

# Tutorial 3: Carrier and Symbol Synchronization

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Department of Electrical and Computer Engineering  
**ELEC 4190 - Digital Communications**

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**Note:** You should try the problems before and during the tutorial session. Your solutions will not be collected or graded.

1. Consider a three-stage self-synchronizing scrambler where the input  $S$  and output  $T$  are related as follows:

$$T(k) = S(k) \oplus T(k-1) \oplus T(k-3)$$

- (a) Design the corresponding descrambler.
  - (b) If the sequence  $S = 1111100000$  is applied to the input of the scrambler, find the output sequence  $T$ . Assume the initial state is 011.
  - (c) Verify that if this  $T$  is applied to the input of the descrambler, the output is sequence  $S$ .
2. Suppose that the loop filter for a PLL in Slide 12 has the transfer function

$$G(s) = \frac{1}{s + \sqrt{2}}$$

- (a) Determine the closed-loop transfer function  $H(s)$  and indicate if the loop is stable when  $K = 2$ .
  - (b) Determine the damping factor and natural frequency of the loop.
3. Consider the PLL in Slide 12 for estimating the carrier phase of a signal in which the loop filter has the transfer function

$$G(s) = \frac{K_1}{1 + \tau_1 s}$$

- (a) Determine the closed-loop transfer function  $H(s)$  and its gain at  $f = 0$  when  $K = 2$ .
- (b) For what range of values of  $K_1$  and  $\tau_1$  is the loop stable and the damping factor is less than 1?
4. The loop filter in a PLL is implemented by the circuit shown below. Determine the system function  $G(s)$  and express the time constants  $\tau_1$  and  $\tau_2$  such that  $G(s) = \frac{1+\tau_2 s}{1+\tau_1 s}$ .

