# ECE 4415/ECE 5415 (ECE4/572)
# MICROCOMPUTER-BASED CONTROL SYSTEMS

## WINTER SEMESTER 2018 5 Jan – 25 Apr ’18

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| Class time: | 5:30 – 7:17 PM Tue & Thu |
| Class room: | 200 Dodge Hall, OU |
| Laboratory: | 182 Engineering Center, OU |
| Lecturer: | Professor KaC Cheok, PhD, ECE Dept, SECS, Oakland University |
| Teaching assistants: | Narendra Kintali |

## Course Description

**ECE 4415/5415 (472/572) – Microcomputer-based Control Systems (4)**
Computer-aided engineering, modeling, analysis, design, evaluation and visualization of dynamical and control systems including algorithms for digital logic, filters, controllers and estimators. Microcomputer-based hardware/software implementation of algorithms including data acquisition, signal conditioning and power processing circuits, computer interface and data communications, input and output devices, graphics displays. Model-based rapid prototyping of embedded microcontrollers and PIC processors. Experiments and projects emphasize real-time applications, programming and hardware integration. With laboratory. Prerequisite(s): ECE 328 or ECE 426 and ECE 431.

## Prerequisite background

**ECE 431 - Automatic Control Systems (4)**
Mathematical modeling of dynamic systems, transfer functions and block diagrams. State-space representations and local linearization of nonlinear systems. Transient and steady-state analysis, stability criteria and state-feedback control. The root-locus method and frequency-response method for control systems analysis and design. Design of PID controllers and compensation networks. Controllability and observability for linear time invariant system2. Computer simulations using Matlab. With laboratory.
Prerequisite(s): ECE 335.

**ECE 426 - Advanced Electronic Circuit Designs (4)**
Design and analysis of analog circuits. Analysis and design of differential amplifiers. Design of signal generators and function generators. Introduction to measurement sensors and interfacing. Introduction to sensors including bio-medical and micro-electromechanical (MEMS) based measurement circuits and systems. Emphasis on analysis and design through a sequence of laboratory experiments and short projects.
Prerequisite(s): ECE 327 and major standing

**ECE 328 - Electronic Circuits & Devices II (4)**
Analysis and design of functional analog circuits with particular specifications. Frequency responses of analog circuits. Building blocks for integrated circuits including current mirror, differential pairs and output stage. Active filters. Interface circuits for micro-electro-mechanical systems (MEMS) and sensors. A laboratory session is integrated to enhance students’ experience in circuit design and analysis.
Prerequisite(s): ECE 327.

**ECE 335 - Signals and Systems (4)**

Basic signals, average value, average power, and energy. Laplace transform and inverse Laplace transform, and transfer function concept and approach in the analysis of electrical and mechanical lumped-parameter linear systems. Systems modeling and analysis in Laplace and differential equation domains. Natural and forced responses of linear time-invariant systems, and concept of convolution. Fourier analysis of signals and systems: Fourier series and Fourier transform, power spectral density, energy spectral density, band width, and filters.
Prereq(s): ECE 276.

**ECE 327 - Electronic Circuits and Devices I (4)**
Characteristics and models of nonlinear circuit elements, such as diodes, BJTs and MOSFETs. Analysis and design of circuits employing these devices, including power supplies, voltage regulators, and amplifiers; Biasing and circuit stability issues. Use of Operational amplifiers, discrete circuit elements; and PSPICE software for circuit design is emphasized in the lab. With Laboratory.
Prerequisite(s): ECE 276.

**ECE 276 - Electric Circuits (4)**
Modeling and analysis of circuits with dependent sources; non-ideal operational amplifiers. Transient and forced responses in RC, RL and RLC circuits. Series and parallel resonant circuits. AC power, three-phase circuits, magnetically coupled circuits. Wye-delta transforms. Introduction to frequency response. Use of PSPICE. With laboratory. Offered fall and winter.
Prerequisite(s): EGR 240.

## WISE SAYING ON LEARNING

- Competence = Knowledge + Experience + Wisdom
    - Knowledge = Knowing what to do
    - Experience = knowing how to do it
    - Wisdom = Knowing when to do it

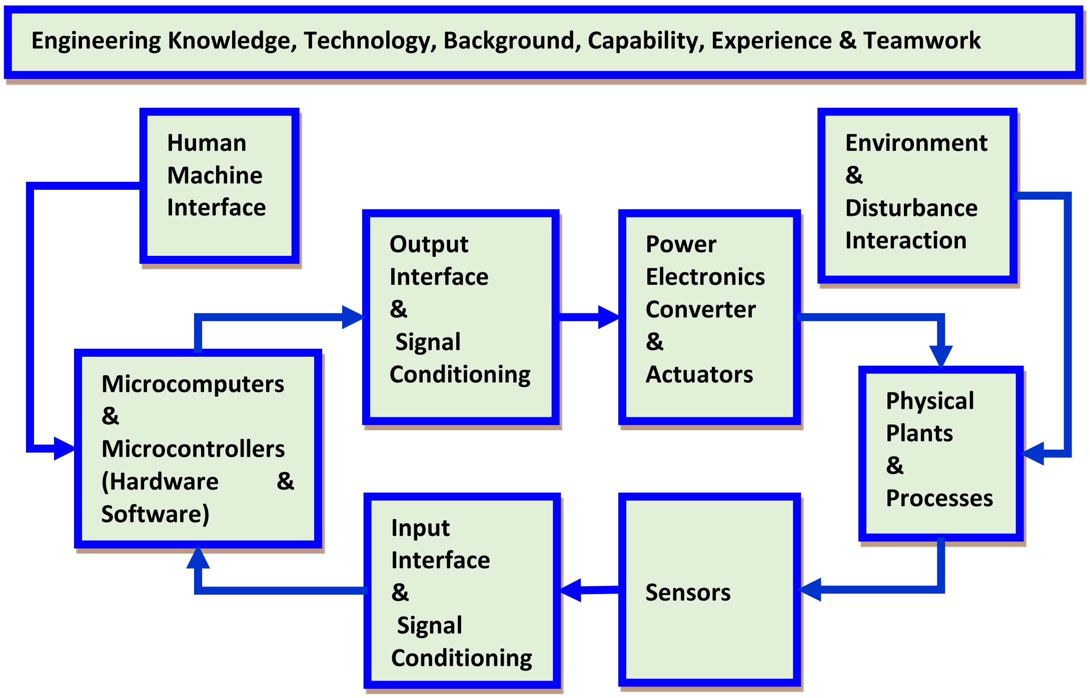
- How do we learn? Individual versus group?
- Tell me & I'll forget. Show me & I'll remember. Involve me & I'll understand.

- A teacher points to a good thing that each student must discover for himself.
- A teacher shows you how to explore & discover.
- Learn as much as you can. Keep the good ones. Discard the bad ones.
- Use only that which works, and take it from any place you can find it.
- What am I learning? How is it useful?

- Knowing is not enough, we must apply it. Willing is not enough, we must do it.
- You must be in the water to learn how to swim!
- With every mistake, we must surely be learning!

- Only 1-10% burden is on the instructor (external exposure) (say 1-10 hr)!
- 10-99% burden is on YOU (own exploration + discovery) (10-100 hrs)!
- If you put in >100% and still don't get it right, then seek further assistance!

**Components of a Microcomputer-based Control System**




## Teaching Approach

### *1 Awareness of Nature's Transitional and Equilibrium States*

a. Laws of forces and dynamics
b. Uncontrolled & controlled
c. Human tends to control a lot

### *2 Microcomputer-based control systems*

a. Current technologies
b. Advanced technologies
c. Future technologies

### *3 Microcontrollers: Arduinos*

a. Everything you want to know about Arduino but were afraid to ask
b. Start with https://www.arduino.cc, Adafruits, Sparkfun, Digikeys,many more
c. Acquire Arduino starter or advanced kits
d. Commands, I/O, shields, libraries
e. Communications: **serial,** Bluetooth, WiFi,ifi, XBee, I2C, etc.
f. Tutorials, references, YouTube
g. Capabilities and limitations
h. New products appearing each week!

### *4 Sensory systems - Examples*

a. Long list of sensors

b. Cameras – USB camera, PIXY camera, Kinect (Explore)

### 5 *Image Acquisition & Processing*

a. Intro to image acquisition & processing using Matlab for tracking a color/blob
b. Matlab Image Acquisition & Processing
c. Image acquisition
d. Find and extract color of laser
**e. Blob analysis**
f. Generate tracking error ex & ey
g. Send the error e to a serial comm

### 6 *Control System - Examples*

a. Real word natural phenomena
b. Man-built control systems
c. Experimental projects
d. Physical to math model

### 7 *Laser/color designated target tracking control system project -IndivProj*

a. Target → camera → image processing →controller → servomotor → line-of-sight aim
b. Conceptual scheme of the control system
c. Image acquisition & processing to track a color
d. Approximate control block diagram
e. Nicolas-Ziegler PID Tuning

### 8 *Signal Representation*

a. Continuous-time waveform - analog signal & Laplace s-transform
b. Discrete-time waveform - digital signal &z-transform
c. Relationship between s & z transforms - Exact & Approximate

### 9 *Systems representation*

a. Linear dynamics systems
b. Continuous-time systems, Ordinary differential equations, s-transfer function
c. Difference equation, z-transfer function, Discretization of ZOH systems
***d. Continuous-time and discrete-time systems*** c2d, d2c conversion
e. Discretization: Euler approximation, bilinear transform, zero-order hold

### 10 *Output responses of system*

a. Transient response - Time constants, settling time, Overshoot, Rise time
b. Zeta & Wn – Poles
c. Zeros
d. Steady state response
e. Frequency response - Sinusoidal response – rubber band animation
f. Fourier transforms, Bode diagrams
g. Low pass filter, midrange filter, high pass filter

### 11 *System identification*

a. In God we trust. The rest must bring data.
b. System ID using Matlab/Simulink using System ID toolbox
c. Verification between experiment and simulation
d. System ID of a servomotor and a delayed computer image processing output

### *12 Controller Design*

a. Root Locus Technique
b. Role of Controller as viewed using root locus technique
c. Explanation of P, PI, PD and PIDF, lead & lag controller
d. Explanation of Nichol-Ziegler Tuning Rule
e. Bode Diagram Technique
f. Frequency domain analysis – Fourier transform

### *13 Simscape*

a. Intro to Simscape
b. Simscape model for Target Tracking System

### *14 Matlab-Arduino Support Package*

a. Add-on download
b. Examples

### *15 Simulink-Arduino Support Package*

a. Add-on download
b. Examples

### *16 Term Project*

a. Teams of three
b. Must utilize computer vision (USB camera, Pixy camera, IR matrix array, etc)

**Learning Outcomes:**

*After successful completion of the course, students should be able to:*

- ✓ Be apply control theory to design a microcomputer control systems
- ✓ Be well versed in using Arduino microcontrollers and its supports
- ✓ Implement of electronics interface circuits for inputs and outputs
- ✓ Formulate & program analog/digital control and signal processing algorithm
- ✓ Design, build & test a microcontroller-based closed-loop control system
- ✓ Implement Matlab/Simulink computer vision based target tracking experiment
- ✓ Simulate & visualize control systems using Matlab/Simulation/Simscape
- ✓ Experienced in setting up system demos, including troubleshooting and debugging
- ✓ Comfortable in learning other technologies for embedded control systems