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

Prof. Brian L. Evans

Date: May 8, 2015 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		Equalizer Design
2	27		QAM Communication Performance
3	30		Automatic Gain Control
4	22		Data Converter Design
Total	100		

Problem 2.1. *Equalizer Design*. *21 points*.

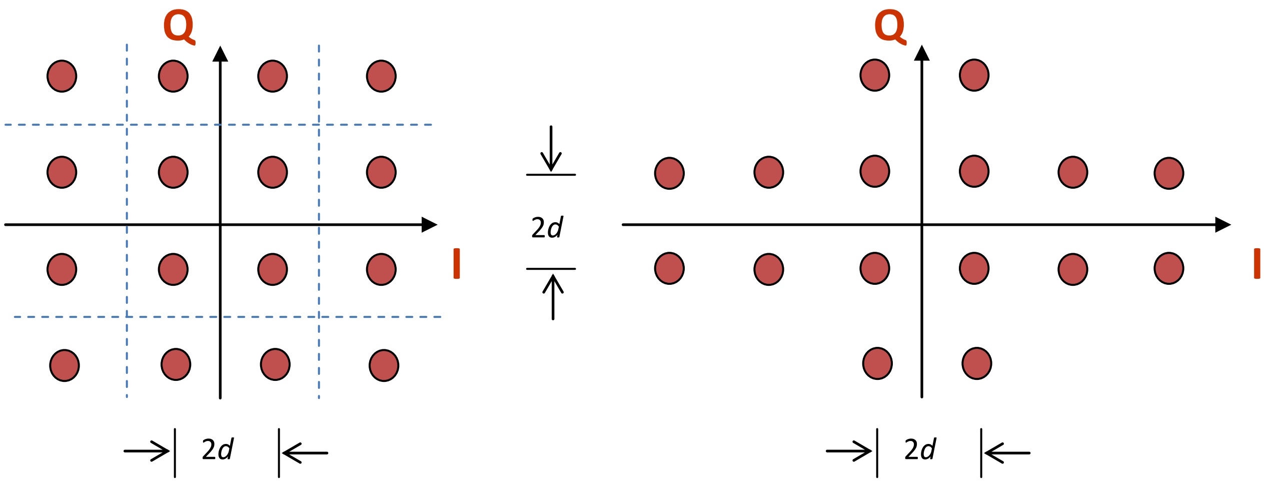
This problem asks you to design an equalizer to compensate for the magnitude and phase distortion of a discrete-time linear time-invariant (LTI) system.

(a) Describe how you would estimate the impulse response of the discrete-time LTI system. *6 points*.

(b) For a discrete-time LTI system with impulse response $h[n] = \delta[n] - a\,\delta[n-1]$ where a is a real number, design a stable discrete-time LTI equalizer so that the impulse response of the cascade of the discretized channel and equalizer yields a delayed impulse. Your approach must handle all possible values of a. *15 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.

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

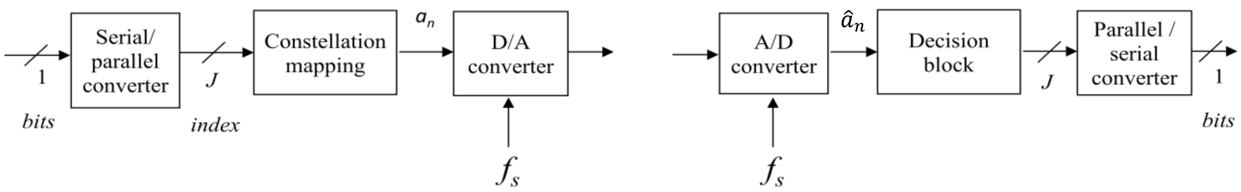
Draw the decision regions for the right constellation on top of the right constellation. *3 points*.

Fill in each entry (a)-(f) in the above table for the right constellation. Each entry is worth *3 points*.

Which of the two constellations would you advocate using? Why? *6 points*.

Problem 2.3. *Automatic Gain Control*. *30 points*.

Consider the simplified transmitter (left) and receiver (right) for baseband pulse amplitude modulation:



System uses J bits per symbol and a constellation spacing of $2d$ in units of Volts.

Your goal is to design an automatic gain control system for the receiver to compensate for fading:

- Fading is modeled as an unknown time-varying gain $g(t)$ or $g[n]$.
- The decision block will feed back the following signal to the automatic gain control system
$$v[n] = \hat{a}_n - a_n$$
where $\hat{a}_n$ is the received symbol amplitude and a_n is the transmitted symbol amplitude.
- The automatic gain control system will adapt its gain $c[n]$ so that estimated symbol amplitudes will become closer in value to the transmitter symbol amplitudes over time.

(a) Determine an objective function $J(v[n])$. *6 points*.

(b) Based on your objective function in (a), derive an update equation to adapt $c[n]$. *9 points*.

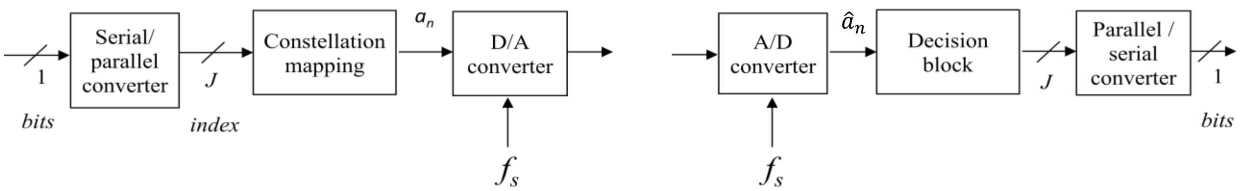
(c) For the answer in (b), what value of the step size would you recommend? Why? *3 points*.

(d) Propose an algorithm to find an initial accurate value of $c[n]$. *6 points*

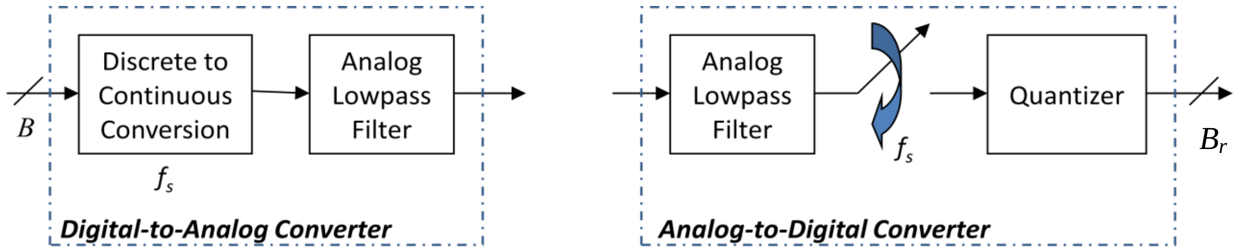
(e) Modify your update equation for $c[n]$ in (b) to improve convergence for $c[n]$ when $g[n]$ is varying quickly with time. *6 points*.

Problem 2.4. *Data Converter Design*. *22 points*

Consider the simplified transmitter (left) and receiver (right) for baseband pulse amplitude modulation



Here are block diagrams for the analog-to-digital (A/D) and the digital-to-analog (D/A) converters:



Communication system uses J bits per symbol and a constellation spacing of $2d$ in units of Volts.

The channel model consists of additive spectrally-flat Gaussian noise with zero mean and variance σ^2.

(a) In the transmitter, what is the smallest number of bits B needed for the D/A Converter? *6 points*.

(b) In the transmitter, what is the second smallest number of bits that could be used for the D/A Converter? *6 points*.

(c) In the receiver, what is the minimum number of bits B_r needed for the A/D Converter so that the quantization noise power at the quantizer output in the A/D Converter is less than or equal to the system noise power at the quantizer input? *10 points*.