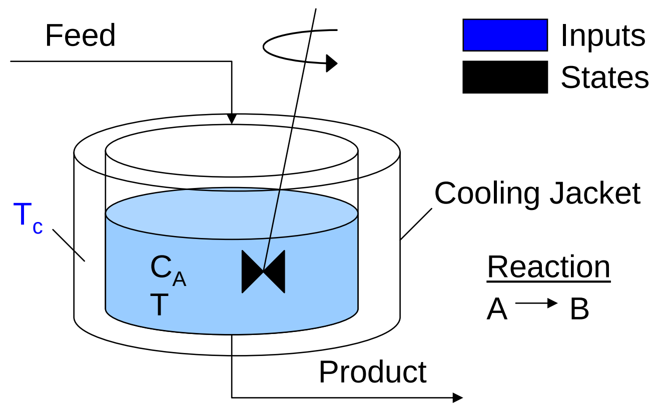
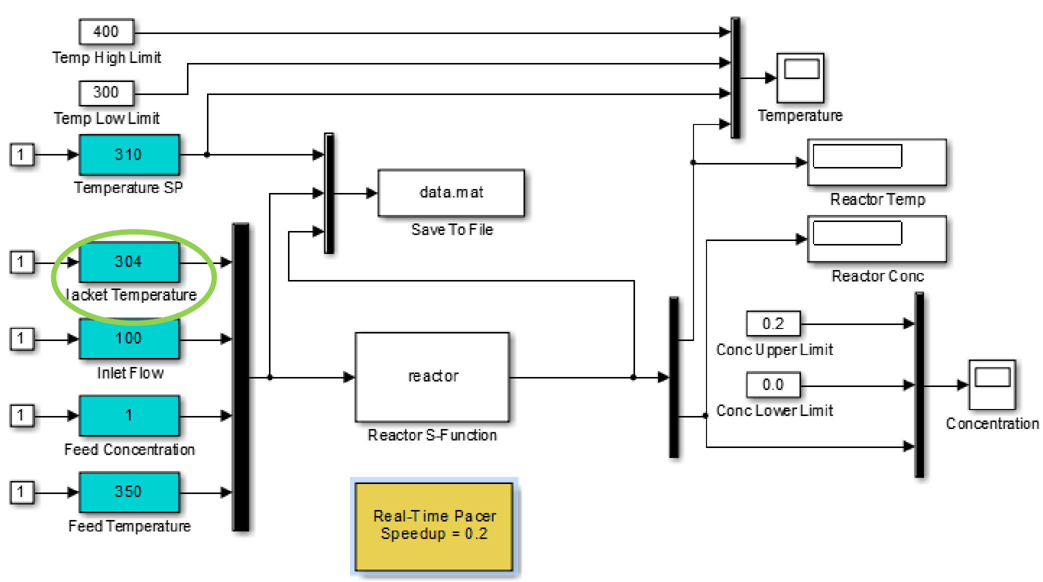
Special Problem 5
ChE 436: Process Dynamics and Control



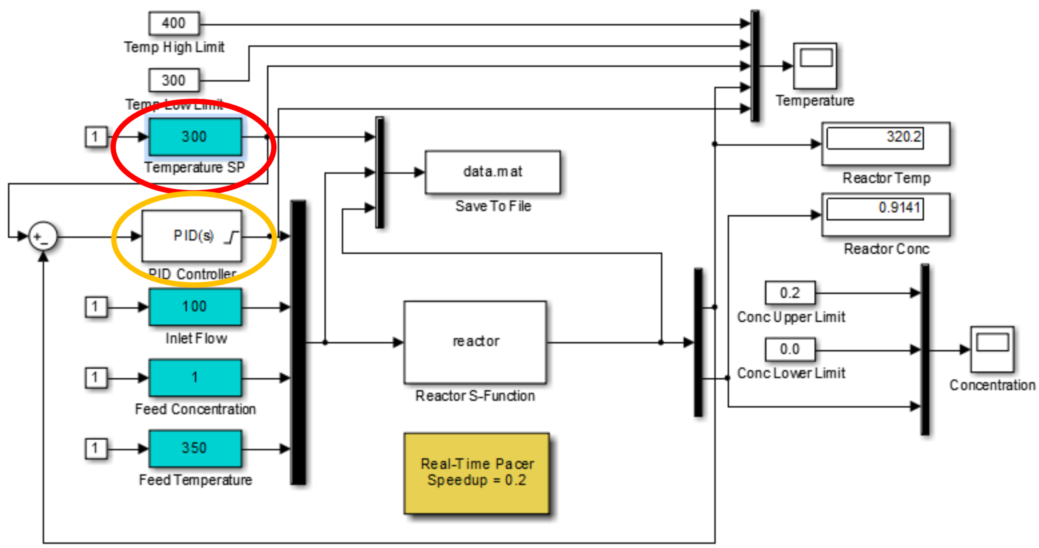
A reactor is used to convert a hazardous chemical "A" to an acceptable chemical "B" in waste stream before entering a nearby lake. This particular reactor is dynamically modeled as a Continuously Stirred Tank Reactor (CSTR) with a simplified kinetic mechanism that describes the conversion of reactant A to product B with an irreversible and exothermic reaction. Because the analyzer for product B is not fast enough for real-time control, it is desired to maintain the temperature at a constant setpoint that maximizes the destruction of A (highest possible temperature). You may use the Simulink models and the Excel workbook provided to fit FOPDT models (download http://apmonitor.com/che436/uploads/Main/sp5_files.zip) or you may do this assignment with Python (see http://apmonitor.com/pdc/index.php/Main/StirredReactor). This problem description continues with instructions for Simulink. In Simulink, don't forget to open the plots by double-clicking the Temperature and Concentration plots. A video link to help with Simulink is available here: http://youtu.be/dJuD2wiQbts

a) Perform the necessary open loop dynamic modeling studies to determine a first order plus dead time (FOPDT) model which describes the relationship between cooling jacket temperature (MV=T_c) and reactor temperature (CV=T). Start at 300K for the cooling jacket temperature (green circled T_c), step up to 303K, down to 297K and back to 300K in a doublet test. Use the file *data.txt* to extract the information for the FOPDT model.



b) Use the K_p, τ_p, and θ_p from part *a* in the Internal Model Control (IMC) tuning correlation and compute the tuning parameters for a PI controller. Assume that the closed loop time constant, τ_c, equals 0.1 τ_p for this investigation. The IMC design relations can also be found in Appendix D of the Practical Process Control book.

c) Using your K_C and τ_I from part *b*, implement a PI controller (orange circled PID controller) with anti-reset windup (be sure to turn off the derivative action). Test the set point tracking capability (red circled reactor SP) of this controller by plotting the response of the process to steps in setpoint of the reactor temperature (not cooling jacket temperature) from 300K up to 320K and then down to 280K. Comment on how the nonlinear behavior of this process impacts your observed set point response performance.



d) Determine a "best" tuning by adjusting K_c and τ_I by trial and error until the controller displays a 10% to 15 % overshoot in response to set point steps from 300K up to 320K and plot this set point step response.

e) Step up the setpoint to achieve a maximum temperature in the reactor without exceeding the maximum allowable temperature of 400K (don't cause a reactor run-away). What is the lowest concentration that can be achieved without exceeding the maximum allowable temperature?