Solutions

2.1

- Lag $= \omega_c T/2$: at 500 Hz, 29.8×0.001 rad $=$ **1.71**°; at 100 Hz, 29.8×0.005 rad $=$ **8.54**°.
- Margins: $PM' = PM - \omega_c T/2 = 65.2 - 1.7 =$ **63.5**° and $65.2 - 8.5 =$ **56.7**°.

2.2

- $|1200 - 1000| =$ **200** Hz; $|700 - 1000| =$ **300** Hz: both fold below the 500 Hz Nyquist frequency, indistinguishable from real signals.

2.3

- $1000 \times 4 \times 30 =$ **120 000** counts per valve turn.
- $360/120\,000 =$ **0.003**° per count.

3.1

- (a) One count per sample: $2\pi/4000/0.001 =$ **1.571** rad/s at the motor.
- The speed estimate jumps in steps of 1.57 rad/s, so $K_d\dot{e}$ would inject that noise: leave D out or filter heavily.
- (b) $\omega_c \tau_d = 29.8 \times 0.0005 = 0.0149$ rad $=$ **0.85**°.
- (c) $I_1 = I_0 + \frac{T}{2}(e_1 + e_0) = 0.001 \times 0.18 =$ **0.00018**.
- $I_2 = I_1 + \frac{T}{2}(e_2 + e_1) = 0.00018 + 0.001 \times 0.14 =$ **0.00032**.
- $u_2 = K_p e_2 + K_i I_2 = 79.4 \times 0.06 + 365.2 \times 0.00032 =$ **4.881** V.

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