ECE 486: Control Systems

Lecture 7B: Open-Loop Control

Key Takeaways

This lecture describes open-loop control.

Open-loop control does not require a sensor and hence it can lead to a cheaper system. It can be effective if:

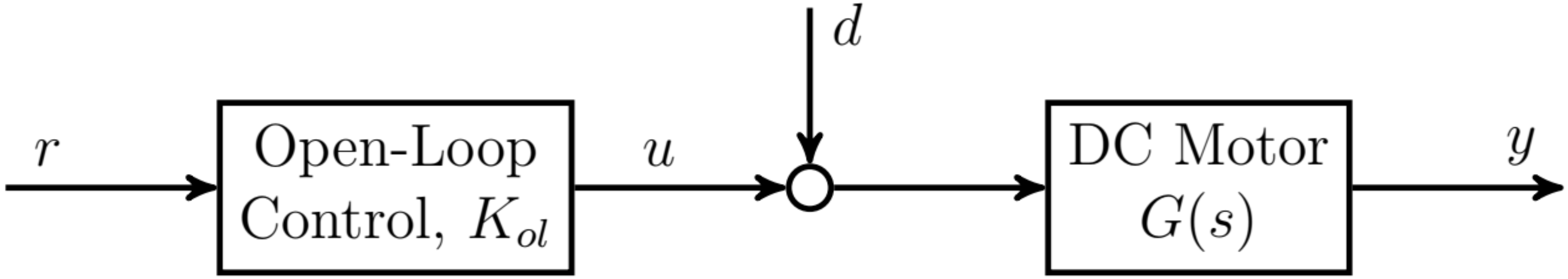
1. The plant is stable,
2. The disturbances are small, and
3. The model is accurate.

If any of these conditions fails, then open-loop control will either fail to achieve stability (if the plant is unstable) or will not provide accurate tracking.

Open-Loop Control

Open-loop control for DC motor:

1. User specifies the desired motor speed, *r(t)*
2. Controller sets input voltage to $u(t) = K_{ol}\, r(t)$ where K_{ol} is a gain to be selected.



Model for Open-Loop Control

Recall the first-order model for the motor:

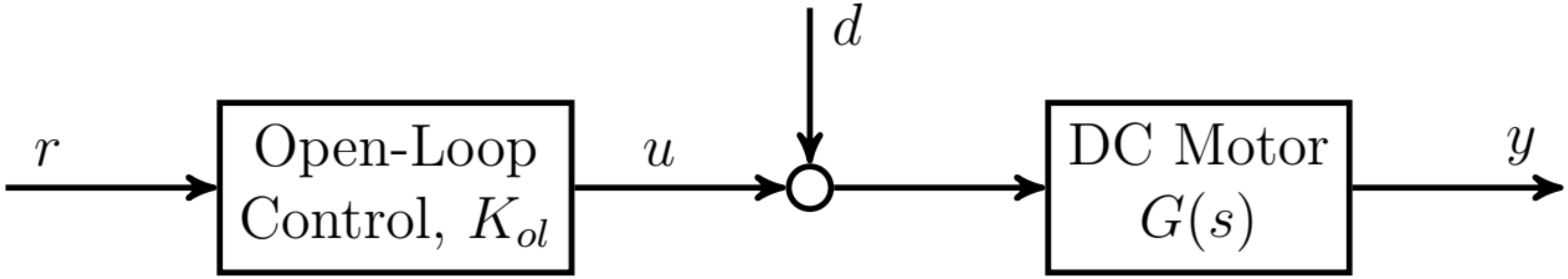
$$\dot{y}(t) + a_0\, y(t) = b_0\, u(t) + b_0\, d(t)$$

$$G(s) = \frac{b_0}{s+a_0}$$

$$\text{where: } \; a_0 = 0.94 \frac{1}{sec} \; \text{ and } \; b_0 = 766.8 \frac{rad}{sec^2\, V}$$

Substitute $u = K_{ol}\, r$ into the model:

$$\dot{y}(t) + a_0\, y(t) = (b_0 K_{ol})\, r(t) + b_0\, d(t)$$



Open-Loop Response

The dynamics of the open-loop system are:

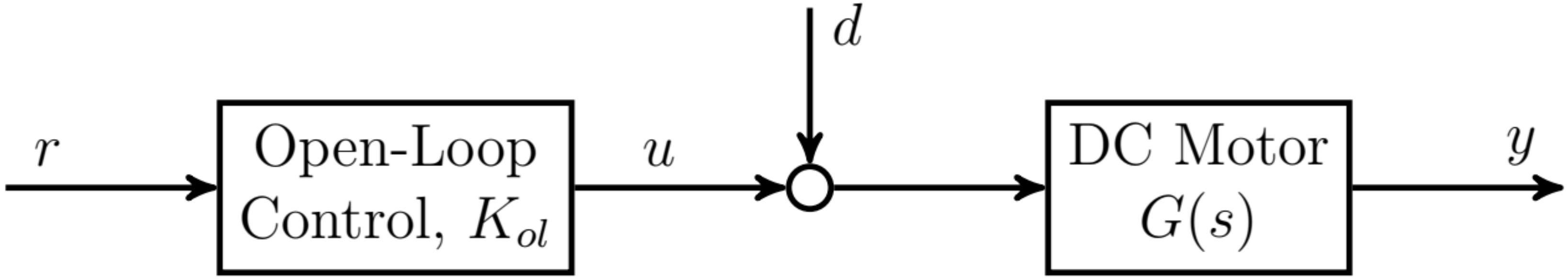
$$\dot{y}(t) + a_0\, y(t) = (b_0 K_{ol})\, r(t) + b_0\, d(t)$$

The response has the following properties:

1. The system has a single pole with $\tau = \frac{1}{a_0} \approx 1.06\, sec$ and settling time $3\tau = 3.18\, sec$. This is the same as for *G(s)*.
2. If $r(t) = \bar{r}$ and $d(t) = \bar{d}$ then:

$$y(t) \to \frac{b_0 K_{ol}}{a_0}\, \bar{r} + \frac{b_0}{a_0}\, \bar{d} \text{ as } t \to \infty$$

Select $K_{ol} = \frac{a_0}{b_0} = \frac{1}{G(0)} \approx 0.0012 \frac{V\, sec}{rad}$ so that $y(t) \to \bar{r}$ if no disturb.

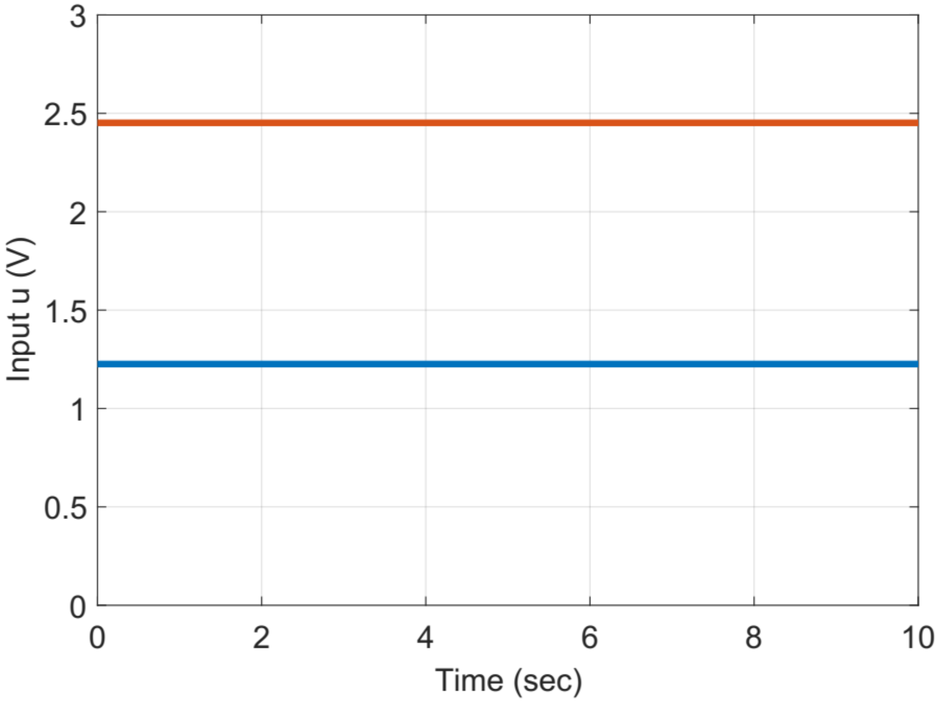


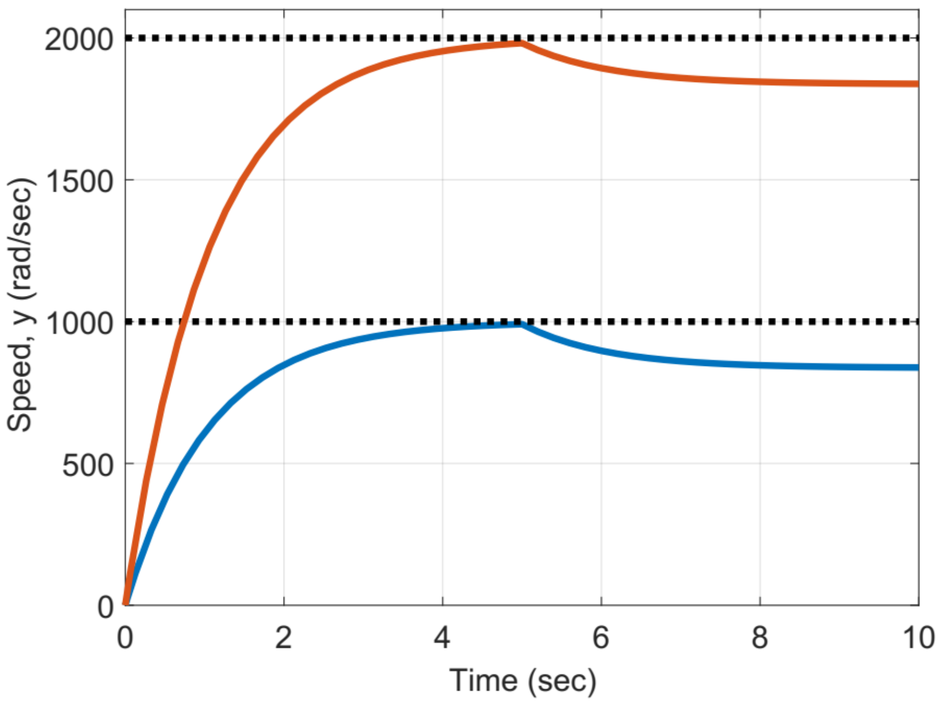
Response of Open-Loop System

Simulations with:

- $r(t) = 1000\frac{rad}{sec}$ and $r(t) = 2000\frac{rad}{sec}$ for $t \geq 0$
- $d(t) = -0.2V$ for $t \geq$ 5sec
- $K_{ol} = \frac{1}{G(0)}$, i.e. exact value of *G(0)* is known.

Open-loop control does not reject disturbances.





Impact of Model Uncertainty

Simulations with:

- $r(t) = 1000\frac{rad}{sec}$
- $\pm 10\%$ variation in (a_0, b_0) in plant dynamics.

Open-loop control is sensitive to model variations.