



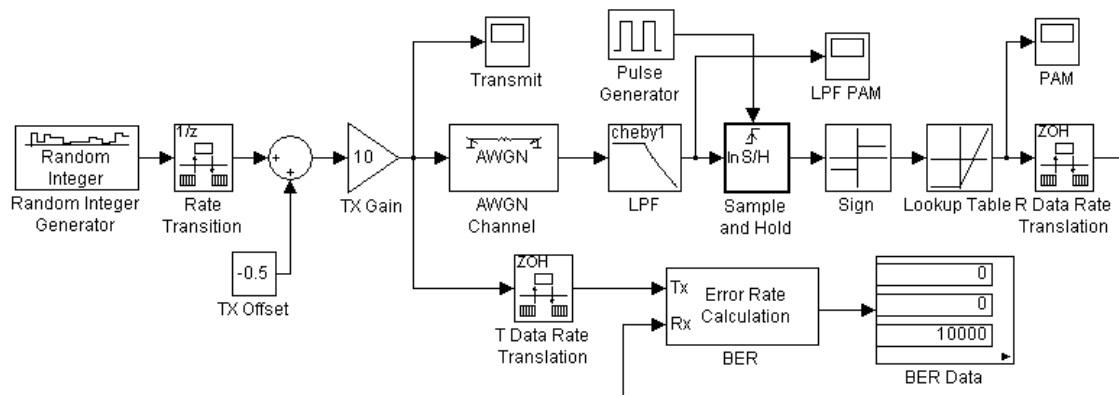
# EE4513 Analog and Digital Communications Laboratory

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## Bit Error Rate of an Extended Receiver for 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 *Simulink* model *Fig29.mdl* shown below is a rectangular polar pulse amplitude modulation (PAM) baseband system with an AWGN channel and a simple sample-and-hold (S/H) receiver with a low pass filter (LPF).



A *what-if* question of digital communications is the BER performance of an *extended* receiver. The simple receiver for rectangular baseband PAM has one S/H and requires no data storage or digital logic for processing before the threshold provide by the *Sign* block and the scaling from the *Lookup Table*. The extended receiver has an *odd number* of S/H circuits and would require digital logic for the selection of the best estimate of the binary data (*majority rule*).

The *Simulink* library provides a *Logic and Bit Operations* blockset which provides support for the combinational logic operations that you will require here. The *Simulink Extras* library has the *Flip-flops* blockset for sequential (storage) logic that you may also require here. Other standard blocks, such as the *Pulse Generator* block, would also be required to configure the complete extended receiver. *Simulink* subsystems should be used to encapsulate the design to facilitate the display.

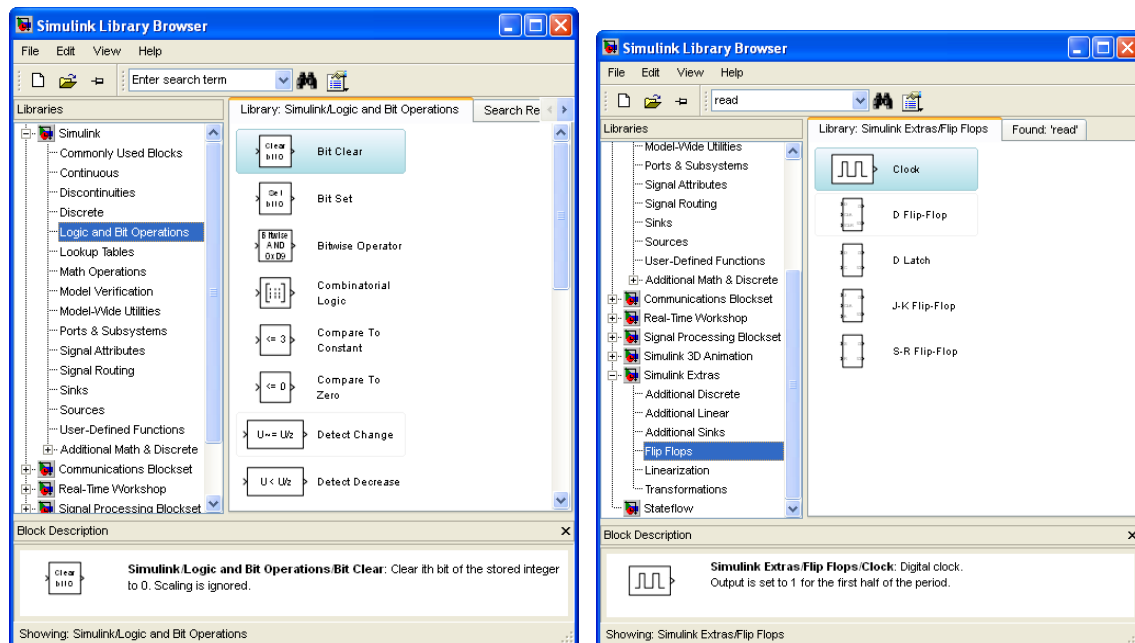
You are to configure an  $N = \underline{\hspace{2cm}}$  (an odd number but  $> 3$ ) S/H circuits in the extended receiver and measure the BER performance of this configuration. The

samples could be spaced *symmetrically* throughout the available bit time  $T_b$ . That is, for  $N = 3$  the sample points would be at  $0.25 T_b$ ,  $0.5 T_b$  and  $0.75 T_b$ .

For some large values of  $N$  the BER performance might be compromised because of the response of the LPF near the bit transition times, especially with no noise. This could be observed in the temporal output waveform *LPF PAM* in the *Simulink* model *Fig29.mdl*. You should comment on this impairment. It may be that the LPF would have to be removed from the extended receiver in this case. Another *work-around* would be for you to investigate *crowding* the  $N$  samples near  $0.5 T_b$ .

Compare these results to the observed BER for the simple LPF receiver in Table 2.3 and the optimum receiver in Table 2.6 in the MS text. Describe your extended receiver circuitry in detail with logic waveforms and validation that the observed BER with no AWGN is zero.

The Random Integer Generator block data source and the rectangular PAM transmitter is to have the same data rate  $r_b = 1$  kb/sec,  $M = 2$  levels (binary) and amplitude  $A = \pm 5$  V as in the *Simulink* model *Fig29.mdl*. The LPF of the receiver is also the same Chebyshev I filter with a cutoff frequency  $f_{cutoff} = 1200$  Hz ( $1.2 \times r_b$ ).



This is a *two-week* Laboratory for Week 6 (October 5-9) and Week 7 (October 12-16) and would be due at the regular Laboratory session in Week 8. It is suggested that you begin the design early to complete the assignment *on-time*.

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