#1

Golden Rules:

→ $V_- = V_+$

→ $I_- = I_+$

provided that:

→ OPamp is operating within spec

→ standard negative feedback

#2

<table>
<thead>
<tr>
<th>Input</th>
<th>Freq</th>
<th>mag</th>
<th>Desired gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sig</td>
<td>1-2 Hz</td>
<td></td>
<td>x10</td>
</tr>
<tr>
<td>noise</td>
<td>200 Hz</td>
<td>0.3 V</td>
<td>x1/3</td>
</tr>
</tbody>
</table>

Desired Circuit:

Input $\rightarrow$ LP $\rightarrow$ Sig $\rightarrow$ Gain $\rightarrow$ (Sig · 10) $\rightarrow$ (Noise · 1/3)

Low Pass:

$$\frac{R}{1 + j\omega C}$$

$$\left| \frac{V_{out}}{V_{in}} \right| = \left| \frac{1}{1 + j\omega RC} \right| = \frac{1}{\sqrt{1 + (\omega RC)^2}}$$

Hence, we want

$$\frac{1}{\sqrt{1 + (\omega RC)^2}} \geq \frac{1}{900}$$

@ 200 Hz, $\omega = 200 \cdot 2\pi = 400\pi$, $(400\pi RC)^2 > 899$

$$RC > 0.0238$$

Let $C = 1 \; \mu F$, then $R = 23860 \; \Omega$

must round up! Standard value is $R = 24K \Omega$
Low Pass: \[
\frac{24K_2}{-} \frac{1}{1\text{M}_F} = 1MF
\]

but what happened to our signal at 2Hz?

\[
\left| \frac{\text{V}_{\text{out}}}{\text{V}_{\text{in}}} \right| = \frac{1}{\sqrt{1+(\omega R C)^2}} \quad \omega = 2\cdot2\pi
\]

= 0.916 gain on our signal

Gain stage:

\[\text{Sig} \rightarrow [\text{LP}] \rightarrow 0.916 \cdot \text{Sig} \rightarrow [\text{XII}] \rightarrow 10 \cdot \text{Sig}\]

note that we now need a gain of 11.

\[
\text{V}_{\text{In}} \rightarrow \rightarrow \text{V}_{\text{out}}
\]

\[
11 = \frac{\text{V}_{\text{out}}}{\text{V}_{\text{in}}} = 1 + \frac{R_2}{R_1}
\]

Let \(R_2 = 10\text{ K}\)

\(R_1 = 1\text{ K}\)

Final Design

\[\text{Input} \rightarrow [\text{LP}] \rightarrow \frac{\text{Sig} \cdot 0.91}{\text{Noise} \cdot 10^2} \rightarrow [\text{Gain} \times 11] = \frac{\text{Sig} \cdot 10}{\text{Noise} \cdot \sqrt{3}}\]
#3 $V_{cc} = 5\, V$

Key to the problem:

The data sheet specifies $V_{oh} > 3.9\, V$ guaranteed for $V_{cc} = 4.5\, V$ @ 4 mA load.

For $V_{oh} = 3.9\, V$ and $V_f = 1.5\, V$, $V_R = 3.95 - 1.5 = 2.45\, V$

\[ R = \frac{V_I}{I} = \frac{2.45\, V}{4\, mA} = 625\, \Omega \]

Possible resistor values are 620 and 680.

In this case, though $V_{oh}$ is guaranteed $> 3.9\, V$, it is 4.2\, V typ, $V_f$ we expect to be in general be higher so $R$ should be sized up.

For $R = 680\, \Omega$ and $V_{oh} = 4.2\, V$, $V_f = 1.49\, V$.

#4

Let state be the 3 sensor inputs. State = LCR ex. 011 Left + sensor off, center + right sensor on

Arrow is done in response to sensor state by controlling the motors. We use the 2 motor speeds for the following activations:

Hard Left, Soft Left, Forward, Backward, Soft Right, Hard Right
6. \( T_{\text{stall}} = 28 \text{ in. oz} \quad w_{\text{NL}} = 1160 \text{ RPM} \)

\[ R = 2 \Omega \]

a. \( V_{\text{stall}} = 12 \text{ V} \quad R = 2 \Omega \Rightarrow I_{\text{stall}} = 6 \text{ A} \)

\[ T = K_t A = 7 \cdot 28 \text{ in. oz} = K_e \cdot 6 \text{ A} \Rightarrow K_t = 11.6 \frac{\text{oz in}}{\text{A}} \]

b. \( I_{\text{stall}} = 6 \text{ A from part a) } \)

Parts c, d, e. desired \( V = 15 \text{ V}, T = 10 \text{ in. oz}, w = 500 \text{ RPM} \)

C. To meet speed, what current is required?

\[ I = I \cdot R + K_e \cdot w \Rightarrow 15 = I \cdot 2 + K_e \cdot 500 \]

\[ K_e = \frac{V}{w_{\text{NL}}} = \frac{12 \Omega}{1160 \text{ RPM}} \quad \text{note that } V = 12 \text{ not } 15 \text{ because } \text{wNL was measured @ 12V}. \]

\[ I = 4.9 \text{ A } \text{ at } 15 \text{ V } = 500 \text{ RPM} \]

\[ T = K_e I = 4.6 \cdot 4.9 = 23 \text{ in oz} > 10 \text{ in oz}. \]

Hence at 4.9 A, we can achieve the required Torque @ 500 RPM.

D. we desire exactly \( T = 10 \text{ in. oz}. \)

\[ I = K_t I = 7 \cdot 10 \text{ in oz} = 4.6 \frac{\text{in oz}}{\text{A}} \Rightarrow I = 2.14 \text{ A} \]

\[ V = I \cdot R + K_e \cdot w = 2.14 \text{ A} \cdot 2 \Omega + \frac{12 \text{ V}}{1160 \text{ RPM}} \cdot 500 \text{ RPM} \]

\[ \text{Duty Cycle} = \frac{2.14 \text{ A}}{1.5} \]

\[ e. I = 2.14 \text{ A from part d}. \]