ECEC-T580: Computing and Controls, Fall 2018-19
Project 2

Objective: To build a hybrid system (consisting of analog and digital components) to control the response (i.e. pole location) of a RC low pass filter by implementing the closed loop control using a microcontroller and associated interface hardware.

Figure 1, depicts an analog control system where $G(s) = \frac{a}{s+a}$ is the model of a single pole low pass filter. The gain K can change the pole location and also the output amplitude.

Figure 1: Analog closed loop system, unity feedback

Adding a computer and additional hardware results in the following pictorial/block diagram shown in Figure 2 (not one for one)

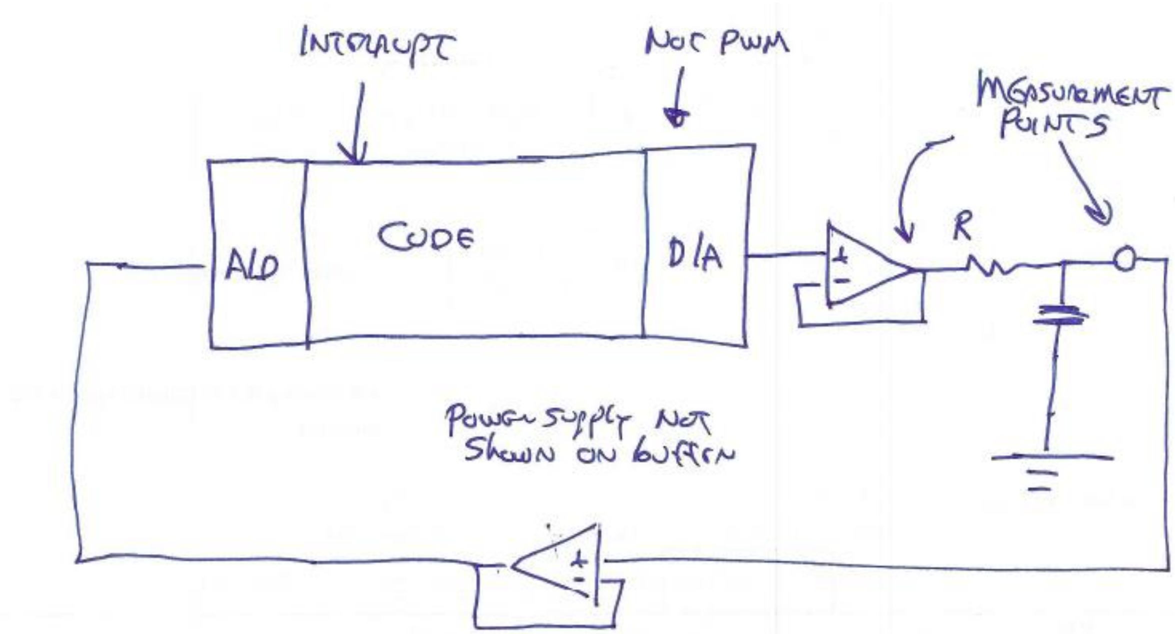

Figure 2: Pictorial/Block diagram depicting closed loop system driving an analog plant buffered by unity gain op amps to prevent loading

As seen in Figure 2, the computer samples the output, implements the summer and gain in the forward loop (not explicitly shown) and then outputs a signal to drive the RC system by means of a D/A converter.

Performance of the computer/analog system will be determined by measuring the step response and comparing it to the Discrete time and Hybrid models implemented in Simulink. Variations for the step amplitude and gain K will be explored in terms of timing, timc constant and final value.

Model-based design approach

The Simulink model that was used in class is included in the project directory and should drive your project.

- Determine a set of RC values and measure them these determine “a” every group should be different – try to get close to 25 rad/sec.
- Change sampling times etc. to see results
- Remember the Hybrid and the digital system produce the same values at the sample time, Hybrid system shown in Figure 3 below.

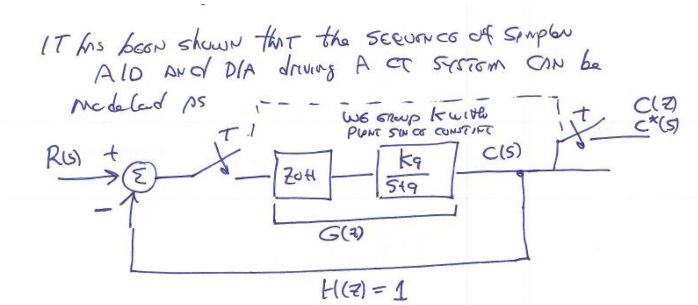

Figure 3: Hybrid model that matches z-transform model – note this does not show effects of quantization

- Your team will need to update the Hybrid model to include the use of the A/D and D/A to show quantizing. You can assume the metric is the digital output at the sampling times – what we did as a class exercise.
    - **Important** – based on your implementation you may introduce an additional delay in the system this would happen if in the interrupt service routine, the process is: |write|read|process - you can experiment with a delay in the feedback loop of the model
- How can you compare the model to the result of your system? This implies comparing outputs of Simulink and system on same plot.

Some general comments or check list items

- Uniformly sample an analog signal – discuss sampling time and results on pole location, quantization etc. Discuss the sampling rate choice 500 Hz might be a good start but see what happens if it gets faster or slower.

- Output must use a D/A (either serial or parallel) – no PWM - discuss how to write all bits at same time.
- Try different values of K (some integer some like 1.333)
- Try different step inputs (integer and float) also what about quantization of input?
- Make sure to scale the system – use the Simulink models
- Measure the processing time that it takes to implement the algorithm and determine its statistics. Present results in table – this should show differences in K and maybe sampling times
- Show appropriate signals, and data types on diagram
- Use two 9 volt batteries for the buffer amplifiers tor make life simpler.
- Figure out a way to compare the Simulink model output and the physical system – overlay plots.

General constraints/guidelines

- Sample and quantize an analog signal such that $0 < x_a < 5$ volts. Do we need to address negative values of the output? Remember you are giving up resolution if you shift but only have a single sided signal.
    - Offset the signal if needed
    - Use the 10 bit internal 0-5v A/D converter
    - Sample the signal using an interrupt, either with an internal timer or external clocking signal
- Implement a D/A via SPI or I2C interface – do now use PWM
    - Remember to check quantization levels and voltage range if you use s serial D/A
    - Need to display both input and outputs signal and get scope picture

What to turn in (per group max 3) :

- 3-5 page terse memo showing detailed system diagram, key waveforms, and results. Make sure figures and plots have numbers and descriptive titles. Use tables and make sure you talk to results in tables. The memo must not leave questions unanswered – i.e. somehow show data types etc.
- Video of working system with voice over describing the scene (upload) Show a few examples that may be summarized in the memo.
- Note each group must have at least one CE and one EE member
- Make sure that you have read the memo and that it is consistent across sections and plots– don't talk about D/A outputs and then implement using a PWM – not consistent – or it shows a misunderstanding.