ECE 360 Prelab 1

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Question 4.2.1

Noting motor parameters from Appendix 1, and with constant current equaling zero, we can simplify equation (2) from the manual and solve for ω_{max}:

$$\begin{aligned}
u_m(t) &= R_m i_m(t) + L_m \dot{i}_m(t) + u_e(t) \\
u_{max} &= k_m \omega_{max} \\
\omega_{max} &= \frac{u_{max}}{k_m} \\
&= \frac{15 \text{ V}}{0.0502 \text{ Nm/A}} \\
&= 298.8 \text{ s}^{-1}
\end{aligned}$$

Question 4.2.2

With zero rotation, we simplify (2):

$$\begin{aligned}
u_{max} &= R_m i_{max} \\
i_{max} &= \frac{u_{max}}{R_m} \\
&= \frac{15 \text{ V}}{10.6 \ \Omega} \\
&= 1.42 \text{ A}
\end{aligned}$$

Question 4.2.3

With input constant voltage and measured constant current, we simplify (2):

$$R_m = \frac{u_m}{i_m}$$

Question 4.2.4

With constant current, we simplify (2):

$$k_m = \frac{u_m - R_m i_m}{\omega_m}$$

Question 4.3.1

From the LT of (5), we find

$$sJ_{eq}\Omega_m(s) = k_m I_m(s)$$
$$I_m(s) = \frac{sJ_{eq}\Omega_m(s)}{k_m}$$

Then, we solve for the transfer function:

$$\begin{aligned}
G(s) &= \frac{\Omega_m(s)}{R_m I_m(s) + sL_m I_m(s) + k_m \Omega_m(s)} \\
&= \frac{\Omega_m(s)}{R_m\left(\frac{sJ_{eq}\Omega_m(s)}{k_m}\right) + sL_m\left(\frac{sJ_{eq}\Omega_m(s)}{k_m}\right) + k_m\Omega_m(s)} \\
&= \frac{\Omega(s)}{\Omega(s)\left(\left(\frac{L_m J_{eq}}{k_m}\right)s^2 + \left(\frac{R_m J_{eq}}{k_m}\right)s + k_m\right)} \\
&= \frac{1}{\left(\frac{L_m J_{eq}}{k_m}\right)s^2 + \left(\frac{R_m J_{eq}}{k_m}\right)s + k_m}
\end{aligned}$$

Question 4.3.2

Considering L_m to be much smaller than R_m, we approximate:

$$G(s) \approx \frac{1}{\left(\frac{R_m J_{eq}}{k_m}\right)s + k_m}$$

Question 4.3.3

Rearranging the equation from the previous question, we obtain

$$\begin{aligned}
G(s) &\approx \frac{\frac{k_m}{R_m J_{eq}}}{s + \frac{k_m^2}{R_m J_{eq}}} \\
&\approx \frac{214.30}{s + 10.76}
\end{aligned}$$

Question 4.3.4

Rearranging the previous equation in a different way, we obtain

$$\begin{aligned}
G(s) &\approx \frac{\frac{1}{k_m}}{\left(\frac{R_m J_{eq}}{k_m^2}\right)s + 1} \\
&\approx \frac{19.92}{0.093s + 1}
\end{aligned}$$

Question 4.3.5

From the LT of (2), assuming $u_m(t) = 0$ and $L_m = 0$, we obtain

$$\begin{aligned} 0 &= R_m I_m(s) + k_m \Omega_m(s) \\ I_m(s) &= \frac{-k_m \Omega_m(s)}{R_m} \end{aligned}$$

Then, from the LT of (5), we obtain $T_d(s)$:

$$\begin{aligned} sJ_{eq}\Omega_m(s) &= k_m I_m(s) + T_d(s) \\ T_d(s) &= sJ_{eq}\Omega_m(s) - k_m I_m(s) \end{aligned}$$

Combining, we obtain the disturbance transfer function:

$$\begin{aligned} G_d(s) &= \frac{\Omega_m(s)}{sJ_{eq}\Omega_m(s) + \frac{k_m^2 \Omega_m(s)}{R_m}} \\ &= \frac{1}{sJ_{eq} + \frac{k_m^2}{R_m}} \end{aligned}$$

Question 4.3.6

Noting that $G(s) = \frac{k_m}{R_m} G_d(s)$, the block diagram is shown in figure 1.