APPLICATION NOTE

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Analog Behavioral Modeling

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Let's take a look at examples of how the Analog Behavioral Modeling feature in the Cadence® PSpice® environment can cope when generic SPICE fails.

First, let's say you need to create a signal whose voltage is the square root of another signal's voltage. Calculating square roots is simple, even for SPICE, through the use of a feedback circuit. However, this technique fails if the reference signal ever goes negative. In this case the functional form of Analog Behavioral Modeling works nicely:

```
Esqrtout_hiout_lovalue= {sqrt (abs(v(input)))}
```

This takes the absolute value of the ground-referenced signal "input" before evaluating the square-root function (you could also use a floating signal-pair by replacing `v(input)` with `v(in_hi)-v(in_lo)` or `v(in_hi,in_lo)`, for example). The absolute-value function is a nonlinear function difficult to perform in generic SPICE.

We can also introduce ideal nonlinearities using the table lookup form of Analog Behavioral Modeling. For example, the one-line, ideal opamp model:

```
Eampout0table {200K*(v(in_hi)-v(in_lo))}=
+(-15,-15)(15,15)
```

has high gain, but its output is clamped between 15 volts. The input to the table is the differential gain formula, but the lookup table has only two entries: so the output of the table is interpolated between these two endpoints and clamped when the input exceeds the table's range. This is a convenient use of the table lookup form, which is not available in generic SPICE.

Small systems of behavioral models are easy to design, also. For example, a true-RMS circuit can be built by decomposing the RMS function: (i) square the signal, (ii) integrate over time, and (iii) take the square- root of the time average. These three operations can be bundled in a tiny subcircuit for use as a module:

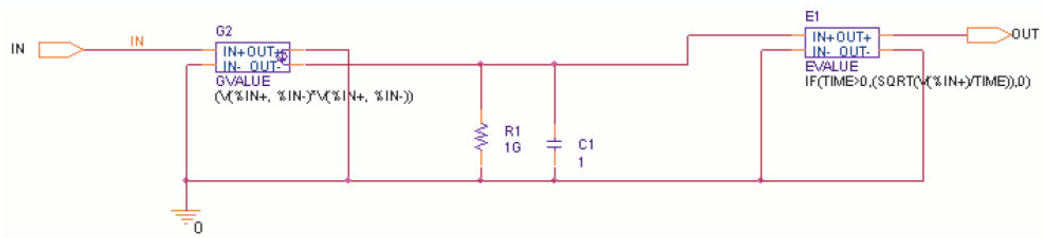


Figure 1: RMS subcircuit

The current source, `G2`, squares the signal, which is then integrated in the capacitor. The voltage on the capacitor is time averaged, and the square-root is taken (the resistor is a dummy load that satisfies the SPICE algorithms). The voltage source `E1` shows that the value of simulated "time" is available in Analog Behavioral Modeling, and may be used as a variable in a formula. Notice that the if-than-else function is used. If time is less than or equal to zero then the output of `E1` is `0`. This prevents convergence problems when `sqrt(v(%IN+)/time)` is evaluated at `time = 0`. If time is greater than zero then the output of `E1` is `sqrt(v(%IN+)/time))`.

Parameter passing into subcircuits also works with Analog Behavioral Modeling, which makes your models more flexible. Here is a small system that is a voltage follower with hysteresis, which would be useful in simulating, say, a mechanical system with gear backlash:

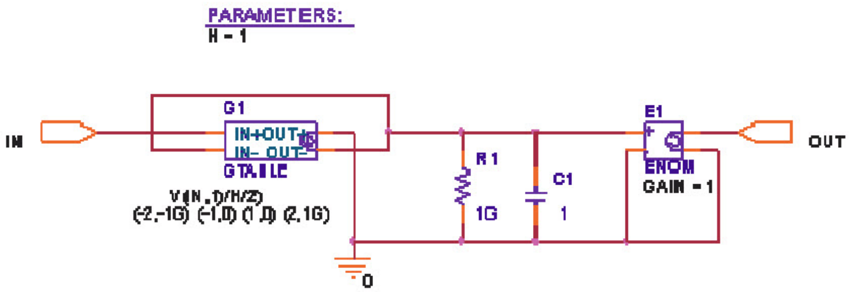
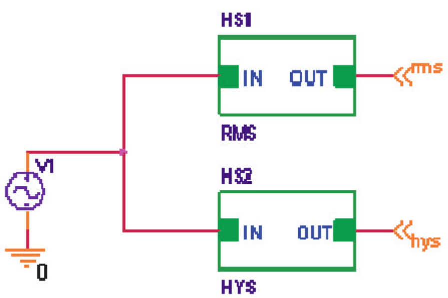


Figure 2: Hysteresis subcircuit

The parameter H defines the size of the hysteresis, and is used in the formula input to the table. The combination of the formula and table defines a dead-band outside of which the output follows the input with an offset of `H/2`. The capacitor serves as memory for the circuit and is nearly ideal except for the DC-bias resistor, which provides a droop time constant of one billion (!) seconds. The voltage follower, `E1`, prevents output loading problems. `E1` could also have gain representing the gear ratio of a mechanical system; then voltage would represent the total turn angle of each gear, and `H` the amount of angular



backlash.

Figure 3: Circuit using RMS and hysteresis subcircuits

Download example file:"abm.zip"

A 1 Hz sine wave was used for the stimulus to the RMS and HYS circuits.

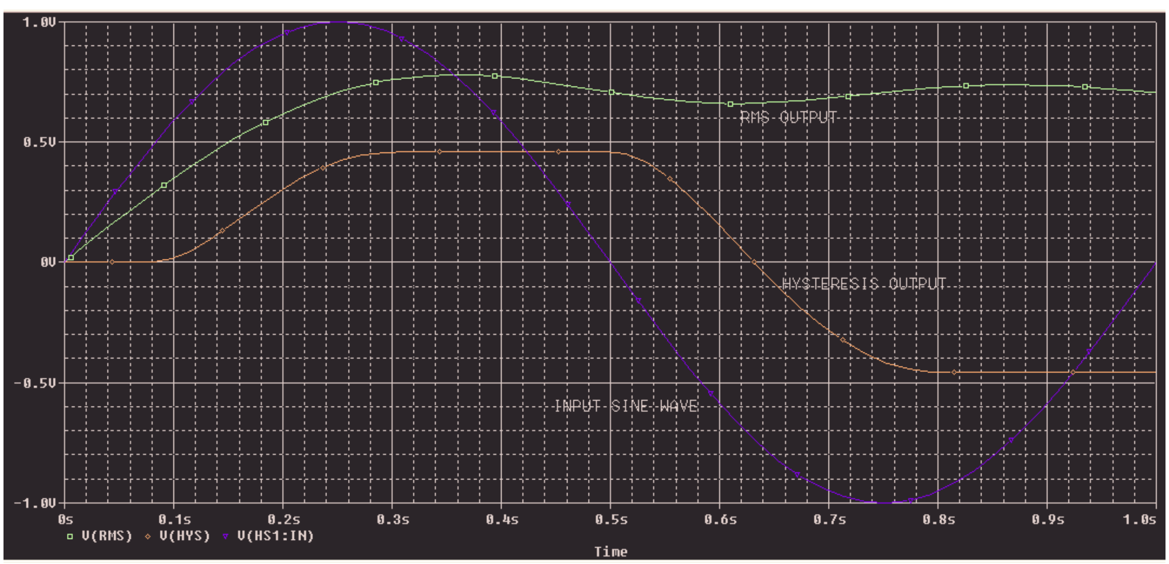


Figure 4: Output from RMS and HYS circuits

In Figure 4, we see a Probe plot of the input, and the outputs from each circuit. Note that the RMS circuit outputs the well-known result of 0.707 volts after one input cycle, while the HYS circuit lags the input by a half volt in each direction for a total hysteresis of one volt. Perhaps these examples will give you ideas for other functions which would be "most difficult" to create with generic SPICE.

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