Kick start a crystal oscillator in Spice

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Starting up oscillator circuits and getting them to maintain oscillation in a Spice simulation is difficult. Some high-frequency crystal circuits require days for the oscillation to reach steady state. Thus, most designers separate the crystal’s circuit simulation from the rest of the system design. However, a technique that gives a "kick" to an RLC equivalent circuit solves this problem. This method makes sure the simulation starts fast and quickly reaches the steady state.

**Figure 1a** shows the equivalent RLC circuit of a quartz crystal. Most clock chips, such as Cypress Semiconductor's ([www.cypress.com](http://www.cypress.com)) CY227x and CY228x families, have a crystal circuit similar to **Figure 1b**. The circuit comprises the crystal, an inverter/gain block, and a feedback network.

Conventionally, Spice uses an initial condition for the RLC resonator, such as setting the inductor initial current to a certain value, to start the simulation. The reference frequency of the most common clock chips is 14.1318 MHz. The simulation takes a least a day to reach constant oscillation amplitude because high-Q resonators require long periods of time to reach a certain energy level.

The key to quickly starting this type of oscillator is giving a kick to the RLC equivalent circuit in the form of a high-voltage damped sinusoid that ultimately fades away. The frequency of this excitation is the expected frequency of the resonator. The source looks like a short circuit in the RLC circuit and does not alter any of the circuit's dc- bias conditions. **Figure 2** shows the simulation input/output waveforms, and **Figure 3** shows the excited sinusoidal voltage. The excited voltage is in the kV range because the voltages across L1 and C1 are in kV range when the LC tank is oscillating.

For a 14.318-MHz crystal, the equivalent circuit has $C_0=4$ pF, $C_1=13.613$ pF, $L_1=9.076$ mH, and $R_1=25$W. The excited voltage source is a simple Spice sinusoidal voltage source, $V_{sin}$ in **Listing 1**. The $V_{sin}$ statement includes the damping factor. (DI#2357)