# math

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## Motor Electrical Characterization

The motor is modeled electrically as a series resistance and inductance,

$$R_{\mathrm{eq}} = R_{\mathrm{motor}} + R_{\mathrm{sense}}, \quad L = L_{\mathrm{motor}}.$$

### Motor Resistance Measurement

A DC voltage of 5 V was applied to the motor in series with a known sense resistor $R_{\mathrm{sense}}$. The voltage drop across the sense resistor was measured as $V_{\mathrm{drop}}$.

The stall current is given by

$$i_{\mathrm{stall}} = \frac{V_{\mathrm{drop}}}{R_{\mathrm{sense}}}.$$

The voltage across the motor resistance is

$$V_{\mathrm{motor}} = 5\ \mathrm{V} - V_{\mathrm{drop}}.$$

Thus, the motor resistance is

$$R_{\mathrm{motor}} = \frac{V_{\mathrm{motor}}}{i_{\mathrm{stall}}} = \frac{5 - V_{\mathrm{drop}}}{V_{\mathrm{drop}}/R_{\mathrm{sense}}}.$$

Using the measured values

$$V_{\mathrm{drop}} = 2.26\ \mathrm{V},$$

the motor resistance was calculated to be

$$R_{\mathrm{motor}} \approx 12.45\ \Omega.$$

### Electrical Time Constant Measurement

The motor was driven with a step voltage using PWM, and the current rise was observed on an oscilloscope. For a first-order $R{-}L$ system, the current reaches 63.2% of its steady-state value at one time constant:

$$i(\tau) = 0.632\, i_{\mathrm{final}}.$$

From the oscilloscope trace, the time constant was measured as

$$\tau \approx 225\ \mu\text{s}.$$

The electrical time constant of the motor is given by

$$\tau = \frac{L_{\text{motor}}}{R_{\text{motor}} + R_{\text{sense}}}.$$

Solving for the motor inductance,

$$L_{\text{motor}} = \tau \left(R_{\text{motor}} + R_{\text{sense}}\right).$$

Using the measured values, the motor inductance was estimated to be

$$L_{\text{motor}} \approx 5.05\ \text{mH}.$$

**Motor-Only Electrical Time Constant**

After estimating the motor inductance, the motor-only electrical time constant is

$$\tau_{\text{motor}} = \frac{L_{\text{motor}}}{R_{\text{motor}}} = \frac{5.05 \times 10^{-3}}{12.45}\ \text{s} = 4.06 \times 10^{-4}\ \text{s} \approx 0.406\ \text{ms} \approx 406\ \mu\text{s}.$$