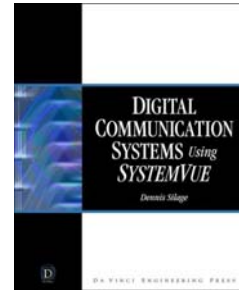
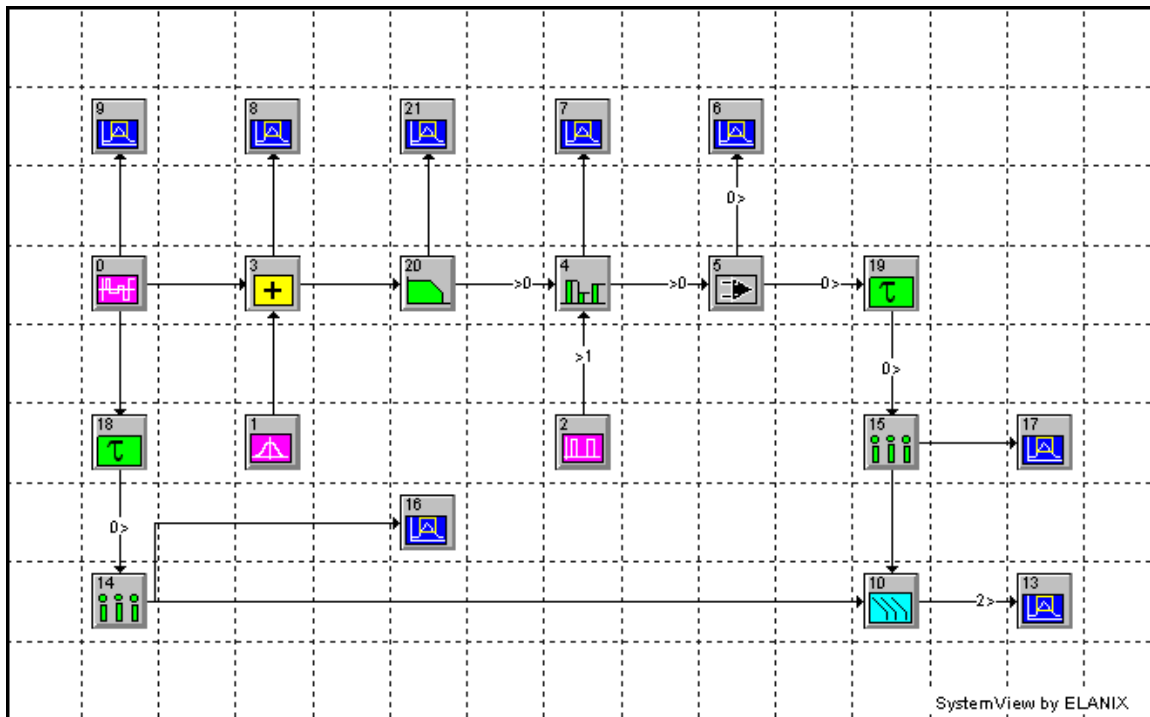


Bit Error Rate Determination in LPF Rectangular PAM



The performance of a digital communication system in the presence of additive white Gaussian noise (AWGN) can be assessed by the measurement of the bit error rate (BER). The *SystemVue* model *Fig2-10.svu* shown below is a rectangular polar pulse amplitude modulation (PAM) system with an AWGN channel and a simple receiver with a low pass filter.

This exercise can be completed using the *Textbook Edition* of *SystemVue* since no new tokens are required and should facilitate your simulation study. The procedure for modifying the parameters of a token in the *Textbook Edition* of *SystemVue* are slightly different than the *Professional Version* of *SystemVue* in the Laboratory and are described in the handout *Modifying System Parameters*.

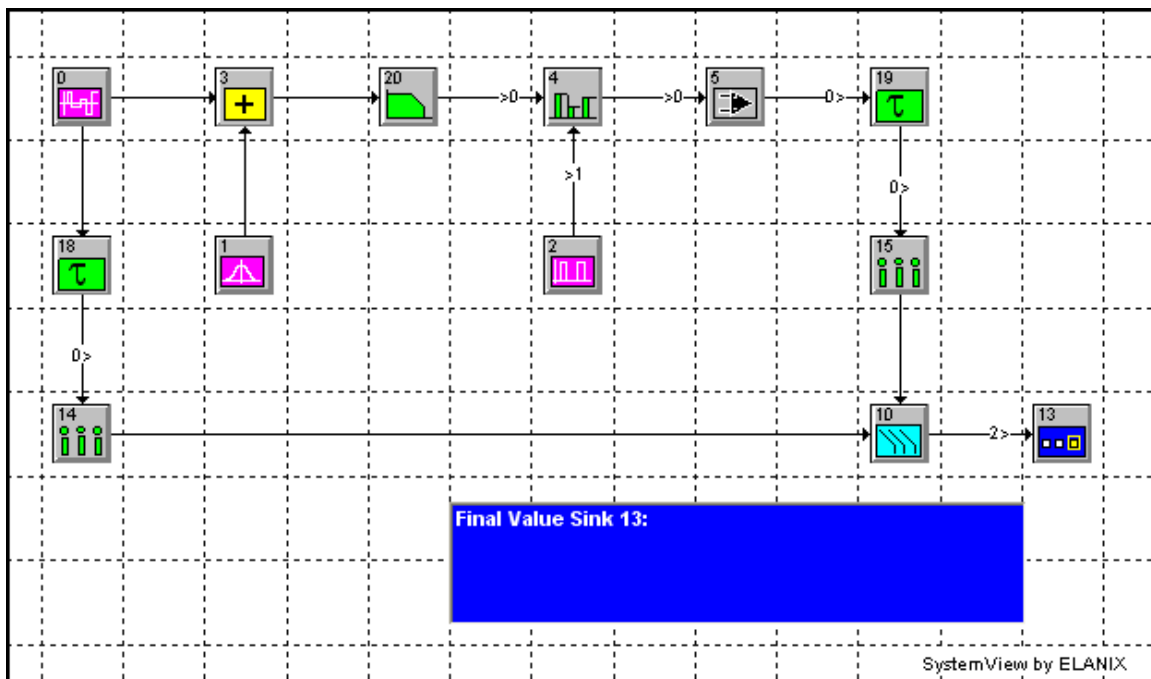


The parameters of the PN source (Token 0) is an amplitude of $\pm A$ V, a rate of r_b b/sec, 2 levels (binary) and 0 V offset and 0° phase. You are to chose a single *random amplitude* from the values $A = 1.2, 1.8, 3.3, 5$ or 12 V and a single *random bit rate* from $r_b = 2$ to 20 kb/sec in steps of 2 kb/sec. The data rate is higher than the *SystemVue* examples (1 kb/sec), so the *System Sampling Time* $T_s = 1/f_s$ and the parameters of the *delay* (Tokens 18 and 19), the *sample-and-*

hold control signal (Token 2), and the parameters of the *down-samplers* (Tokens 14 and 15) must all be carefully chosen for the simulation to be correct.

The performance of the LPF binary PAM digital communication system can be first verified by a small number of binary PAM data samples sent with *no AWGN* ($\sigma = 0$ V) which should result in 0 BER. Set the Delay (Token 18) to obtain a consistent sample at the mid-point $T_b/2$ of the filtered received pulse. In the example Fig2-10 the delay was 1.5 msec for a data rate $r_b = 1$ kb/sec ($T_b = 1$ msec) and would be different here in your Laboratory.

Once the Delay and system is configured properly, you can use the *SystemVue* model Fig2-10DT.svu shown below which deletes the unused Analysis Windows (Tokens 6, 7, 8, 9, 16, 17 and 21) and substitutes a Final Value token for the BER (Token 13) when the BER simulation is executed. Use a total *System Time* that would produce a data transmission of 10 000 points or $10^4 T_b = 10^4 / r_b$ for your Laboratory. Note that BER is the total number of bit errors reported by the BER Token (Token 18) divided by 10^4 .



Obtaining 0 BER with no AWGN for each of the two simulations below is crucial since all other reported measurements will be incorrect if this is not met. If a non-zero BER with no AWGN is obtained, carefully inspect the waveforms in the Analysis Windows for a small number of *test bits* (25 to 50) as binary PAM data samples and ascertain from the system model where and why the data is being misread producing bit errors. Timing parameters and delays are the usual problems that can cause this performance error and may be different in each of the two simulations specified,

Calculate the power in the transmitted signal and compute the SNR in dB in the standard range ∞ ($\sigma = 0$), 6, 2, 0, -2, -6 dB by first determining then setting σ appropriately. Table 2.3 shows the BER performance for fixed steps of 2.5 V in the value of σ and not steps in the SNR as you are to have in this Laboratory. Your data will be a different table but the results in Table 2.3 can be used in your discussion of BER performance in your Laboratory.

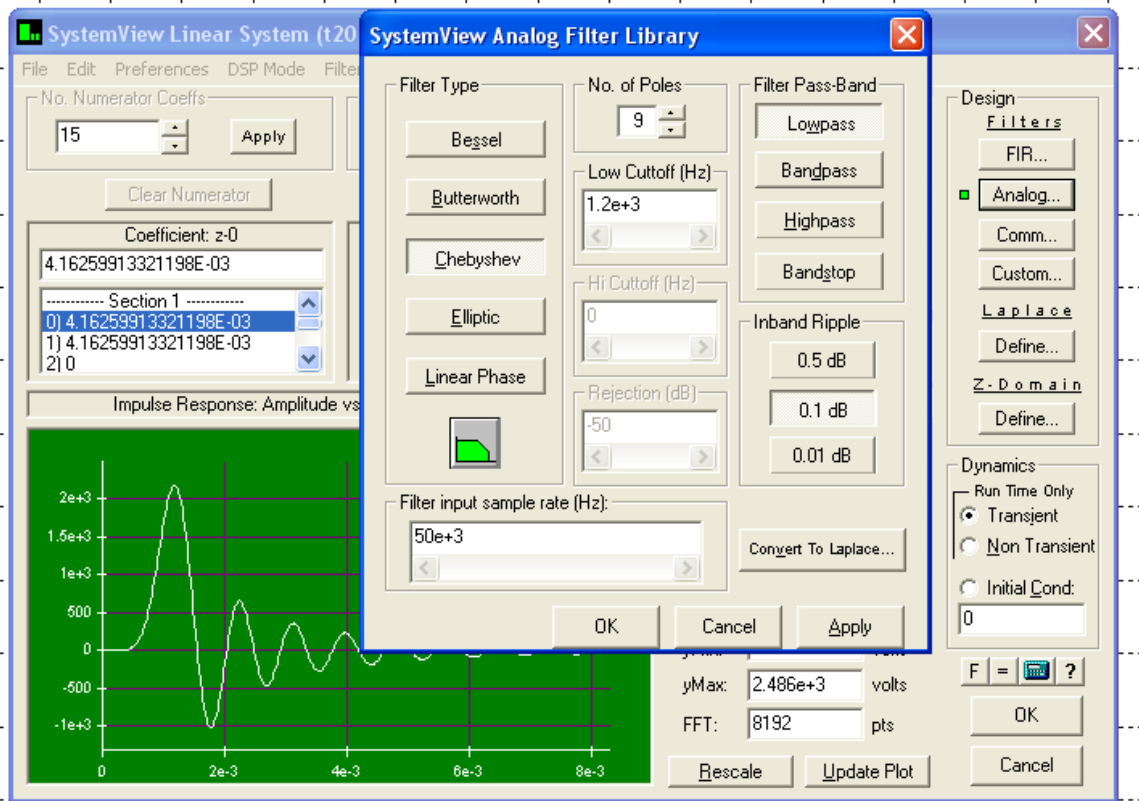
The noise power is σ^2/R_L and the power in the signal is A^2/R_L for rectangular PAM. Since SNR is the ratio $[A^2 / R_L]/[\sigma^2 / R_L]$, the SNR is independent of R_L since R_L divides out. It is not reasonable in digital communications to even report a BER greater than approximately 0.1 (1 in 10 bits in error).

The *first* BER simulation has no LPF filter. When using the *Textbook Edition* of *SystemVue* set the cutoff frequency f_c as high as possible with the maximum number of poles (usually, but not always, 9 representing the energy storage lumped L-C elements in the LPF) and report this value. The maximum cutoff frequency obtainable is a function of the *SystemVue simulation sampling frequency* f_s and limited by the Nyquist rate to less than $f_s / 2$ Hz. In the *Professional Version* of *SystemVue* in the Laboratory the LPF filter token can be deleted.

The *SystemVue* Analog Filter Library token window is shown below. The analog lowpass filter types available are Bessel, Butterworth, Chebyshev, Elliptic, and Linear Phase.

The *second* BER simulation has an analog LFP of a type based on the first letter of your last name: A-E: Bessel; F-J: Butterworth; K-O: Chebyshev; P- T: Elliptic; and U-Z Linear Phase. You are also to report of the characteristics of your analog filter (cutoff frequency performance, ripple in passband, stop band attenuation) with research references from any source. The cutoff frequency f_c of the analog filter is to be twice the data rate r_b in Hz and with the maximum number of poles available in *SystemVue*.

Compare the BER results of the two simulations with and without a LPF for the binary rectangular PAM receiver.



Shown below are a binary rectangular PAM signal with LPF and no AWGN (left) (SVU Figure 2.11) and with SNR = 7.69 dB (SVU Figure 2.12).

