ME569: Powertrain Control

Fall 2015 (3 credits), Mon/Wed 9:00-10:30am **CHRYS** 165

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Course statement: The course covers essential aspects of electronic engine control followed by recent control problems arising in direct injection, variable valve timing, active boosting, and flexible-fuel combustion. The course includes models and feedback control design of spark ignition (gasoline), compression ignition (diesel), and thermal ignition (HCCI) engines. We will practice system identification, averaging, feedforward, feedback, multivariable control, and estimation.
* Basic ordinary differential equations (ODE) and control requirements are necessary (see below).
**Matlab and Simulink experience is necessary.

Home Page: (https://ctools.umich.edu/portal): Lecture notes and handouts will be posted in Ctools.
Email: CTools emailing and Piazza posts will be used to send you announcements. You can always email me with questions **(use ME569F15 in your message subject).**
*First describe the problem you are facing in the text of your post. This will help me when I travel and cannot open attachments or when I use my phone. You could **attach a pdf** with your question (m-file, sml-file, and resulting graphs in one PDF). If I need more info, I will ask for it.
** I typically try to respond **within a day**, but my ability to help declines as e-mail volume increases; I **typically cannot help during the due day** of the HW because I have meetings during the day.

Textbook (recommended – not required – can be reached in mirlyn online):
"Introduction to Modeling and Control of Internal Combustion Engine Systems" by L. Guzzella and C.H. Onder, Springer-Verlag 2004, ISBN 3-450-22274 http://mirlyn.lib.umich.edu/Record/008158097
And/Or
"Modeling and Control of Engines and Drivelines (Automotive Series)" by Lars Eriksson and Lars Nielsen (Feb 27 2014), ISBN: 1118479998 (available online) http://mirlyn.lib.umich.edu/Record/012844556

Grading: HW (5%), Exam 1 (45%), Exam 2 (50%)
Office Hours: Tentative: Tue 4-5 (GSI) & Wed 4-5 (Prof), Wed 8:00-9:00 (GSI), Thu 12-1 (GSI)
Prof. office hours @ 2044 Auto Lab (AL), whereas the GSI @ 3028 Phoenix Memorial Lab (PML)
Wed 8:00-9:00 (GSI @webex only)

Homework:
There will be approximately one HW per week. Typically issued on Wed and due on Thu at 7:00pm. Homework problems in this course are hard but rewarding because they are derived from real world problems. Homework counts for very small % of your grade, because we cannot grade it in detail.

- If you submit your HW with a majority of questions well solved then the assigned grade will be "3".
- If seriously attempted almost all the questions, then the assigned grade will be "2."
- If we see many gaps in your answers then the assigned grade will be "1."
- If your submission is mostly blank or missing, then we will grade it with "0."

Thus, the HW grade is unimportant and it will up to you to work on the homework, submit your best version and study the posted solutions. Finally, your HW will be submitted to the Ctools by the specified time and date. No late homework will be accepted!

Exams: 2 hours in class time. Open notes. Bring only a regular Calculator. No computers or other electronics will be allowed. Distance-learning students are welcome to take the exam on campus; otherwise they will need to organize a proctor.
Midterm A: TBD (typically after study break)
Midterm B: TBD (typically before the last week of course)
Back-up Exam: based on registrar (if any of the regular midterms have been missed)

Course Outline:

Chapter 1: Background and Motivation

Chapter 2: Control Oriented Modeling – Manifold Filling Dynamics

The Basics: Ideal Gas Law, Mass Conservation, Energy Conservation
The Assumptions: Space-averaging and Cycle-averaging
The Fidelity: Detailed and Mean-Value Models
Event-averaging in time- and crankangle-domain
Regression and mapping data
Linearization

Chapter 3: Basic Internal Combustion Engine Control Functionalities

Air-to-Fuel Ratio Control
The Fast Response: Feedforward Control with Air Charge Estimation
The Accurate Response: Feedback with Oxygen Sensors (Linear and switching sensor)
The Balanced response: Cylinder-to-cylinder Maldistribution (Lifting Control technique)

Idle Speed Control
The Three Devils: Unmeasured Disturbance, Actuator Authority, and Model Uncertainty
The Three Tools: Feedforward and Feedback
Spark Compensation—sequential loop closing

Spark Timing Control
The Easy Way: The Look-Up Table
The Right Way: Feedback with Knock Sensor
The Amazing Way: Combustion sensing, Estimation and HCCI control

Exhaust Gas Recirculation
External EGR Control
Internal EGR Control
Control of Variable Camshaft Timing and Variable Valve Timing

Boosting
The standard: Control of Wastegate
The challenge: Coordinated control of VGT and EGR
The fun: Optimal Control of Electrically Assisted Turbocharging

Chapter 4: Control of Advanced Combustion Engines

Lean Combustion & Exhaust Aftertreatment Control
Ethanol-Gasoline Flex Fuel Vehicles (FFV)
Low Temperature Combustion Control (HCCI, PCCI, PCI)
On-board Diagnosis

Chapter 5: Drive Cycles for Fuel Efficiency Estimation

Open to graduate or senior students in Mechanical, Electrical, Chemical, Aerospace, and Marine Engineering with basic control engineering and dynamics background (ME360 and ME461 equivalent). Permission from the instructor is required for senior undergraduate students.

As you know ME461 is a pre-requisite for this class. Below is a list of the MATH and Controls notions I will be using a lot in the class and you should know.

1. Ordinary Differential equations

2. Linearization

3. Laplace and transfer functions (poles, zeros, DC gain)

4. Frequency Domain Representation of systems and signals: bandwidth, roll-off rate, DCgain, natural, damped frequencies ...

5. Stability, characteristic equation, eigenvalues

6. Time responses, overshoot, undershoot, settling time, damping ratio, time constant, rise time ...

7. States, state-space representation

8. Basics of PID controllers, Root locus ...

Items 1-6 are a must! Do not take this class if you do not know or feel comfortable with 1-6. You can probably study items 7-8 and catch up while taking this class.

Below are some recommended books for Control and Systems Review:

a. Modern control systems / Richard C. Dorf, Robert H. Bishop.
b. Feedback control of dynamic systems / Gene F. Franklin, J. David Powell, Abbas Emami-Naeini.
c. Modern control engineering / Katsuhiko Ogata.
d. Control systems engineering / Norman S. Nise.

My favorite is b. Chapter 1-4

For review of Internal Combustion Engine (ICE) principles, read the 1st chapter of Internal Combustion Engine Fundamentals by John B. Heywood