Transmission lines simulate digital filters in PSpice

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Designers use PSpice mainly to simulate analog circuits. However, you can also simulate digital filters with it. The main components in a digital filter are delay elements, adders, and multipliers. Although you can implement adders and multipliers using operational amplifiers, you can simulate a delay element with a transmission line. The transmission line in PSpice is a long-forgotten element that can realize a delay of seconds.

Figure 1 The transfer function for a second-order recursive digital filter has coefficient values that yield a lowpass, highpass, band-reject, or bandpass-transfer function.

For example, Figure 1 shows a second-order recursive digital filter. The transfer function for this filter is:

\[ H(z) = \frac{B_2 z^2 + B_1 z + B_0}{z^2 + A_1 z + A_2}, \]

where \( H(z) \) is the digital-filter-transfer function, \( z \) is the z-transform variable, the \( A \)s are the coefficients of the denominator polynomial of the transfer function, and the \( B \)s are the coefficients of
the numerator polynomial of the transfer function. You can obtain the coefficient values with software available for filter design (Reference 1). The sampling frequency, \( f_s \), relates to the transmission-line delay as \( t = 1/f_s \).

For example, a bandpass digital filter with a 3-dB passband from 900 Hz to 1 kHz, a sampling frequency of 6 kHz, and a Butterworth characteristic yields the following transfer function:

\[
H(z) = \frac{z^2 - 1}{z^2 - 0.9096107 + 0.809374}.
\]

In this case, the transmission-line delay is \( 1/6000 = 166.67 \) µsec. If you additionally specify an impedance, \( Z \), of 1Ω for the transmission line, then the parameters for the transmission line are \( Z_0 = 1 \Omega \), and \( t = 166.67 \) µsec. Figure 2 shows the PSpice circuit. The VCVSs (voltage-controlled voltage sources), E1 and E2, simulate voltage followers, and VCVSs E3 and E4 and the resistors that connect to them simulate summers. Figure 3 shows the results of the simulation.

**Figure 2** In the PSpice circuit, the VCVSs (voltage-controlled voltage sources), E1 and E2, simulate voltage followers, and VCVSs E3 and E4 and the resistors that connect to them simulate summers.
Figure 3 In this PSpice simulation, the digital bandpass filter uses transmission lines as delay lines.

Reference