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.

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

$$H(z)=\frac{B_0z^2+B_1z+B_2}{z^2+A_1z+A_2},$$

where H(z) is the digital-filter-transfer function, z is the z-transform variable, the As are the coeffieients of the denominator polynomial of the transfer function, and the Bs 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:

$$H(z)=\frac{z^2-1}{z^2-0.9096707z+0.809374}.$$

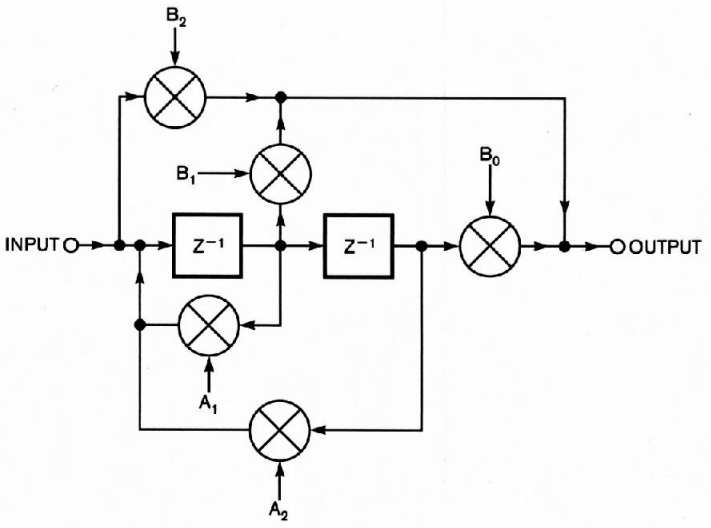

Figure 1 The transfer function for a second-order recursive digital filter has coefficient values that yield a lowpass, highpass, band-reject, or bandpass-transfer function.

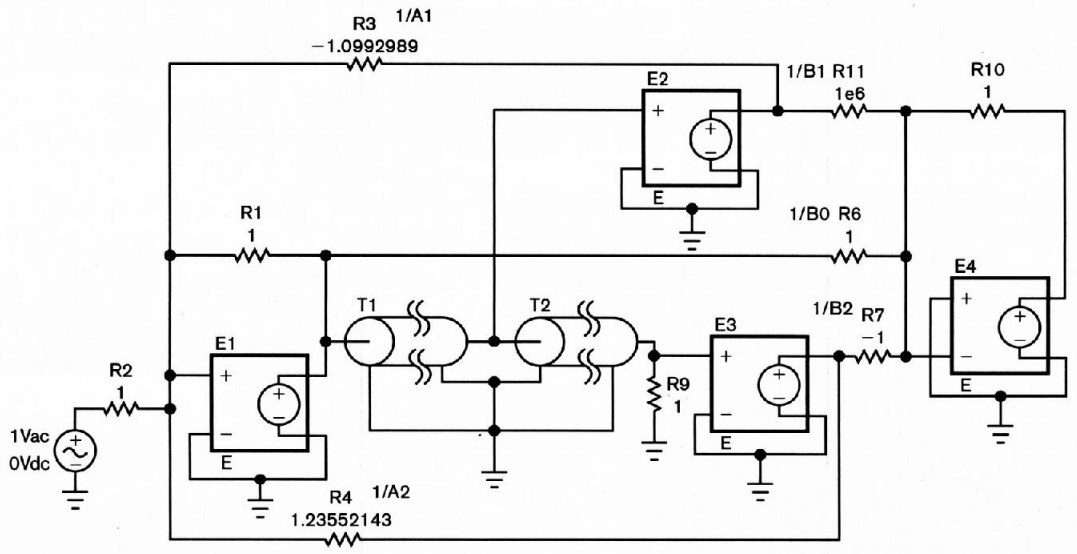

Figure 2 In the PSpice circuit, the VCVSs (voltage-controlled voltage sources), E1 and E2, simulate voltage followers, and VCVSs E3 and E4 and the resistors that connect to them simulate summers.

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=1Ω, 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. EDN

REFERENCE

1 López, David Báez, "Windows Based Filter Design with Winfilters," *IEEE Circuits and Devices*, Volume 13, 1997, pg 3.

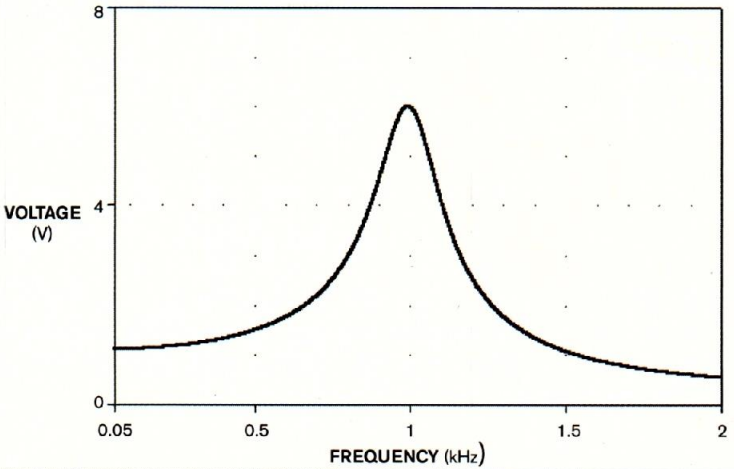

Figure 3 In this PSpice simulation, the digital bandpass filter uses transmission lines as delay lines.