TEACHING INSTRUCTIONAL DESIGN (BRP)

COURSE

CONTROL SYSTEM

by

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PREFACE

Teaching Instructional Design (BRP) of Control System is one of the few courses for students taking the Instrumentational Physics concentration and is designed to be taken after students have finished the prerequisite courses of Electronics 1 and 2. In this course, students will learn about the basic concepts of feedback and control systems, Laplace transformation, linear transfer function systems, linearization of unilinear systems, modelling mathematical systems, mechanical and electrical systems, block diagram modelling, graphical signal flow modelling, state variable models, error signal analysis, sensitivity of feedback control system towards the variety of parameters in the control system, signal disturbance in a feedback control system, controlling the transient response of a system, steady state errors, second order system, effects of third pole and zero's in a second order system, work index of control systems, simplification of linear systems, analyzation of loop systems (open and closed loop), testing the stability of control systems using characteristic functions and the Ruth Hurwitz method, control system design: root locus concept, parameter design of control system using the root locus, determining the parameters of PID using trial and error methods, identifying the process of a stable open loop system, determining the parameters of a PID with the Direct Synthesis, Inter Model Control, System Index, Ziegler Nichols, Cohen Coon and Reactive Curve methods, analyzing the frequency response using the Bode and Nyquist plot, designing PI, PID, Lead, Lag, and Lead Lag systems, and finally, designing feedback systems with state variables. We hope this BRP can be used as a reference both for the teacher and the student and anyone who hopes to learn Embedded Systems.

Depok, May 2016

Dr. Arief Sudarmaji

I. General Information

1.	Name of Program / Study Level	:	Physics / Undergraduate
2.	Course Name	:	Embedded System
3.	Course Code	:	SCFI6043716
4.	Semester	:	6
5.	Credit	:	4 credits
6.	Teaching Method(s)	:	Self Directed Learning, Case Study, Simulation, Problem Based Learning, Project Based Learning
7.	Prerequisite course(s)	:	Electronics 1 and Electronics 2
8.	Requisite for course(s)	:	-
9.	Integration Between Other Courses	:	Laboratory Work of Control System
10.	Lecturer(s)	:	Dr. Arief Sudarmaji
11.	Course Description	:	Giving the basic concepts about control systems such as feedback and control systems, Laplace transformation, linear transfer function systems, linearization of unilinear systems, modelling mathematical systems, mechanical and electrical systems, block diagram modelling, graphical signal flow modelling, state variable models, error signal analysis, sensitivity of feedback control system towards the variety of parameters in the control system, signal disturbance in a feedback control system, controlling the transient response of a system, steady state errors, second order system, effects of third pole and zero's in a second order system, work index of control systems, simplification of linear systems, analyzation of loop systems (open and closed loop), testing the stability of control systems using characteristic functions and the Ruth Hurwitz method, control system design: root locus concept, parameter design of control system using the root locus, determining the

parameters of PID using trial and error methods, identifying the process of a stable open loop system, determining the parameters of a PID with the Direct Synthesis, Inter Model Control, System Index, Ziegler Nichols, Cohen Coon and Reactive Curve methods, analyzing the frequency response using the Bode and Nyquist plot, designing PI, PID, Lead, Lag, and Lead Lag systems, and finally, designing feedback systems with state variables.

II. Course Learning Outcome (CLO) and Sub-CLOs

A. CLO

Students are able to understand problems and apply interfacing and programming methods in embedded systems effectively and efficiently. (C3) (ELO 3, 5, 6, 7)

B. Sub-CLOs

1	Explaining the basic concepts of Control Systems and sample configurations of control systems, analyzing control systems and target criteria's of designing a control system as well as the process that has to be followed while designing one (C2 and C3)	1
2	Explaining the basic concepts of the Laplace transform, modeling in electrical, mechanic and electromechanics systems, and linearization of non-linear systems (C2 and C3)	1
3	Explaining the basic concepts pole and zeroes of a transfer function to determine the response time from a control system, explaining quantitively the response of a first order system, explaining the normal response of a second order system, and determining the damping ratio, natural frequency, settling time, peak time, percent overshoot, and rise time of a second order system (C2 and C3)	1
4	Explaining the basic concepts of steady-state error and its specifications, determining the steady state error as a result of an interrupt, determining the sensitivity of a steady-state error as a result of a change in the parameters of the control system, and explaining the Routh Hurwitz method to determine the stability in a control system (C2 and C3)	1
5	Explaining the basic concepts of the root locus technique, the characteristics of the root locus technique, how to plot using the root locus, and using the root locus to determine the main parameters for the components of a control system (C2 and C3)	1
6	Explaining the basic concepts of the root locus technique to design a control system or a compensator for increasing the transient performance and steady state error of a system, and realizing the compensator physically (C2 and C3)	1
7	Explaining the basic concepts of the frequency response in a control system, plotting the frequency response, Nyquist diagram sketch and using it to determine the stability of a control system, define and draw a Bode plot, determining the gain margin, and determining the phase margin (C2 and C3)	1
8	Explaining the basic concepts of setting the gain to fulfill the criteria needed for the transient response, to design a control system or a compensator to increase the transient performance and the steady state error performance with the frequency response method (C2 and C3)	1
9	Explaining the basic concepts on mathematical models used to represent the linear time invariant state system, models in the electric and mechanic state space, changing a transfer function to a state space and backwards, as well as linearization in a state space system (C2 and C3)	1
10	Explaining the basic concepts of designing a state feedback controller with a determined position for the pole, determining if a system is controllable and observable, designing a state feedback controller to fulfill the specifications of the transient response and steady state error performance (C2 and C3)	1

11	Explaining the basic concepts of modelling the digital computer in a feedback system, the z-transform and the inverse z-transform, determining the transfer function for sampled data's, determining the stability of a sampled-data system and determining if the sampling rates to stabilize the system, and designing a digital control system to fulfill the criterions of a steady state error and transient response (C2 and C3)	1
12	Explaining the basic concepts of designing and tuning a PID controller using the Direct Synthesis, IMC, Ziegler Nichols, Cohen Coon and the Reactive Curve method (C2 and C3)	1
13	Designing an embedded system in the form of a project (C3)	1

III. Teaching Plan

Week	**Sub-CLO**	**Study Materials**	**Teaching Method**	**Time Required**	**Learning Experiences (*O-E-F)**	**Sub-CLO Weight on Course (%)**	**Sub-CLO Achievement Indicator**	**References**
1	1	Introduction to Control Systems	Lecturing classes and individual tasks	200 minutes	50% O, 10% E, 40% F	7	Able to explain the basic concepts of: a) Control Systems and sample configurations of control systems b) Analyzing control systems and target criteria's of designing a control system c) The process that has to be followed while designing one	No. 1 Chap1, Page 1 No. 2 Chap1, Page 1
2	2	Modelling in the frequency domain	Lecturing classes and individual tasks	200 minutes	50% O, 10% E, 40% F	7	Able to explain the basic concepts of: a) Laplace transform	No. 1 Chap 2 Page: 33

							b) Modeling in electrical, mechanic and electromechanics systems c) Linearization of non-linear systems Assembly Programming	Chap 3 Page 107
3	3	Characteristics and performance of a closed control system (1)	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Pole and zeroes of a transfer function to determine the response time from a control system b) Explaining quantitively the response of a first order system c) Explaining the normal response of a second order system d) Determining the damping ratio, natural frequency, settling time, peak time, percent overshoot, and rise time of a second order system	No. 1 Chap 4 Page: 157 No. 2 Chap 4 Page 234
4	4	Characteristics and performance of a closed control system (2)	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Steady-state errors and its specifications b) Determining the steady state error as a result of an interrupt c) Determining the sensitivity of a	No. 1 Chap 2 Page 299 No. 2 Chap 4 Page 234 No.1 Chap 7 Page 335

							steady-state error as a result of a change in the parameters of the control system d) Routh Hurwitz method to determine the stability in a control system	
5	5	Root Locus Method	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) The root locus technique b) The characteristics of the root locus technique c) How to plot using the root locus d) Using the root locus to determine the main parameters for the components of a control system	No. 1 Chap 8 Page 381 No. 2 Chap 7 Page 443
6	6	Designing a control system using the root locus method	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) The root locus technique to design a control system or a compensator for increasing the transient performance and steady state error of a system b) Realizing the compensator physically	No. 1 Chap 9 Page 449 No. 2 Chap 10 Page: 757
7	7	Frequency Response Method	Lecturing classes and	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of:	No. 1 Chap 10 Page 525

			individual tasks				a) The frequency response in a control system b) Plotting the frequency response c) Nyquist diagram sketch and using it to determine the stability of a control system d) define and draw a Bode plot, determining the gain margin, and determining the phase margin	No. 2 Chap 8 Page: 554 No. 2 Chap 9 Page 634
8	**Mid Term Exam**							
9	8	Designing a control system using the frequency response method	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Setting the gain to fulfill the criteria needed for the transient response b) Designing a control system or a compensator to increase the transient performance and the steady state error performance with the frequency response method	No. 1 Chap 11 Page. 613 No. 2 Chap 10 Page. 772
10	9	Modelling in the time domain	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Mathematical models used to represent the linear time invariant state system b) Models in the electric and	No. 1 Chap 3 Page. 115 No. 2 Chap 3 Page. 161

							mechanic state space c) Changing a transfer function to a state space and backwards d) Linearization in a state space system	
11	10	Designing a control system in the state space	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Designing a state feedback controller with a determined position for the pole b) Determining if a system is controllable and observable c) Designing a state feedback controller to fulfill the specifications of the transient response and steady state error performance	No. 1 Chap 12 Page. 649 No. 2 Chap 11 Page. 834
12	11	Digital Control Systems	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: a) Modelling the digital computer in a feedback system, the z-transform and the inverse z-transform b) Determining the transfer function for sampled data's c) Determining the stability of a sampled-data	No. 1 Chap 13 Page. 707 No. 2 Chap 13 Page. 984

							system and determining if the sampling rates to stabilize the system d) Designing a digital control system to fulfill the criterions of a steady state error and transient response	
13	11	Digital Control System	Lecturing classes and individual tasks	200 minutes	10% O, 30% E, 60% F	7	Able to explain the basic concepts of: e) Modelling the digital computer in a feedback system, the z-transform and the inverse z-transform f) Determining the transfer function for sampled data's g) Determining the stability of a sampled-data system and determining if the sampling rates to stabilize the system h) Designing a digital control system to fulfill the criterions of a steady state error and transient response	No. 1 Chap 13 Page. 707 No. 2 Chap 13 Page. 984
14	12	Designing and Tuning the PID controller	Lecturing classes and individual tasks	200 minutes	10% O, 80% E, 10% F	7	Able to explain the basic concepts of designing and tuning a PID controller using the Direct Synthesis, IMC, Ziegler Nichols, Cohen	No. 3 Chap 12 Page 199

							Coon and the Reactive Curve method	
15	13	Group Project	Lecturing classes and individual tasks	200 minutes	10% O, 80% E, 10% F	9		No. 1, Chap 9 Page 353
16	**Final Exam**							

*) O : Orientation
E : Exercise (Quiz)
F : Feedback

Refences:

1. N.S. Nise, M.A, *Control Systems Engineering*, 7th edition, Wiley, 2015.
2. R. C. Dorf and R.H. Bishop, *Modern Control System*, 12th edition, Prentice Hall, 2011
3. D.E. Seborg, T.F. Edgar, D.A. Mellichamp, and F.J. Doyle, *Process Dynamics and Control*, 4th edition, Wiley, 2017.

IV. Assignment Design

Week	Assignment Name	Sub-CLO	Assignments	Scopes	Working Procedure	Deadline	Outcome
1-14	In-Class Quizzes, Homework and Simulations	1-12	Questions	Summarize the specific week's material and simulations	Individual Tasks	1 week	Quiz results in class and program design
15	Group Project	13	Final Project	Designing the equipment	Group Task	1 week	Student Power-point and results of the presentation

V. Assessment Criteria (Learning Outcome Evaluation)

Evaluation Type	Sub-CLO	Assessment Type	Frequency	Evaluation Weight (%)
In-class quiz	1-7 and 8-12	Evaluation Sheet	6	10
Homework and Simulations	2-12	Evaluation Sheet	12	10
Group Project	13	Evaluation Sheet	1	20
Mid-Term Exam	1-7	Essay Questions	1	30
Final Exam	8-12	Essay Questions	1	30
Total				**100**

VI. Rubric(s)

A. Criterions for the Group Project Presentation

Grade	Presentation Performance
85-90	The group is able to give a logical, clear, and on time presentation. The group is also able to answer the questions from other students or the teacher
75-84	The group is able to give a logical and clear explanation while being able to answer questions from other students or the teacher but is not able to manage their time correctly.
65-74	The group is able to give a clear explanation but isn't able to explain the logic behind their project

55-64	The group isn’t able to give a clear explanation nor explain the logic behind their group project nor having good time management skills
<55	

B. Criterions for the Mid-Term Exam and Final Exam

Grade	Quality of Answer
100	The answers are precise, every definition and main components are included
76-99	The answers precise enough, all definitions and main components that are needed to answer the question are almost precise
51-75	The answers are less precise, the definitions and main components that are needed to answer the question are less precise
26-50	The answers are very unprecise, the definitions and main components that are needed to answer the questions are missing a lot of details
<25	Wrong answer