WEBENCH® Simulation Engine

Introduction

WEBENCH® Simulation Engine (WBSE) is a general-purpose circuit simulation program that analyzes electronic circuits using direct-method circuit simulation techniques. These techniques provide precise waveforms for voltages, currents, and charges in the circuit.

WBSE simulates circuits containing a range of devices, including:
• Resistors
• Capacitors
• Inductors and mutual inductance
• A variety of independent and dependent voltage and current sources
• Lossy and lossless transmission lines

The range of non-linear devices include:
• Bipolar junction transistors
• Junction field-effect transistors
• MOS field-effect transistors

Users only need to specify the pertinent model parameters and WBSE uses built-in models for these non-linear semiconductor devices.

WBSE requires at least one file as an input. The input file should contain the circuit description in the form of a netlist of primitive circuit components, the models used for all non-linear devices in the circuit, the analysis that need to be performed on the circuit, the options to be used for the analysis, and finally the outputs that need to be saved.

Overview

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Analyses performed by WEBENCH® Simulation Engine [WBSE] can be grouped into 3 domains:

• **DC domain**

These analyses compute the stable dc state of the circuit. All device parameters are computed first. Next, WBSE performs iterations to propagate the dc values of all independent sources in the circuit to all other nodes and devices in the circuit. Iterations continue until a steady-state is achieved. In the steady state, voltage on nodes, charge on capacitors, flux in inductors, and currents through resistors become constants.

DC domain analyses include:

- **OP : operating point** analysis
- **DC : dc transfer curve** analysis

• **Time domain**

In time domain, WBSE first computes the time=0 steady state solution. Then 'time' is increased and the value of time-varying independent sources change. As a result, node voltages change, capacitors charge or discharge, and currents through devices change. WBSE takes appropriately small time-steps and re-computes the stable state. This process is repeated until the end of the time-domain simulation.

Time domain analysis includes:

- **TRAN : transient** analysis

• **Small-Signal Frequency domain**

These analyses work on a stable operating point of the circuit. At the operating point, WBSE generates the linearized small-signal model of the circuit. In small-signal frequency domain, the circuit's behavior is analyzed at different real or complex frequencies.

Frequency domain analyses include:

- **AC : ac** analysis

The operating point for small-signal analyses can either be a stable dc solution where all independent sources are set to their "dc" values, or it can be a converged time-point solution during a transient analysis, where all time-varying independent sources are set to their time values.

Overview: Transient Analysis

TRAN : Transient analysis

A **transient** analysis performs a time-domain analysis of your circuit over a specified time interval. Before starting the transient analysis, WBSE computes the operating point of the circuit using the time=0 values of all independent sources that have a time function. Other independent sources get their **dc** values at time=0. This is an operating point analysis that results in an "**initial transient**" solution of the circuit. After the time=0 solution is obtained, WBSE starts to increment '**time**' in steps. The voltages of all time dependent sources are updated. Capacitive components in the circuit are allowed to charge and discharge, and flux through inductors is allowed to change. Currents through devices can change. WBSE recomputes the solution of the circuit at the new time-point. It does so by starting from the previous timepoint solution. The process repeats until time reaches the specified stop time for the transient analysis.

Time-stepping

WBSE can take a fixed-time step for the entire transient analysis. More commonly, WBSE computes a new time-step size at every time-point. The step-size is based on circuit characteristics, and the rate of change of voltages and currents in the circuit. (Details in Transient Analysis Parameters)

Accuracy

Accuracy parameter settings also determine the time-step size. Loser error tolerance settings will make WBSE take bigger time-steps. This will finish the transient simulation sooner at the cost of inaccuracies in the results. Tighter error tolerances will keep the time-steps smaller. The results will then be more accurate at the cost of longer run times. (Details in Transient Analysis Parameters)

Transient Analysis Parameters

Simulation Time & Interval Parameters

TSTEP

Defines the time-step size for fixed time-step controlling methods. It may also be used as default values of some parameters on some independent sources. An example is the rise-time of a pulse source.

TSTART

If the waveform output of a transient analysis is not interesting from time=0 to a certain time value, the size of the waveform files written by WBSE can be reduced by setting TSTART to the time value from which you want to see the waveforms. This does not save simulation time, because the transient analysis always starts from time=0.

TSTOP

Stop time value at which transient analysis stops.

TMAX

For variable time-step methods step-size can become large if there is no activity in the circuit. Specifying TMAX will not allow WBSE to take a step-size larger than that value. The default (**1/20th of TSTOP**) can be too large for oscillator circuits. For accurate results on such circuits, be sure to set TMAX to no more than 1/20th of the period of oscillation.

TRES

Certain devices can cause discontinuous events at their output during a transient analysis. Discontinuous events include instantaneous switching. PWL and math expression types of controlled sources can exhibit such behavior. Truncation error becomes large when this happens, and it can make WBSE take very small time-steps. Reducing time-step to **TMIN** to locate the exact corner and recovering to larger time-steps can be inefficient. **TRES** allows you to set a higher threshold than **TMIN** to resolve such transitions.

Usually **TRES** is significantly larger than **TMIN**.

Accuracy & Convergence Parameters

LTERATIO

Local truncation error (LTE) is the error in integration over time. This represents the difference between the computed solution and the predicted solution derived from an extrapolation of the solutions at the previous few time points. LTE needs to be controlled in a transient analysis to avoid inaccuracies in results due to very large time-steps.

Tolerance for LTE, or Tolerance_{LTE} is defined as a constant multiple of Tolerance_{NR}:

$$LTERATIO = Tolerance\ LTE / Tolerance\ NR$$

RELTOL and ABSTOL parameters control the accuracy of the solution to within the specified tolerance at any given time. This tolerance is called the Newton-Raphson tolerance, or $Tolerance_{NR}$. It is defined by the equation:

$$ToleranceNR = ABSTOL + RELTOL \times REF$$

In other words, **LTERATIO** is defined as: To reduce LTE, while keeping error tolerance for voltages and currents the same, you can make LTERATIO smaller. To reduce them both, you can make RELTOL and/or ABSTOL smaller. If you make RELTOL and/or ABSTOL larger, and want to maintain the same LTE tolerance, you will also need to decrease LTERATIO.

MAXITERS

WBSE usually takes less than 3 iterations to converge at any time point > 0. If 'MAXITERS' iterations are reached without convergence at any time-point, the time-step size will be reduced and convergence attempted again at an earlier time point. In other words, the transient analysis backs up. Backups due to reaching this iteration limit usually indicates other problems in the circuit or models.

MAX_LIMITING_ITERS

Maximum iteration allowed during transient with devices enter limiting mode, default value is 200.

UIC

This parameter tells WBSE to bypass the traditional "initial transient convergence" flow and just use the provided "**Initial Conditions**" as the time=0 solution. The **IT** values, if specified, are ignored. If not used carefully, 'UIC" can cause serious non-convergence problems at the first time point of the transient analysis. This is especially true if, at the very first time point, voltages in the circuit have sharp changes from zero or the initial conditions provided.

Overview: AC Analysis

AC : AC analysis

An **ac** analysis determines the response of a linearized small-signal model of your circuit, to the frequency of 'ac' sources in your circuit. Typically, in an **ac** analysis, you sweep the frequency of the ac sources while your circuit is biased at the same operating point. WBSE allows you to sweep other variables as well in an ac analysis.

Prerequisites for AC analysis

To perform an **ac** analysis, there should be at least one independent "ac" source in the circuit. If there are multiple "ac" sources, WBSE will write a warning but continue the simulation. The effect will be a superposition of all the ac sources in the circuit.

AC Analysis Parameters

POINTS

Number of points through the AC sweep. Definition depends on TYPE of SWEEP.

SWEEP TYPE

Types of Sweep:
LINEAR - Linear. Size will be "(stop-start)/(points-1)".
DECADE - Logarithmic by octaves. Points specified are per decade.
OCTAVE - Logarithmic by decades. points specified are per octave.

START FREQ

Start value of frequency sweep.

STOP FREQ

Stop value of frequency sweep

Overview: DC Analysis

DC : DC analysis

A **dc** analysis determines a series of dc solutions of the circuit while one or more circuit variables are swept. Originally, as the name implies, this analysis was designed to sweep the dc value of an independent voltage or current source and watch the circuit response.

WBSE computes the dc solution at the first point of the sweep variable(s) starting from zero or the specified initial conditions. All subsequent points of the sweeps are solved by taking the previous solution as the initial guess. The assumption here is that the step size of the sweep is small and so the solution will change very slightly. Two situations invalidate this assumption. First is the case of nested sweeps when the inner loop variable switches back to its starting value while the outer loop variable takes the next step. The second case is when the circuit switches states very abruptly due to high gains of some circuit components. Default iteration count limits, and step sizes can be adjusted to solve non-convergence problems that such situations can cause.

DC Analysis Parameters

POINTS

Number of points through the DC sweep. Definition depends on TYPE of SWEEP.

SWEEP TYPE

Types of Sweep:
LINEAR - Linear. Size will be "(stop-start)/(points-1)".
DECADE - Logarithmic by octaves. Points specified are per decade.
OCTAVE - Logarithmic by decades. points specified are per octave.

SWEEP VARIABLE

Name of the variable to be swept.

START VALUE

Start value of sweep variable.

STOP VALUE

Stop value of sweep variable.

Tolerance Parameters

Tolerance parameters control the accuracy of a computed value while iterating to a converged solution. In other words, they limit the error to within the desired tolerance for accuracy. These parameters are optional and can be specified on all of the analyses described above. Accuracy parameters are described in the table below.

The equation that uses these parameters to compare two values, **Val_1** and **Val_2** of a variable is:

$$|Val_1 - Val_2| <= ABSTOL + RELTOL \times \min(|Val_1|, |Val_2|)$$

Here **ABSTOL** (=**VABSTOL** for voltages or **IABSTOL** for currents) is the "**absolute**" error component of the error. **RELTOL** is the "**relative**" error component.

RELTOL

Default=**1e-3**
Relative error tolerance.

VABSTOL

Default=**1e-6**
Absolute voltage error tolerance.

IABSTOL

Default=**1e-9**
Absolute current error tolerance.

GMIN

Default=**1e-12 mhos**
This option sets the minimum conductance value allowed for any of the elements in your circuit. A gmin conductance between a pair of nodes in the circuit is "nearly" an open circuit. The current through this conductance should be several orders of magnitude smaller than other currents through those nodes. Generally a gmin conductance should not change your simulation results. If there are real conductances in your circuit that are close to gmin, you can reduce the value of this option.

PSpice Model Convergence Options

CHECK_DCMAX

Default=**true**
If set to "**false**", this option turns off the checking of currents and voltages at a **dc** operating point against the values of CURMAX **(**Default=1 amp) and VOLTMAX (Default=1 amp) options.

TRAN_LIMITING

Default=**false**
Enable device limiting during the transient, critical for behavior model or control source with abrupt transitions.

OPTSTEP

Default=**off**
Enable TI proprietary optimal time-stepping algorithm (still in beta).

Supported Devices

List of devices that are supported by WEBENCH® Simulation Engine

- Bipolar Junction transistor
- Capacitor
- Voltage-controlled voltage source
- Voltage-controlled current source
- Current-controlled current source
- Current-controlled voltage source
- Diode
- Independent current source
- Independent voltage source
- Inductor
- Mutual Inductor
- Junction FET
- MOSFET
- Resistor
- Subcircuit instantiation
- Transmission line
- Voltage controlled switch

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