

# ECE 557: *Control, Signals, and Systems Laboratory*

## Notes for Lab 1 (Introduction to DAQ, dSPACE, and Simulink)

### 1. Class introduction

- Course web page: <http://www.ece.ohio-state.edu/~pavlict/ece557/>
- Distribute syllabus (also available on-line)
- Instructor
  - Ted Pavlic (sounds like “maverick”)
  - E-mail: <[pavlic.3@osu.edu](mailto:pavlic.3@osu.edu)> (put “ECE 557” in your subject)
  - Office (CL 351) hours: See [web page](#) for hours. Appointments (and, usually, walk-ins) OK.
- Purpose of course
  - **5** — Rank 4 and *outside* graduate students, **5** — Control emphasis, **7** — Not 551
  - Exploration of signals and systems through applications of control (especially feedback)
  - Complements ECE 551 and ECE 755
  - Historically, true analog controllers (e.g., RC networks) were used
  - Now, PC downloads to a DSP that lives on a PC expansion card
- Other labs (**ECE 757**, **ECE 758**, ECE 508, ECE 609)
- Grades (posted on Carmen)
  - Pre-lab assignments (30%), Lab reports (40%), Lab clean-up (10%), Final exam (20%)
    - \* Individual grades: Pre-labs and final exam
    - \* Group grades: Lab reports and lab clean-up
  - Lab report grading rubric given on course web page
  - Final letter grade curve
- Make-up dates (during office hours?)
- Save data for lab report on floppy, removable media, or over ECE network
- Groups of **two**

### 2. Lab text: *Control Systems Technology Lab* by Yurkovich and Abiakel

- Pre-lab assignments correspond to the *Laboratory Preparation* sections of each lab
- Detailed instructions are given for the in-class experience
- Labs build in a logical order. The final lab can be viewed as incorporating aspects of all of the previous labs
- Due to time and hardware limitations, the last two very similar labs are combined into one lab

### 3. Refresher: Continuous-time linear systems (see next page)

### 4. Complete the *Introduction to DAQ, dSPACE, and Simulink* lab

- Use frequency-domain system identification to determine the transfer function of a “Black Box”
- Note the slightly different location of the “Black Box”
- *Simulink* tips:
  - Set MATLAB working directory to location of saved files
  - Configure *Simulink* for ODE5 fixed-step (0.001 s) solver and RTI1104 target hardware
  - Hotkey for building is **Ctrl** - **B**
- *dSPACE ControlDesk* tips:
  - To prevent problems, do **work** on **local** hard drive — you can copy to network later
  - Start *dSPACE ControlDesk* before doing *Simulink* builds
  - Use **simState** with 2-option radio button (Run = 2, Stop = 0) and repeated runs
  - Press **Enter** / **↵** to commit numeric input changes (i.e., do not *click* away)

- Refresher: Continuous-time linear systems
  - Digression: Fourier and Laplace
    - Fourier showed that periodic functions can be built out of sums of other periodic functions — in particular, sums of  $e^{j\omega t}$  (“phasors” from ECE205)
      - \*  $2\cos(\omega t) = e^{j\omega t} + e^{-j\omega t}$  (in fact,  $e^{j\omega t}$  is *itself* a sum of cos and sin)
    - Laplace extended the theory to functions that are not periodic
      - \* Use  $s$  instead of  $j\omega$  where  $s = \sigma + j\omega$  and  $e^{st} = e^{\sigma t}e^{j\omega t}$
      - \*  $e^{\sigma t} \times 2\cos(\omega t) = e^{st} + e^{-st}$
      - \* What happens when  $\sigma = 0$ ? ...  $\sigma > 0$ ? ...  $\sigma < 0$ ?
      - \* Remember that  $\Re(s) = \sigma$  (i.e.,  $\sigma$  is the real part of  $s$ )
  - Example **linear** time-invariant (LTI) system:  $y'' + 2y' + y = x' - 5x$ 
    - Passes some components of the input
    - Strips out some components of the input
    - Introduces new components from within
  - Transient response: Introduced components
    - The transients (introduced components) of a *stable* system will die out
      - \* Initially, transient characteristics can be nice (e.g., better rise time, overshoot, etc.)
      - \* But eventually we want them to go away
    - To ensure stability, solve for  $y$  when  $x$  is zero — in a stable system,  $y \rightarrow 0$  as  $t \rightarrow \infty$
    - Try a single  $y = e^{st}$  component (recall Laplace and linearity) — can we solve for a valid  $s$ ?
      - \*  $y' = se^{st}$ ,  $y'' = s^2e^{st}$ , and  $e^{st} \neq 0$
    - What happens when  $\Re(s) < 0$ ?
    - In this interpretation, a *pole* **attracts** the system to it
  - “Zero dynamics”: things stripped out
    - It’s also interesting to see what dynamic inputs will have *no impact* on the output
    - Set  $y = 0$  and solve for valid  $s$
    - These signals will not pass easily through the system
    - Stability of zero dynamics isn’t a concern here; we count on the user giving us bounded inputs (Bounded-Input–Bounded-Output (BIBO) stability)
    - So system is *pulled* toward *poles* and away from *zeros*
  - Transfer function and the original “pole” and “zero”
    - Assuming that the system is stable, take  $x = Ae^{st}$ , assume  $y = Be^{st}$  and solve for  $B/A$
    - Result is polynomial
    - Plot its *magnitude* in 3D with magnitude axis extending to the sky and complex plane parallel to the ground
    - The “poles” are really like tent poles — they hold up the function
    - Evaluating  $B/A$  for any simple sinusoid ( $s = 0 + j\omega$ ) is the same as walking along the imaginary axis — cross-section of magnitude function *is* the transfer function
    - Consider difference between a real pole and an imaginary pole
  - To do *frequency-domain system identification* for a *linear* system, we walk along the imaginary axis and record the transfer function we discover. With it, we can characterize an unknown system
  - Important point to remember: we care about  $\Re(s) < 0$  because  $e^{st} \rightarrow 0$  as  $t \rightarrow \infty$ , and so we can assume transients will die out and only steady-state will remain
    - Remember that “steady-state” does **NOT** mean constant/DC — it just means *no transients*