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Open Loop Control

Introduction

Manchester Robotics

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Open Loop Control

Introduction

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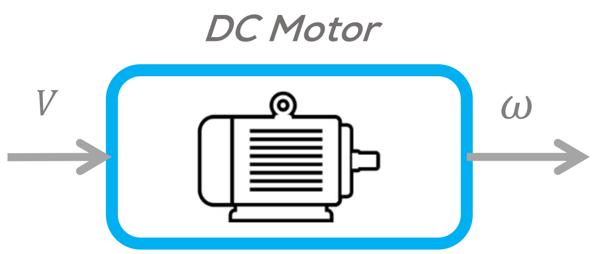
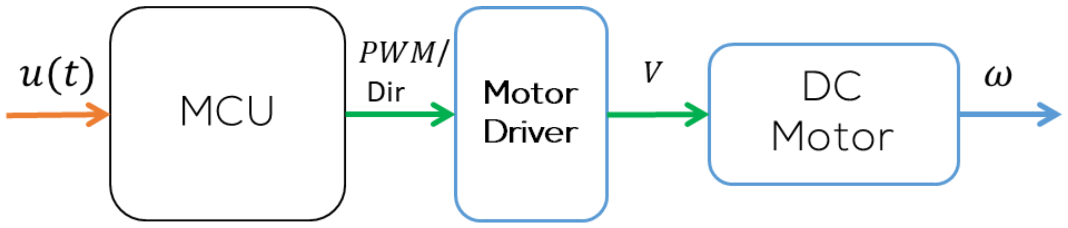
Problem Statement

- Let the system (in this case the DC motor) to be represented as a black box, as shown in the picture. The input to the motor is Voltage V and the output is the angular speed ω.



- The DC motor to be controlled by a microcontroller (MCU), requires a Motor Driver to change direction and regulate the speed.

- Typically, the motor is controlled using a PWM (Pulse Width Modulation) Signal. The user defines the percentage of the duty cycle of the signal $u(t)$, and the frequency (Typically predefined ~490-1000 Hz).



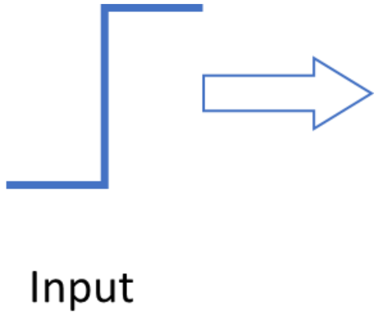
- The duty cycle percentage $u(t)$, is in the range $\text{duty } cycle\ (\%) \in [0, 100]\%$

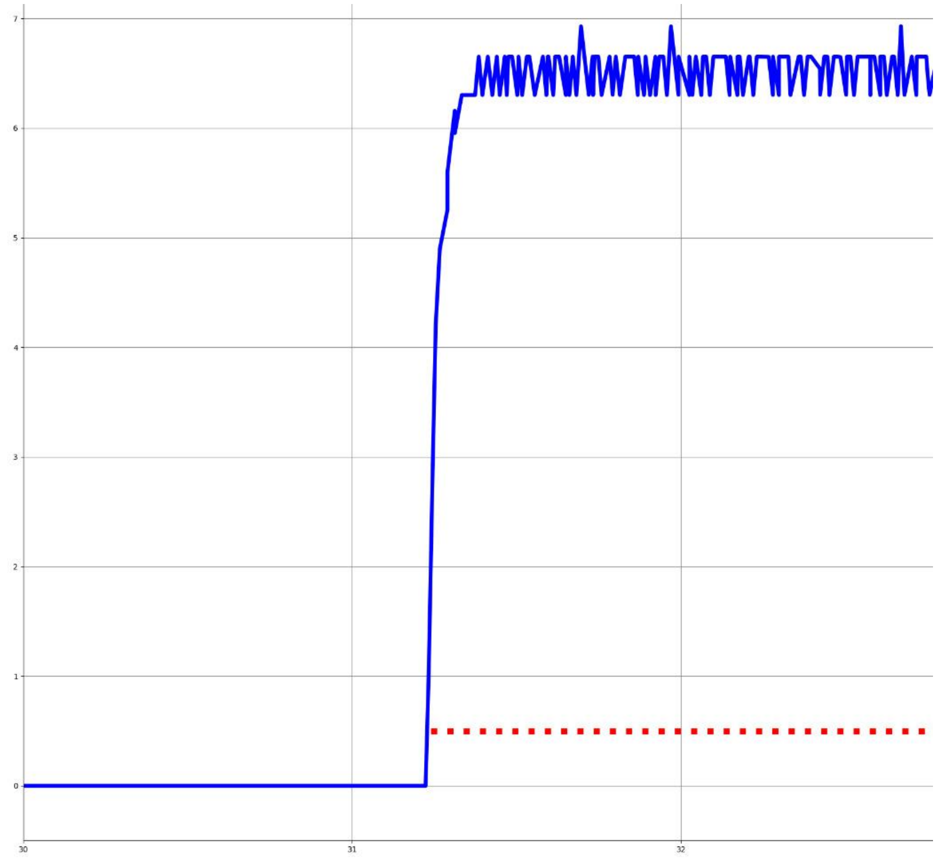
Problem Statement

- Let a value $u(t) = 0.5$ to be the input to the system (step input).
- It can be observed that the output of the tends to a steady state and resembles a first/second order system without delay. For simplicity we will use a first order system of the form

$$G(s) = \frac{K}{\tau s + 1}$$

- The figure shows the output velocity to be $6.6\frac{rad}{s}$. Making the gain K of the system to be $K = \frac{\Delta\omega}{\Delta u} = 13.2$.
- The parameter τ (since this is a system without offset and no delay), is obtained by measuring the time when the 63.21% of the total output change ($\Delta\omega$) is present i.e., $\tau = t_{(0.6321 \cdot \Delta\omega)}$. For this system, the $\tau \approx 0.04$



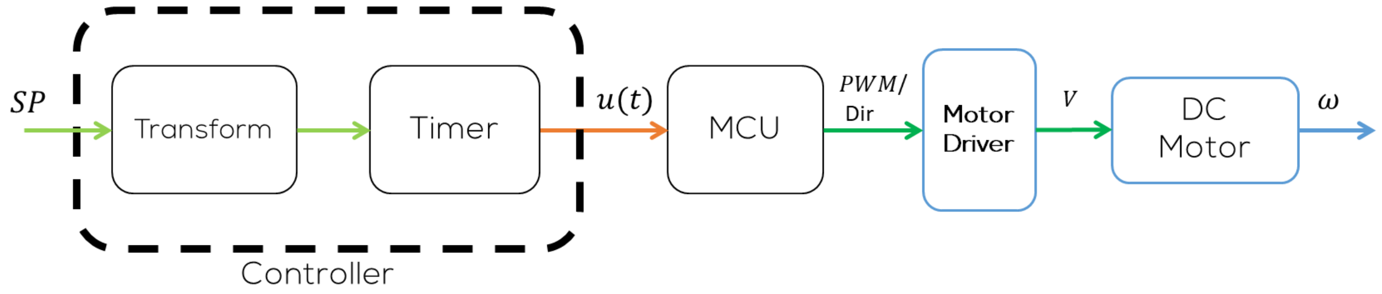


Problem Statement

- Knowing the system's model, a question arises. Can we use this information to try controlling the motor speed?

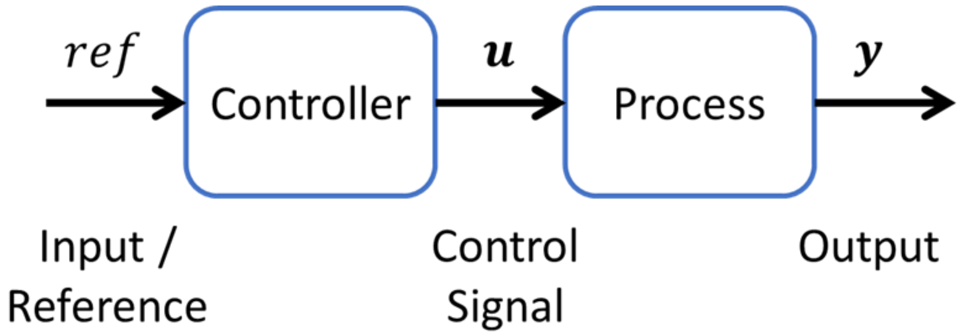
$$G(s) = \frac{13.2}{0.04s + 1}$$

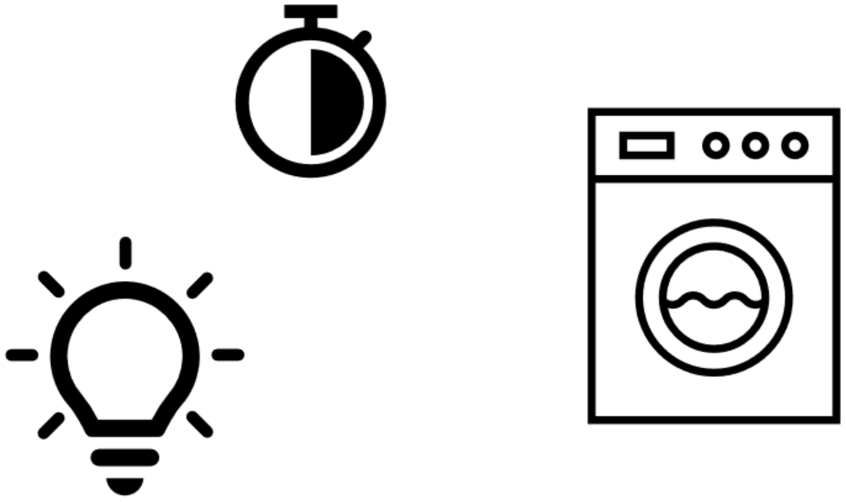
- We know that the system will reach the steady state very fast ($\sim 4\tau$).
- Therefore, would it be possible just to make a small transformation (linear), using the gain of the system, to try controlling the speed of the motor?
- Furthermore, if that is possible can we use a timer to control the angle travelled by the motor and regulate its position?.
- This is called open loop control.



Open Loop Control

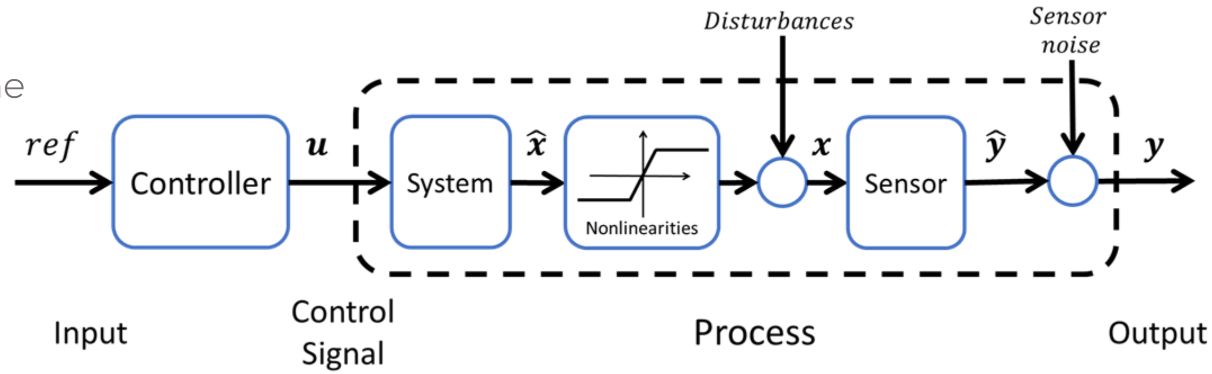
- Open Loop Control System is a system in which the control action is independent of the output of the system.
- In this type of control, the output is regulated by varying the input or reference.
- The output of the system is determined by the current state of the system and the inputs that are received from the controller.
- Some examples of this type of control systems are Windows, window blinds, washing machines, microwave ovens, hair drier, bread toaster, Door Lock System, some stepper motors, turning on/off lights, some remote-controlled applications, etc.

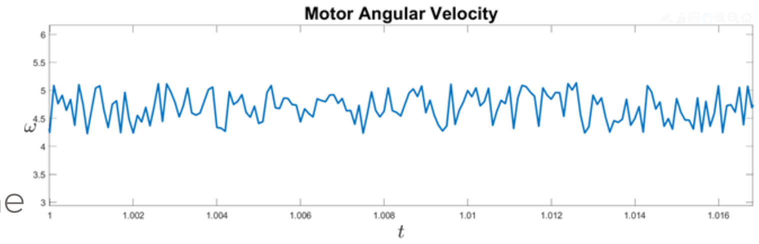




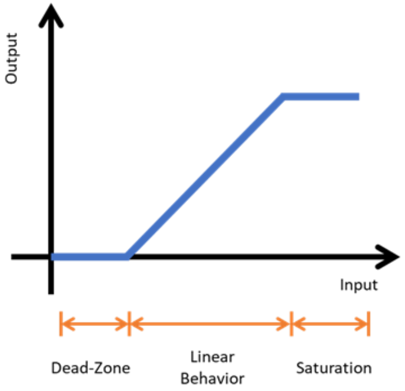
Open Loop Control

- In reality, every process present disturbances, nonlinearities and noise.
- Disturbances and noise come from the environment that surrounds the system.
  - On motor, some disturbances can come from manufacturing, environment perturbations, etc.
  - On the other hand, the noise is present when reading the values of the motor encoders (Sensors).
- Nonlinearities are an intrinsic characteristic of a system in which the output does not linearly follow the input (output not proportional to the input).
  - For the case of the motor, the nonlinear behavior can be seen as a saturation and dead-zone.





Noisy Signal (Angular velocity)

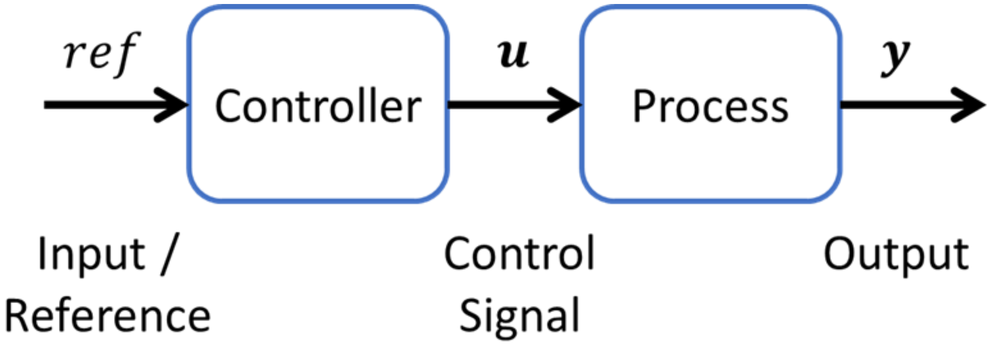


Nonlinear behavior

Open Loop Control: Advantages

Open Loop Advantages:

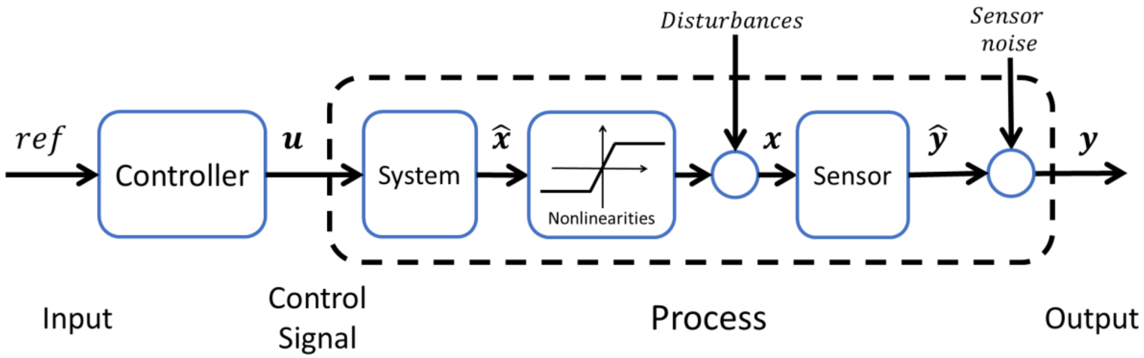
- Simple to design and implement, provided that the user has some experience with the system.
- The cost for design, implement and maintain is relatively low compared with other controllers.
- Maintenance is considered simple, no high technical level required (for most of the controllers).
- The behavior of the controller is quite stable, provided that the system is in a controlled environment, such that the process does not present big disturbances, or the process is not dangerous when unsupervised.



Open Loop Control: Disadvantages

Open Loop Disadvantages:

- This type of control is not robust against disturbances (cannot correct the output in the presence of a disturbance).
- An open-loop system has no self-regulation or control action over the output value.
- Not reliable
- The input depends on the experience of the user.
- Each input determines a fixed operating point of the system.
- Controller must be altered manually in case of an output disturbance or uncalibrated controller.
- Requires re-calibration often.
- Prone to errors in the output and control signal
- Does not take into consideration changes on the process over time.
- Also, there is no chance to correct the transition errors in open loop systems so there is more chance to occur errors.



Thank you

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