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

Prof. Brian L. Evans

Date: December 11, 2017 Course: EE 445S

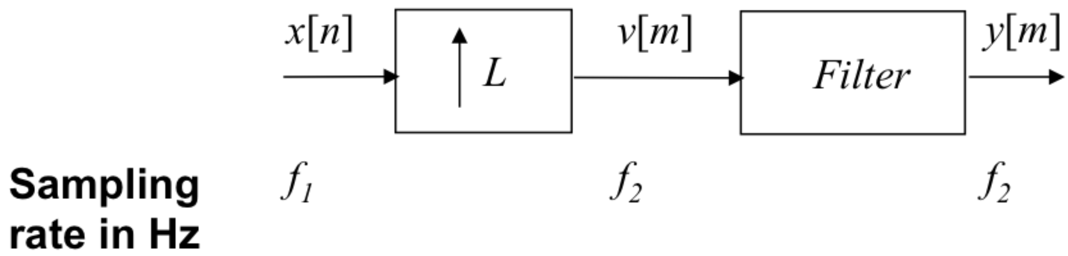
Name: ____
Last, First

- 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	24		Interpolation
2	27		QAM Communication Performance
3	28		Baseband Pulse Amplitude Modulation
4	21		Potpourri
Total	100		

Problem 2.1. *Interpolation*. *24 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 $v[m]$ in terms of $x[\ ]$. *3 points.*

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

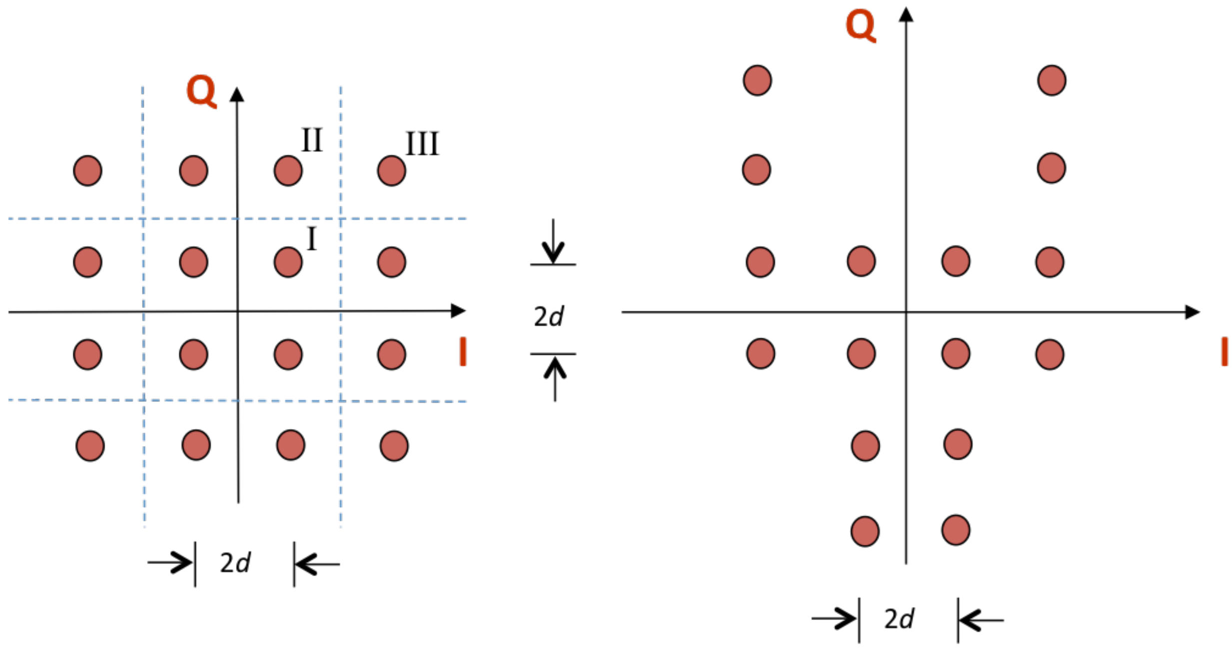
(c) Specify the filter's passband frequency ω_{pass} and stopband frequency ω_{stop} in rad/sample to pass as many frequencies in $x[n]$ as possible and reduce as many artifacts due to upsampling in $y[m]$ as possible. *6 points*.

(d) To ensure that the amplitude values of $x[n]$ remain unchanged after upsampling and filtering, give a constraint on the impulse response of the filter. *6 points.*

(e) Give the formula for an infinite impulse response that meets the conditions for (c) and (d) above. *6 points.*

Problem 2.2 *QAM Communication Performance. 27 points.*

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

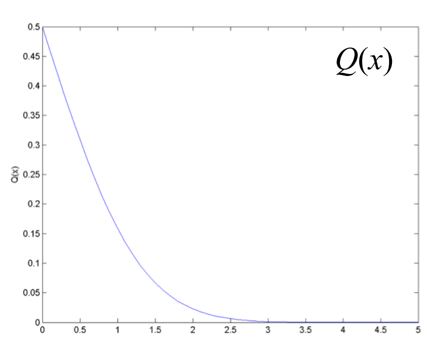


Energy in the pulse shape is 1. Symbol time T_{sym} is 1s. The constellation on the left includes the decision regions with boundaries shown by the in-phase (I) axis, quadrature (Q) axis and dashed lines.

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

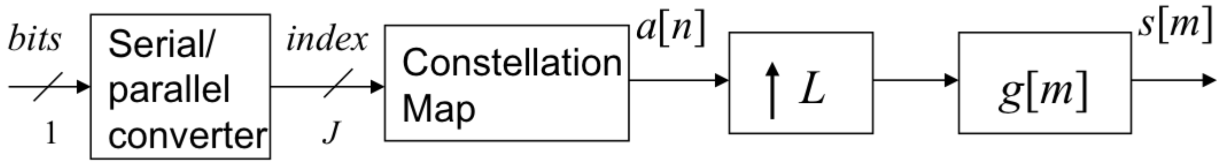
	Left Constellation	**Right Constellation**
(a) Peak transmit power	$18d^2$	
(b) Average transmit power	$10d^2$	
(c) Draw the decision regions for the right constellation on top of the right constellation.		
(d) Number of type I regions	4	
(e) Number of type II regions	8	
(f) Number of type III regions	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 constellation has a lower probability of symbol error vs. signal-to-noise ratio? Why? *6 points.*

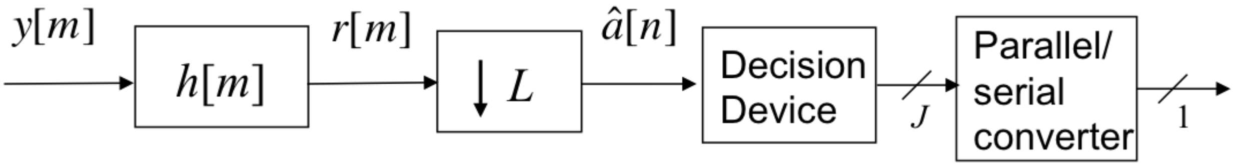


Problem 2.3. *Baseband Pulse Amplitude Modulation. 28 points.*

A baseband pulse amplitude modulation transmitter is described as



A baseband pulse amplitude modulation receiver is shown below



where

$a[n]$ symbol amplitude	f_s sampling rate	$g[m]$ pulse shape
J bits/symbol	L samples/symbol	$h[m]$ FIR filter

(a) What two roles does the finite impulse response (FIR) filter $h[m]$ play? *4 points.*

(b) For the rest the problem, the FIR filter $h[m]$ will be replaced with an adaptive FIR equalizer.

i. Give initial values for the coefficients of $h[m]$. *6 points.*

ii. During training, we will adapt the FIR equalizer coefficients based on the error vector in the decision device, i.e.

$$e[n] = \hat{a}[n] - a[n]$$

Give an objective function $J(e[n])$. *6 points.*

iii. Denote the FIR coefficients at iteration k as a vector $\vec{h}_k$ and derive the update equation for $\vec{h}_{k+1}$, where k is a symbol index. *9 points.*

iv. What range of values would you recommend for μ? *3 points.*

Problem 2.4. *Potpourri. 21 points*

(a) Give formulas for the system delay and computational complexity vs. the length L_g of a square root raised cosine pulse shape used in a baseband digital pulse amplitude modulation transmitter and receiver. System delay is from the time that the bit stream goes into the transmitter to the time that it would appear at the receiver output. *12 points*.

(b) Consider a digital pulse amplitude modulation system in which a transmitter sends a training sequence that the receiver uses to adapt a variety of subsystems to compensate for different impairments. For each receiver subsystem below, specify the name of an algorithm (or describe an algorithm) that could be used during data transmission (i.e. when no training data is available) to update each system.

i. Automatic Gain Control. *3 points.*

ii. Channel Equalization. *3 points.*

iii. Symbol Clock Recovery. *3 points.*