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

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

1. Class introduction
   - Distribute syllabus
   - Introduce instructor
     - Contact information
     - Office hours
   - 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 (instructor policy takes precedence)
     - 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
   - Save data for lab report on floppy, removable media, or over ECE network
   - Groups of **two** (instructor policy takes precedence)
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 may be 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 $\sigma = 0$? $\ldots \sigma > 0$? $\ldots \sigma < 0$?
      - Remember that $\Re(s) = \sigma$ (i.e., σ 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, $y \to 0$ as $t \to \infty$
    - 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 $e^{st} \to 0$ as $t \to \infty$, 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*