

ME 333 Introduction to Mechatronics

Assignment 2

Due Tuesday Jan 17 at the beginning of class

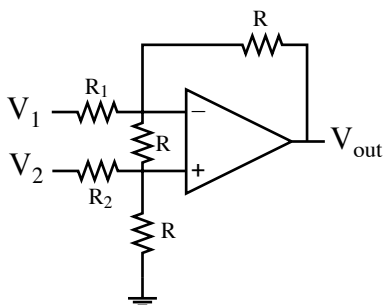
1. You are designing a feedback control system for a robot joint using op amps. Let V_{ref} be a voltage that indicates the desired (reference) angle for the joint. Let V_{sens} be the voltage from a potentiometer on the joint that indicates the actual angle of the joint. You decide to use PID (proportional-integral-derivative) control to keep V_{sens} as close as possible to V_{ref} . This means that the control voltage you will send to the motor is equal to the sum of K_P times the current error $V_{\text{err}} = V_{\text{ref}} - V_{\text{sens}}$, K_I times the time-integral of the error, and K_D times the time-derivative of the error (the rate of change of the error). The proportional term is to try to correct the current error (like a spring pulling the joint to the desired angle), the derivative term is to try to anticipate future error (like a damper on the joint velocity error), and the integral term allows the control voltage to be non-zero even when there is no error. This is necessary, for example, for the robot joint to be stationary with zero error when it needs to be apply a torque in a gravity field. How to choose K_P , K_I , and K_D is a topic for ME 391 or ECE 360.

For all of the following questions, use realistic resistor and/or capacitor values.

- Design a circuit using op amps that calculates V_{err} from the inputs V_{ref} and V_{sens} .
- Design an op amp circuit that takes in V_{err} and outputs $V_P = -10 V_{\text{err}}$.
- Design an op amp circuit that takes in V_{err} and outputs V_I , which is -2 times the time-integral of V_{err} .
- Design an op amp circuit that takes in V_{err} and outputs V_D , which is -5 times the time-derivative of V_{err} .
- Design an op amp circuit that takes in V_P , V_I , and V_D and outputs $V_{\text{control}} = -V_P - V_I - V_D$.

You have designed a PID control circuit. In practice, you could make a PID controller with fewer op amps. You might use potentiometers instead of fixed resistors in the op amp circuits so you can easily change the controller gains K_P , K_I , and K_D . Also, you would likely need a low-pass filter on your error signal, or on the output of the derivative circuit, so there is not too much high-frequency noise due to the derivative term.

2. Calculate V_{out} as a function of V_1 and V_2 in the circuit below.



3. Calculate the voltage range for V_{in} for which the LED is off and for which the LED is at its maximum brightness. The transistor gain is 100. As always, assume the diode drop is 0.7V and show your work.

