not of interest, it may be set to a high value (100 dBm) to reduce its influence on the simulation.

- Since the amplifier parameters are referenced to the output of the device, they directly indicate the clipping and saturation levels regardless of the amplifier’s gain.

C-11. Notes Specific to Active Mixers:

- Since the mixer parameters are referenced to the input of the device, changing the gain parameter of a mixer token will cause the clipping and saturation levels of the device to change also. If the clipping and saturation levels of the mixer are required to remain unchanged with the new gain, it is necessary to convert the remaining parameters.

C-12. Notes Specific to the Passive Mixer:

- While the passive mixer is not discussed in detail in this section, its parameters are referenced to the input signal. The passive mixer’s In P1dB and In IP3 follow the same general rules that are described for the active mixer.
<table>
<thead>
<tr>
<th>Token Description</th>
<th>Abbreviation</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amplifier, Fixed</td>
<td>Amp-Fixed</td>
<td>11</td>
</tr>
<tr>
<td>Amplifier, Traveling Wave Tube (TWTA)</td>
<td>Amp-TWT</td>
<td>15</td>
</tr>
<tr>
<td>Amplifier with Variable Gain</td>
<td>Amp-VG</td>
<td>17</td>
</tr>
<tr>
<td>Attenuator, Fixed</td>
<td>Attn-Fixed</td>
<td>21</td>
</tr>
<tr>
<td>Buffer Circuit (non-inverting)</td>
<td>Op-Buff</td>
<td>54</td>
</tr>
<tr>
<td>Capacitive-Coupled Resonator Circuit</td>
<td>LC-Resn</td>
<td>41</td>
</tr>
<tr>
<td>Charge Pump Circuit</td>
<td>RC-Cpump</td>
<td>86</td>
</tr>
<tr>
<td>Differentiator Circuit</td>
<td>RC-Diff</td>
<td>88</td>
</tr>
<tr>
<td>Diode Circuit with Input to the Anode</td>
<td>D-Anode</td>
<td>23</td>
</tr>
<tr>
<td>Diode Circuit with Input to the Cathode</td>
<td>D-Cath</td>
<td>25</td>
</tr>
<tr>
<td>Diode, Zener Circuit with Back-to-Back Pair</td>
<td>D-Zen-2</td>
<td>27</td>
</tr>
<tr>
<td>Diode, Zener Circuit with Input to the Anode</td>
<td>D-Zen-An</td>
<td>29</td>
</tr>
<tr>
<td>Diode, Zener Circuit with Input to the Cathode</td>
<td>D-Zen-Ca</td>
<td>31</td>
</tr>
<tr>
<td>High Pass Filter LC Circuit</td>
<td>LC-Hpf</td>
<td>33</td>
</tr>
<tr>
<td>High Pass Filter RC Circuit</td>
<td>RC-Hpf</td>
<td>90</td>
</tr>
<tr>
<td>Hysteresis Circuit</td>
<td>Op-Hyst</td>
<td>55</td>
</tr>
<tr>
<td>Integrate and Dump Op Amp Circuit</td>
<td>Op-I-Dmp</td>
<td>57</td>
</tr>
<tr>
<td>Integrate and Dump RC Circuit</td>
<td>RC-I-Dmp</td>
<td>92</td>
</tr>
<tr>
<td>Inverter, Single Input Op Amp Circuit</td>
<td>Op-Invert</td>
<td>59</td>
</tr>
<tr>
<td>Low Pass Filter LC Circuit</td>
<td>LC-Lpf</td>
<td>35</td>
</tr>
<tr>
<td>Low Pass Filter Simple LC Circuit</td>
<td>LC Lpfs</td>
<td>37</td>
</tr>
<tr>
<td>Low Pass Filter RC Circuit</td>
<td>RC-Lpf</td>
<td>94</td>
</tr>
<tr>
<td>Mixer, Double-Balanced, Active</td>
<td>Mix-Act</td>
<td>45</td>
</tr>
<tr>
<td>Mixer, Double-Balanced, Passive</td>
<td>Mix-Psv</td>
<td>49</td>
</tr>
<tr>
<td>PID Circuit</td>
<td>Op-PID</td>
<td>60</td>
</tr>
<tr>
<td>PLL Filter, Single Input Op Amp circuit</td>
<td>Op-PLL1</td>
<td>62</td>
</tr>
<tr>
<td>PLL filter, Differential Input Op Amp Circuit</td>
<td>Op-PLL2</td>
<td>64</td>
</tr>
<tr>
<td>PLL Filter RC Circuit</td>
<td>RC-PLL</td>
<td>96</td>
</tr>
<tr>
<td>Power Combiner: 2-Way, 180-Degree</td>
<td>PCmb 180</td>
<td>68</td>
</tr>
<tr>
<td>Power Combiner: 2-Way, 0-Degree</td>
<td>PCmb-2</td>
<td>69</td>
</tr>
<tr>
<td>Power Combiner: 3-Way, 0-Degree</td>
<td>PCmb-3</td>
<td>70</td>
</tr>
<tr>
<td>Power Combiner: 4-Way, 0-Degree</td>
<td>PCmb-4</td>
<td>72</td>
</tr>
<tr>
<td>Power Coupler: 2-Way, 0-Degree</td>
<td>PCoupler</td>
<td>74</td>
</tr>
<tr>
<td>Power Splitter: 2-Way, 180-Degree</td>
<td>PSplit 180</td>
<td>76</td>
</tr>
<tr>
<td>Power Splitter: 2-Way, 0-Degree</td>
<td>PSplit-2</td>
<td>78</td>
</tr>
<tr>
<td>Power Splitter: 3-Way, 0-Degree</td>
<td>PSplit-3</td>
<td>80</td>
</tr>
<tr>
<td>Power Splitter: 4-Way, 0-Degree</td>
<td>PSplit-4</td>
<td>82</td>
</tr>
<tr>
<td>Power Splitter: 2-Way, 90-Degree (Hilbert)</td>
<td>PSplit 90</td>
<td>84</td>
</tr>
<tr>
<td>Quadrature Tank Circuit</td>
<td>LC-Quad</td>
<td>39</td>
</tr>
<tr>
<td>Sum of 3 inputs Op Amp Circuit</td>
<td>Op-Sum3</td>
<td>66</td>
</tr>
<tr>
<td>Tank circuit</td>
<td>LC-Tank</td>
<td>43</td>
</tr>
</tbody>
</table>