DC motor data & control

Zhu Chenhao

ITMO ID: 375462

HDU ID: 22320630

Motor Performance Calculations

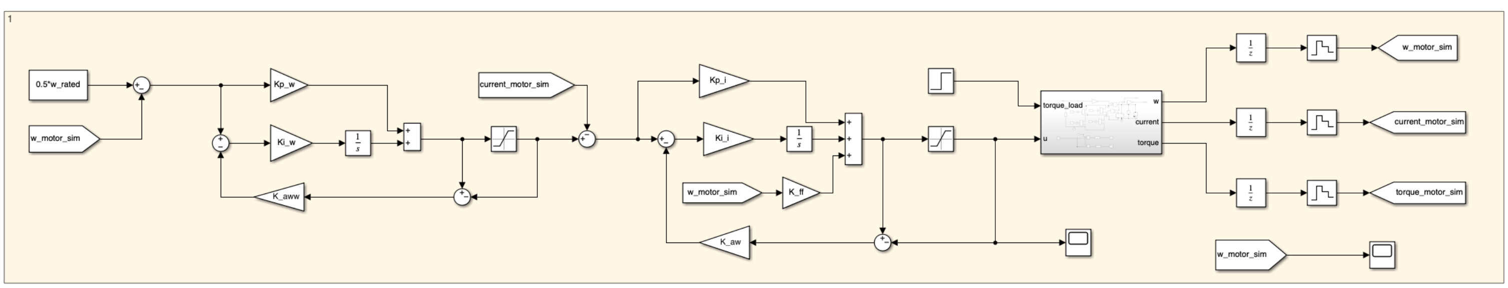
This section computes the main steady-state quantities of the motor, such as rated angular speed, starting torque, rated current, and starting current. These parameters characterize the operational limits and are essential for controller tuning.

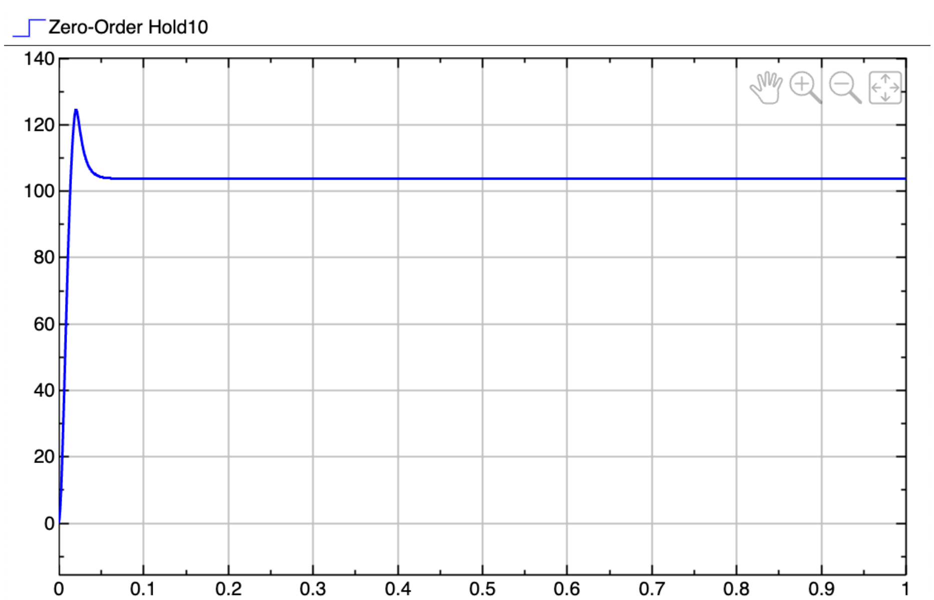
Current Controller Design

The current control loop is tuned for a fast, aperiodic (exponential) response. The electrical time constant is used to calculate the proportional and integral gains that ensure a stable, high-bandwidth current control.

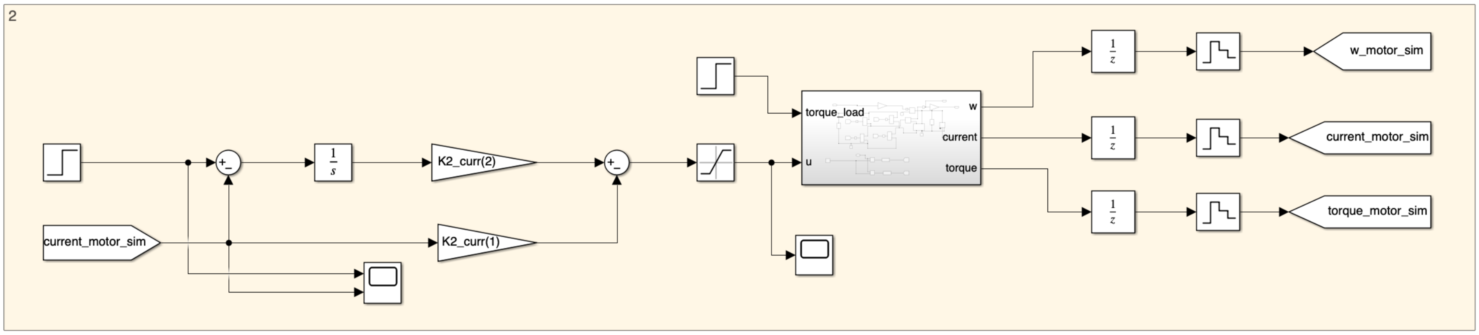
Speed Controller Design

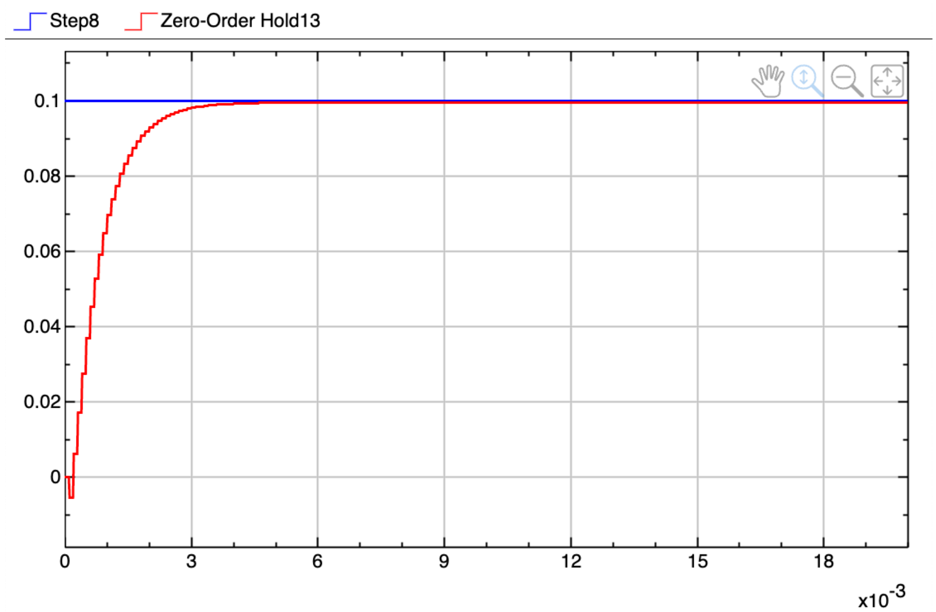
The speed control loop is tuned using the magnitude optimum criterion. Its bandwidth is set lower than the current loop (typically by a factor of five) to ensure a proper cascade structure and smooth torque response.



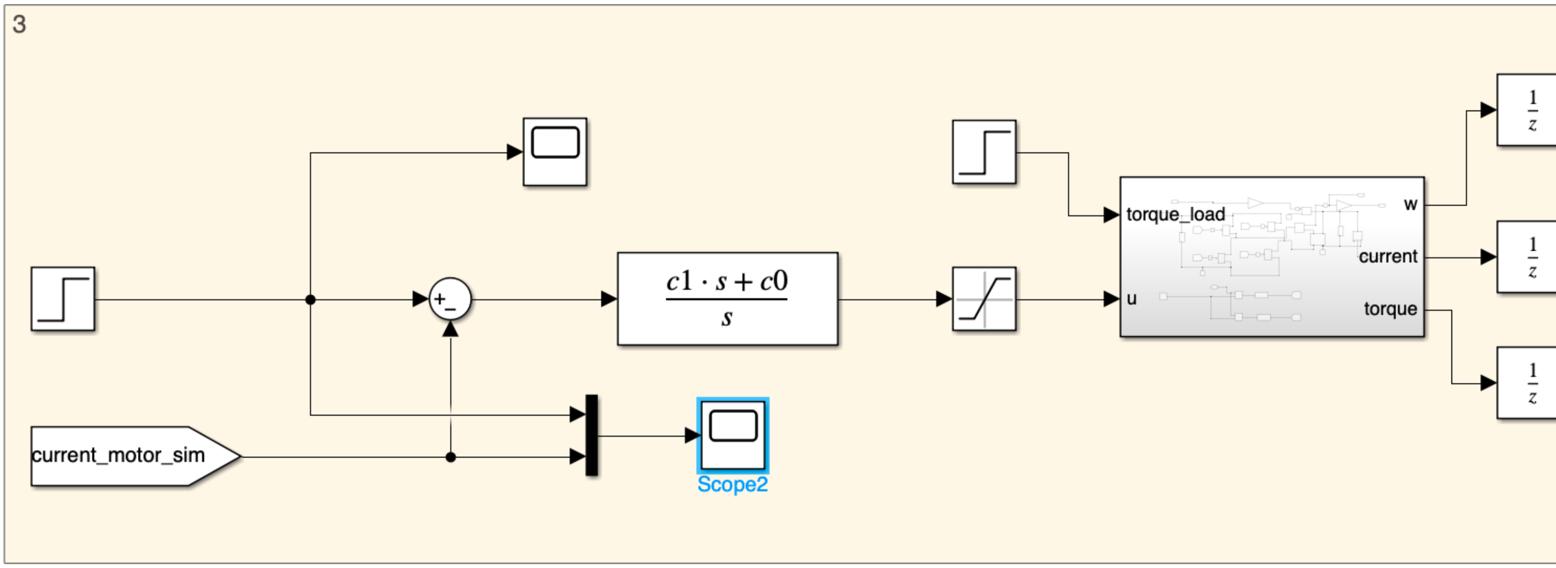


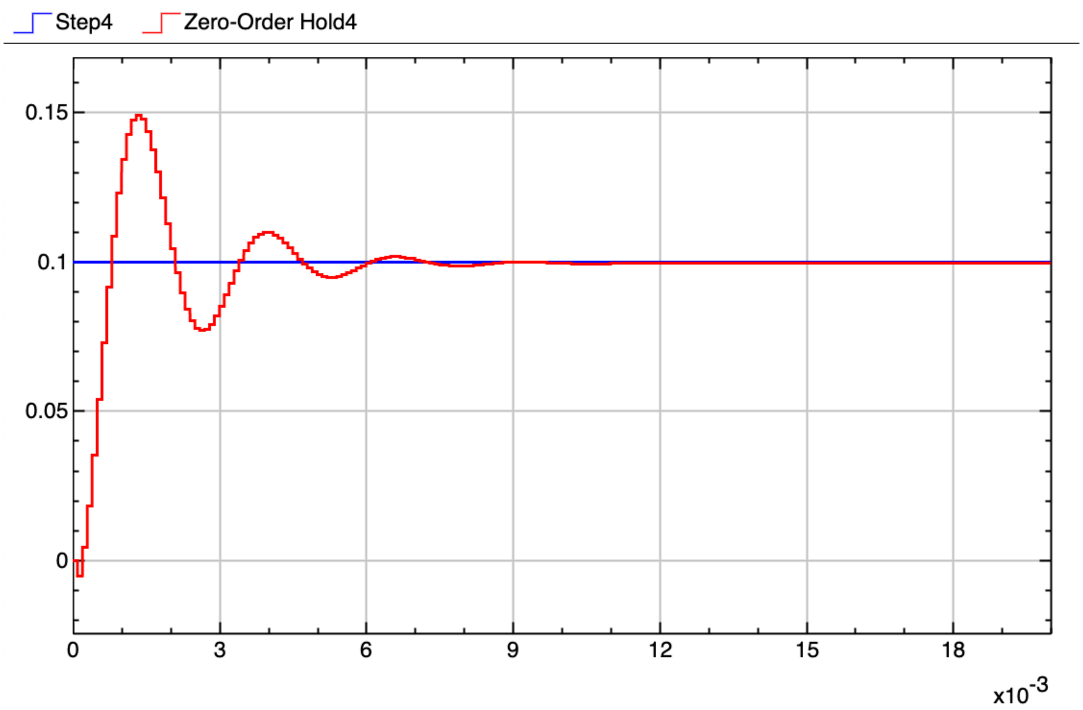
1) Current controller. Full-state feedback control with internal model





2) Current controller. Polynomial controller





3) Speed controller without current loop. Full-state feedback control with internal model

Speed Controller with Internal Model

This section designs a **full-state feedback controller with an internal model** for the DC motor speed loop.

Unlike the cascaded approach (current + speed loops), the control law here acts directly on the motor voltage.

The internal model ensures **zero steady-state error** to constant speed commands, while Bessel poles define a **smooth, non-oscillatory transient**.

Bandwidth and Model Parameters

The target **speed control bandwidth** is set lower than the current control bandwidth to achieve a slower, more stable dynamic response.

DC Motor State-Space Model

A simplified second-order model of the DC motor is formed, describing both electrical and mechanical dynamics.

Here, the current loop is not considered explicitly — voltage directly drives the armature circuit.

Reference (Internal) Model

An integrator-based reference model is added to guarantee zero steady-state error for a constant speed reference.

This model introduces two additional integrator states.

Augmented (Combined) System

The DC motor model and the reference model are **combined** into an augmented system that includes both the plant dynamics and the internal model.

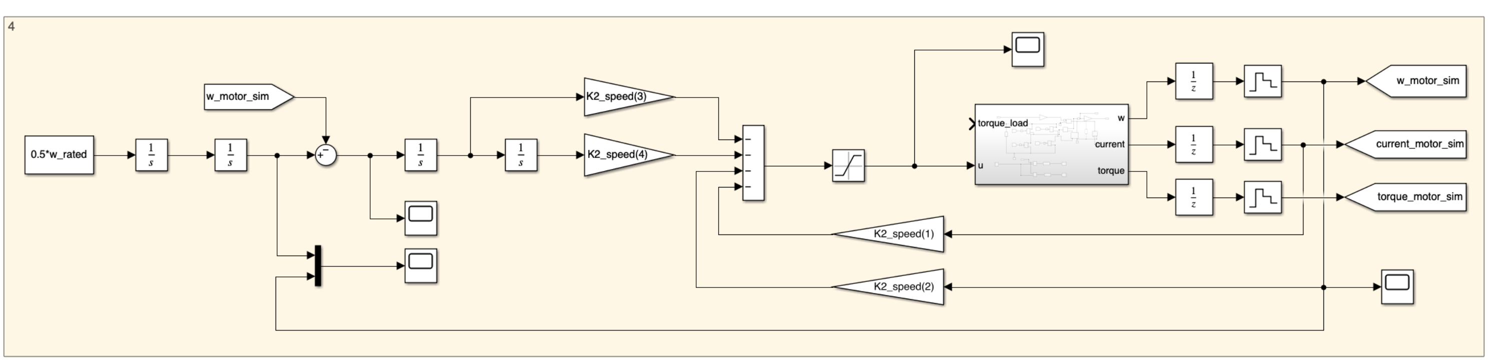
This unified model is used for full-state feedback gain calculation.

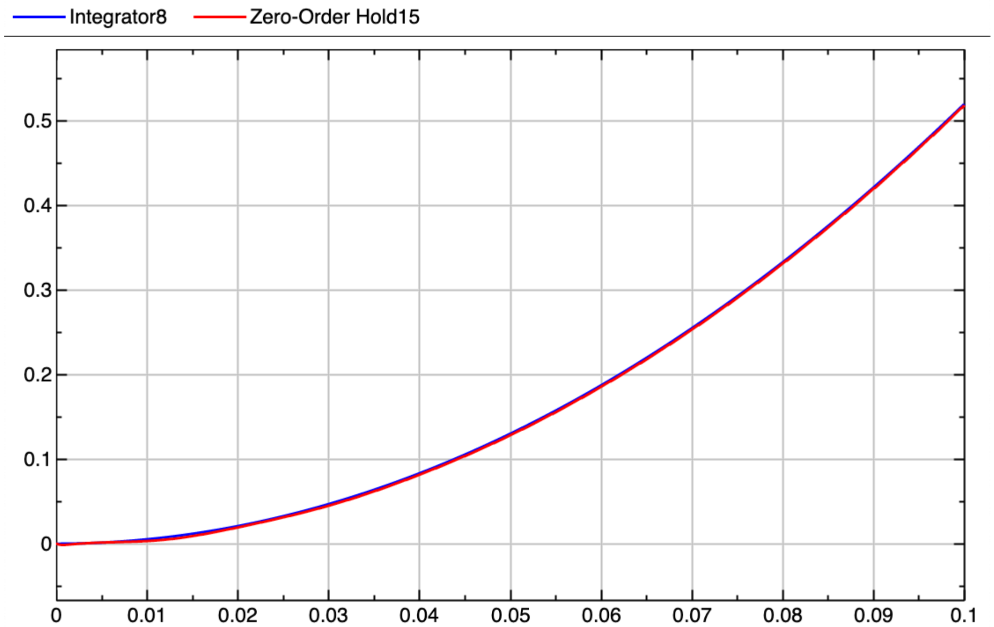
Pole Placement with Bessel Distribution

The desired closed-loop poles (eigenvalues) are determined using the **Bessel polynomial** corresponding to the chosen bandwidth `wsc`.

These poles ensure a smooth transient and high stability margins.

The `place()` function computes the feedback matrix `K2_speed` to assign these poles to the augmented system.





4) Speed controller with current loop. Polynomial controller

The desired speed-loop bandwidth `wsc` is selected higher than in the previous design (half of the current-loop bandwidth) to improve dynamic performance while maintaining stability.

Auxiliary coefficients `Tt`, `K1`, and `K2` link the electrical and mechanical subsystems:

Desired Closed-Loop Dynamics via Bessel Polynomial

A **4th-order Bessel polynomial** is used to specify the ideal transient of the closed-loop system.

This ensures an aperiodic, well-damped speed response with minimal overshoot:

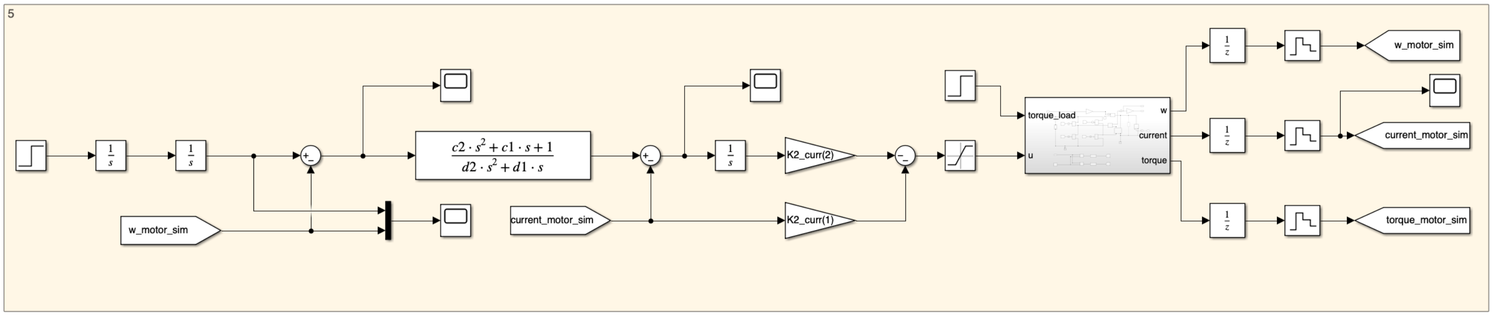
Computation of Controller Coefficients

The normalized coefficients are then transformed into the controller parameters that define its transfer-function structure.

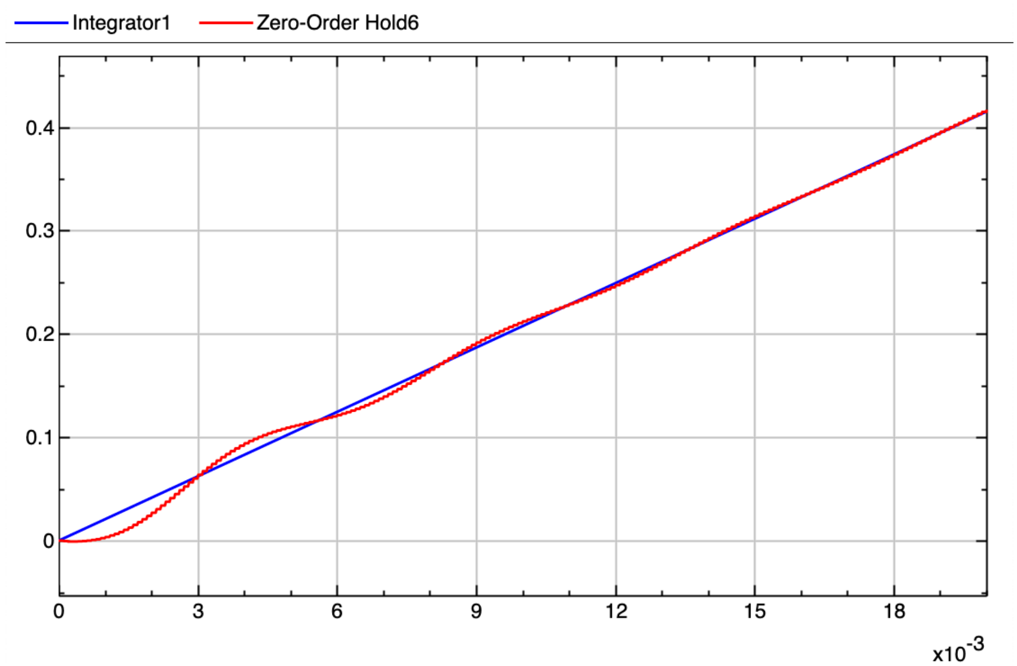
- `c1`, `c2` → numerator (zero) coefficients shaping transient response
- `d1`, `d2` → denominator (pole) coefficients governing damping and speed of regulation

This polynomial-based controller, combined with the fast inner current loop, provides precise speed regulation and robust disturbance rejection.

The Bessel-based coefficient selection guarantees a **non-oscillatory** transient and smooth torque behavior suitable for high-performance electric-drive applications.



5
w_motor_sim
current_motor_sim
K2_curr(2)
K2_curr(1)
torque_load
u
w
current
torque
w_motor_sim
current_motor_sim
torque_motor_sim



Integrator1
Zero-Order Hold6
0.4
0.3
0.2
0.1
0
0
3
6
9
12
15
18
x10^-3