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Pre-Lab 10: Control and Navigation

Control Theory

Control is an engineering sub-discipline defined as "that branch […] which deals with the design, identification and analysis of systems with a view towards controlling them, i. e., to make them perform specific tasks or make them behave in a desired way" (Control theory. (n.d.) Webster's Revised Unabridged Dictionary. (1913). Retrieved July 8 2014 from http://www.thefreedictionary.com/Control+theory).

Figure 1 shows the abstracted diagram of a generic control system. This generic version of a control system involves a reference, a measure of error, a *controller*, and a device ("plant") to be controlled, all connected in a negative-feedback "control loop".

In your wall-avoiding (curb-feeling) vehicle design, the vehicle must remain close to the wall. The flex sensor measures the deviation from the wall (the error) and provides that feedback to the oscillator circuit (the controller) you built which drives the motors and the car (the plant). Therefore, as the flex sensor bends against the wall, its resistance changes causing the duty cycle of the square wave signal to change in response, finally changing the relative speeds of the motors so that the vehicle moves away from the wall.

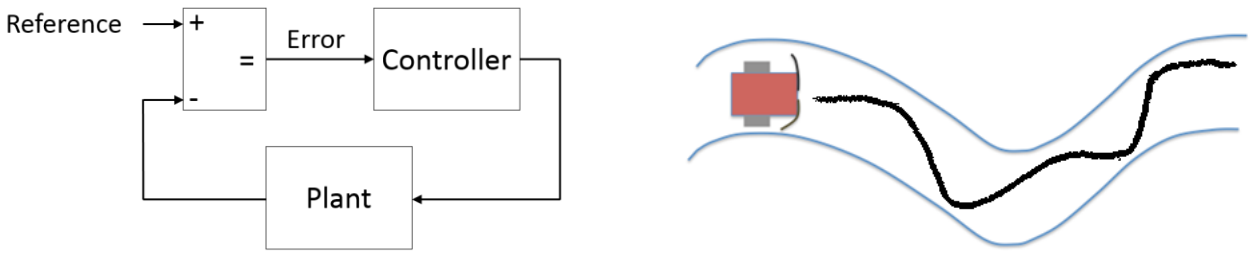

Figure 1: A generic control system involves a reference, a measure of error, a system "controller", and a device ("plant") to be controlled, all connected in a "control loop". The curb-feeling car is a control system.

There will be two distinct tasks today. For the first task, we will provide the design procedure. For the second task, you will imitate the design procedure to complete your own individualized design! To be successful, you will need to identify the operating characteristics of the devices involved, primarily the sensors and the motors. Some of these devices were already

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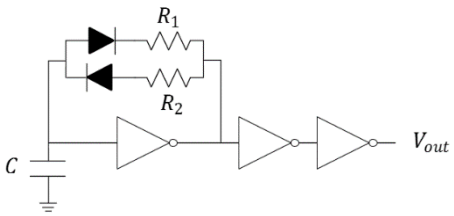
investigated in previous laboratory experiments, however, you will need to do your own characterization of any new components introduced into your system.

If the car's nominal speed is set too high, we might say the "loop gain" is too large. This could result in "unstable" behavior as the car reacts abruptly to small changes in the flex sensors, possibly turning sharply away and then back into the wall.

Question 1: Discuss how the choices of the values of resistor R_1 and R_2 and capacitance C control the feedback "loop gain".

Question 2: Using input from the flex sensors on their vehicles Nick and Tommy design their feedback systems each has chosen values of the resistor R_1 (the flex sensor) and $R_2$and capacitance C to select their car speed. Suppose Nick designs his system to use a PWM range of 40-60% duty cycle to control his wheel speed. Tommy uses a PWM range of 80-100% to control his wheel speed. Who is likely to have a *more stable* control system? Why? (Just give heuristic justification)



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The Engineering Design Algorithm

When an engineer takes on the task of designing a new device, he or she will inherently follow a number of procedures that highlight their skills as effective problem solvers. These skills have been summarized and are often referred to as the steps of engineering design or, more formally, the Engineering Design Algorithm. We will adapt the version given by Orsak, et. al., in the textbook, *Engineering Our Digital Future: The Infinity Project*.

The Engineering Design Algorithm:

1. Evaluate the challenge by defining goals and constraints
2. Research the problem to design possible solutions
3. Choose the best solution from the options and build a prototype
4. Test and evaluate the prototype and return to earlier steps as needed

Watch this interesting video about the design of the modern-day coffee maker and then answer the questions that follow. https://www.youtube.com/watch?v=4j4Q_YBRJEI (or search the Internet for "engineer guy coffee maker").

Question 3: Name at least two constraints of a good coffee maker and explain how they add to the challenge of designing one.

Question 4: Hypothesize about what problems the inventor of the coffee maker may have encountered and what he/she may have had to do to overcome them.