The University of Texas at Austin
Dept. of Electrical and Computer Engineering
Midterm #2

Prof. Brian L. Evans

Date: December 5, 2016 Course: EE 445S

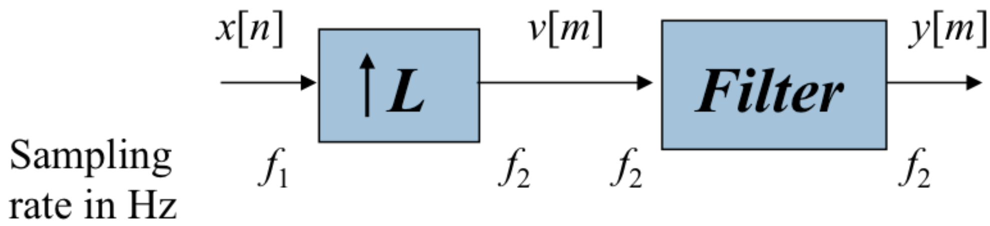
Name: ____
Last, First

- The exam is scheduled to last 50 minutes.
- Open books and open notes. You may refer to your homework assignments and the homework solution sets. You may not share materials with other students.
- Calculators are allowed.
- You may use any standalone computer system, i.e. one that is not connected to a network. **Disable all wireless access from your standalone computer system**.
- Please turn off all smart phones and other personal communication devices.
- Please remove headphones.
- All work should be performed on the quiz itself. If more space is needed, then use the backs of the pages.
- **Fully justify your answers unless instructed otherwise**. When justifying your answers, you may refer to the Johnson, Sethares & Klein (JSK) textbook, the Welch, Wright and Morrow (WWM) lab book, course reader, and course handouts. Please be sure to reference the page/slide number and quote the particular content in your justification.

Problem	Point Value	Your score	Topic
1	21		Interpolation
2	27		QAM Communication Performance
3	28		Phase Locked Loop (PLL)
4	24		Communication System Design
Total	100		

Problem 2.1. *Interpolation*. *21 points*.

Interpolation can change the sampling rate of discrete-time signal $x[n]$ through discrete-time operations of upsampling by L and then filtering:



(a) Give a formula for f_2 in terms of f_1. *3 points*.

(b) Specify the filter's passband frequency ω_{pass} and stopband frequency ω_{stop} in rad/sample to pass as many frequencies in $x[n]$ as possible and reduce artifacts due to upsampling. *6 points*.

(c) If $x[n]$ is represented with B bits, specify the passband tolerance A_{pass} in dB and the stopband attenuation A_{stop} in dB. *6 points*.

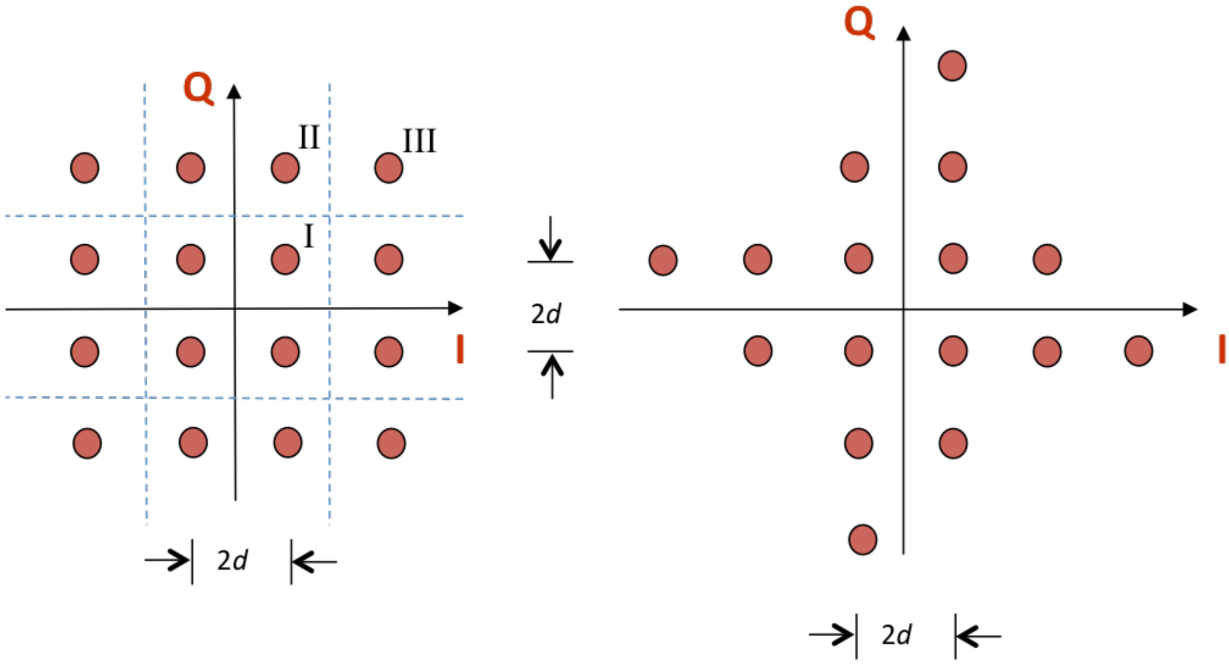
(d) Give an advantage for each type of interpolation filter below. *6 points*.

i. Finite impulse response filter.

ii. Infinite impulse response filter.

Problem 2.2 *QAM Communication Performance. 27 points.*

Consider the two 16-QAM constellations below. Constellation spacing is $2d$.



Energy in the pulse shape is 1. Symbol time T_{sym} is 1s. The constellation on the left includes the decision regions with boundaries shown by the in-phase (I) axis, quadrature (Q) axis and dashed lines.

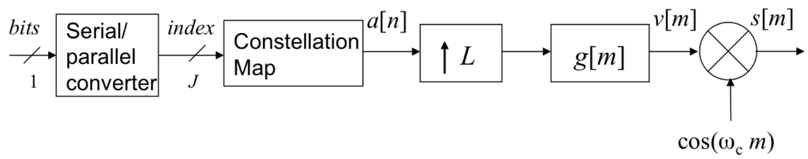
Each part below is worth 3 points. **Please fully justify your answers.**

	Left Constellation	**Right Constellation**
(a) Peak transmit power	$18d^2$	
(b) Average transmit power	$10d^2$	
(c) Draw the decision regions for the right constellation on top of the right constellation.		
(d) Number of type I regions	4	
(e) Number of type II regions	8	
(f) Number of type III regions	4	
(g) Probability of symbol error for additive Gaussian noise with zero mean & variance σ^2	$3Q\left(\frac{d}{\sigma}\right) - \frac{9}{4}Q^2\left(\frac{d}{\sigma}\right)$	

(h) Which of the constellations would you advocate using? Why? Please give two reasons. *6 points*.

Problem 2.3. *Phase Locked Loop (PLL). 28 points.*

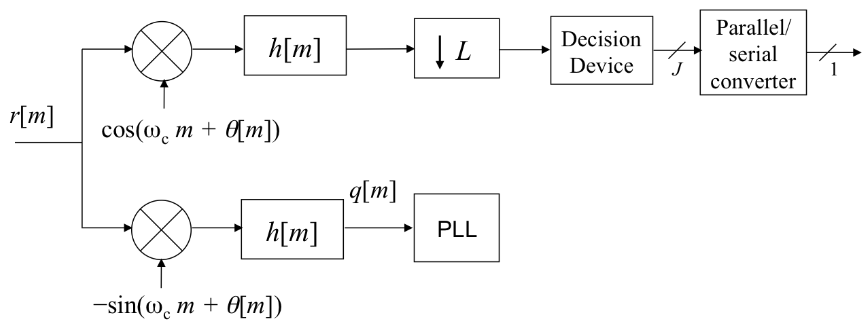
The discrete-time transmitter below is for pulse amplitude modulation (PAM) with upconversion:



where

$a[n]$ symbol amplitude	f_s sampling rate	$g[m]$ pulse shape
J bits/symbol	L samples/symbol	ω_c carrier frequency

The discrete-time PAM receiver below has two downconversion paths, and one feeds into the PLL:



$\theta[m]$ is the carrier phase offset, and $h[m]$ represents a lowpass finite impulse response (FIR) filter.

(a) When the receiver carrier phase matches the transmitter carrier phase, i.e. when $\theta[m] = 0$, show that $q[m]$ is zero. *6 points.*

(b) Develop a steepest descent algorithm to estimate the carrier phase offset, $\theta[m]$, per the steps below.

i. Give an objective function. *6 points.*

ii. Give an update equation for $\theta[m+1]$ in terms of $\theta[m]$. *9 points.*

iii. Give an initial value of $\theta[m]$. *3 points.*

iv. What values of the step size, μ, would you use. Why? *4 points.*

Problem 2.4. *Communication System Design. 24 points*

For M-level pulse amplitude modulation systems, the probability of a symbol error in the receiver is

$$P_{error} = \frac{2(M-1)}{M}\, Q\left(\frac{d}{\sigma}\sqrt{T_{sym}}\right)$$

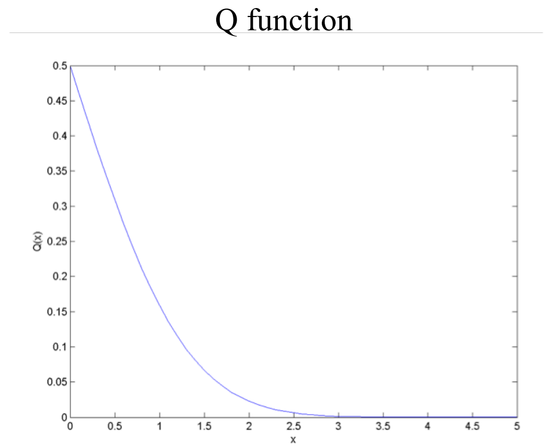
where

$2d$ is spacing between adjacent constellation points in Volts,

σ^2 is variance of the noise in the communication channel,

T_{sym} is symbol time, and

$$Q(x) = \frac{1}{\sqrt{2\pi}} \int_x^{\infty} e^{\frac{-y^2}{2}}\, dy$$



(a) How would you choose M, d and T_{sym} for a high-speed communication link with probability of symbol error of 10^{-3}. *9 points.*

(b) How would you choose M, d and T_{sym} for a low-speed control channel with probability of symbol error of 10^{-7}. The control channel would allow the feedback of information from receiver to transmitter, such as estimated SNR and channel impulse responses, with high accuracy. *9 points.*

(c) Give an optimal encoding for symbols of bits for the 8-PAM constellation below. In what sense is your encoding optimal? *6 points.*