Tips for Saber Users in the Simulation of Power Electronic Circuits

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Abstract: In this article, some useful tips for Saber users are described for successful simulation of power electronic circuits. The tips described were tried on power electronic converters operating at frequencies as high as 40kHz and a maximum power of 10kW. The simulation was done on a Sun Sparc station with 16Meg of real Memory. All the tips described here are for the 3.1a Version using the human interface.

1 Writing an Appropriate Netlist: (for human interface version)

Usually writing a Saber netlist is the easiest thing to do for any Saber User. However, there are many ways to write an appropriate netlist. First of all you should include in your netlist shorts if you want to measure the current in the branches instead of the zero dc voltages. However, this may not be the best way especially in the case of templates with their own internal current. You may also want to specify the value of the series resistance for the c and l templates. To do this more efficiently, you have to specify a value for the built-in series resistor. This specification allows you to have a more realistic model without adding an external resistance. In case of the capacitor, when you do not specify a value for the built in (Electrical Serial Resistance) E.S.R, the number of nodes is reduced which leads to a corresponding saving in the simulation time.

In some cases, the addition of shorts or zero-dc voltages is not necessary because you can get the current by specifying them in the SIGLIST. When you are only interested in getting the waveforms from Saber and not the details of the commutations, it is much better to replace the semiconductors with the ideal switches. There is a variety of switches implemented in the Saber Template Library.

It is also better to specify the group of the diode or the semiconductor in the netlist, especially when you are operating at high frequencies (e.g diode.1 e1 e2=group=high_speed). You can also specify some parameters of the model like the saturation current or the distribution. Keep in mind that it is much better to replace the semiconductors with behavioral switches, as many as you can, because this gives you an idea about the functioning of the converter. Some components like the IGBT are not very appropriate to use especially at high frequencies. Actually the IGBT model used by Saber is highly non linear and thus requires a lot of simulation time. It is much easier to use either digital switches like the sw_l4, pwm_l4, the behavioral switch, or the state-spaced averaged models. It is also useful to replace the control circuit by pulse voltage sources. In the case of switching power supplies you can replace the switch and its control by one element.

2 Ways of running Saber:

Usually when you want to run Saber for an application, you start by a dc analysis and then the transient analysis. In some cases the transient does not take a lot of time but in many converters the transient is very long and takes several thousand clock cycles before reaching the steady state. As we are not very interested in this numerical transient, it is advisable to run it as fast as possible and to get rid of it.

One way to do that is to take a big TIME STEP and a large Truncation Error. Generally a truncation error of 0.001 is more than sufficient. In some cases it is even possible to specify a truncation error of 0.1. It is also important that you specify certain parameters during the dc analysis (e.g. you can specify the value of the output voltage and save a lot of time for the simulator to reach that point).

The SIGSET command is also useful in this case. It allows you to create an initial point to start the dc or the TRansient analysis. Note that SIGSET does not work in conjunction with the simulation. An alternative to it is the use of the option HOLDNODES which works in conjunction with the simulation of the dc analysis. You may want to specify not to release HOLD after the dc analysis in order to help the dc simulation converge more quickly and/or easily. When RELHOLDnodes is set to yes, it will solve the dc holding the nodes to the specified values. When finished, it will automatically use the final point of the dc analysis as an initial point to solve a normal dc. This option is valid only when a steady-state solution exists. When there is no steady solution, one has to set RELHOLD to NO. This is true in the case of oscillators. However, you have to be careful when using the HOLDNODES because it may result in a different result than the SIGSET, especially in case of circuits with parasitic elements such as inductors or capacitors. The SIGSET command specifies only the value of the node voltage while the HOLDNODES imposes the voltage and the current. SIGSET is essentially an initial point editor, and as such, has no validity with regards to simulation.

Another important thing to consider is the files created by Saber for each analysis. In general if you are not interested in extracting the initial point or any variables from any level of hierarchy not already in the SIGList for the PLotfile(s), you do not need to keep the data file. Therefore it is easy to tell Saber to ignore it simply by giving an underscore `_' instead of a name in the transient analysis menu. Ie, ``DF _'' The same thing applies for the plot file. You may only need to keep the initial point and the end point. Ie, TRIP and TREP.

After completing the transient and reaching the steady state, a good accuracy is needed in order to have a very good result. For best accuracy, TruncationERRor may be set to 0.1m and the TruncationERRorTYPE to ALL for the version 3.2. (For previous release use STATIC.) It may be helpful to increase the DENSITY to 16 or 32 or even in some cases to 64. Generally a time step of 0.001u is good enough for power electronic converters operating at high frequencies (up to 50 kHz). However, it is not a critical parameter since Saber uses a variable-size timestep which automatically adjusts the timestep in order to keep to the accuracy settings (eg, TruncationERror). Keep in mind to use for each transient the previous result. This is possible by using the CONTinue menu and CONTinue TRansient with the appropriate TimeEnd.

3 Avoiding Troubles with Saber: (Transient Analysis)

In some cases and even with all the precautions taken, you may run in trouble and get an error message. The error message may be one of the followings:

1 SINGULAR JACOBIAN MATRIX
2 ALGORITHM NO NON LINEAR SOLUTION
3 PL DATABASE EOF
4 CLASS-OPEN-FILE

One way to get around the first error if it has happened during the transient analysis is to run Saber with the hierarchy flattened:

```
Saber -d flat file.sin
```

This usually fixes the problem. If the problem has not been fixed, try to fix it either by increasing the density or by reducing the truncation error and the time step. It is also sometimes useful to change the time resolution of the simulator. You may also need to alter parameter values so that various instances of a template type don't have too wide of a range of values (e.g c.1=1p; c.2 =1 #Farad). This problem may also arise from choosing a very small TimeStep relative to TimeEnd because of the wide difference of time constants (stiff system).

The second error is usually fixed by the adjustment of the truncation error and the density. A couple of other things to do in this case is:

1. Switch to the first order integration method.

2. switch to the Trapezoidal integration method.

However, the last two methods may not be very accurate if the converter is operating at high frequencies.

When you get the message PL DATABASE EOF, you have to run again the simulation for a few cycles. It is also possible to fix the problem by editing the ASCII *.pl.* file and changing the value for npoints (near the bottom of the file) to a slightly smaller value. Therefore, you will avoid the need to resimulate.

Whenever you get the error CLASS-OPEN FILE you need to check your disk quota because you went over it.

In some cases you may need to run the simulation step by step and after each step use the old transient end point (TRep) as your new transient initial point (TRip). When you are using IDEAL SWITCHES instead of real models of the semiconductors, you have to be aware that the ON resistance of the switch should be finite. Theoretically you can use a zero ON resistance and an infinite OFF resistance but it is advisable to give a small ON resistance and a big value but finite for the OFF resistance. The same thing applies to the rise time and the fall time of many templates like the pulse template. The Rise and Fall times must be strictly positive.