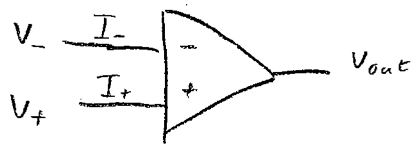
Practice Midterm Solutions

#1



Golden Rules:

→ $V_- = V_+$

→ $I_- = I_+$

<u>provided that:</u>

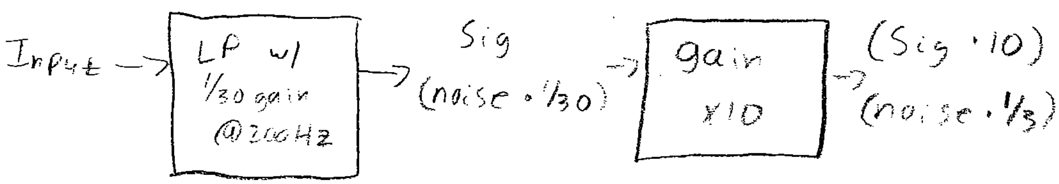
→ OPamp is operating within spec

→ standard negative feedback

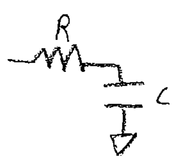
#2

Input	Freq	mag	Desired gain
Sig	1-2 Hz		x10
noise	200 Hz	0.3v	x 1/3

Desired circuit:



<u>Low Pass:</u>



Design gain @ 200Hz to be 1/30

$$\left|\frac{V_{out}}{V_{in}}\right| < 1/30$$

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

Hence, we want $\frac{1}{1+(\omega RC)^2} < 1/900 \Rightarrow (\omega RC)^2 > 899$

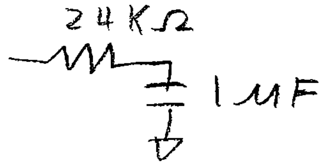
@ 200 Hz, $\omega = 200 \cdot 2\pi = 400\pi$ $\therefore (400\pi RC)^2 > 899$

$\Rightarrow RC > 0.0238$

Let $C = 0.1 \mu F$, then $R = 23860\ \Omega$

<u>must round up!</u> Standard value is $R = 24K\Omega$

∴ Low Pass:



but what happened to our signal at 2Hz?

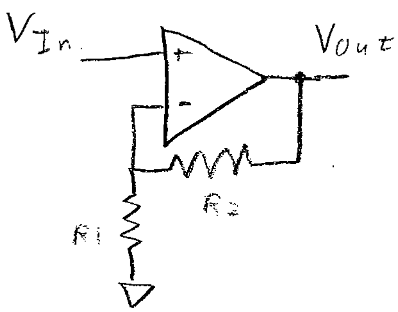
$$\left|\frac{V_{out}}{V_{in}}\right| = \frac{1}{\sqrt{1+(\omega RC)^2}} \qquad \omega = 2 \cdot 2\pi$$

$$= 0.916 \text{ gain on our signal}$$

Gain stage:

sig → [LP] → 0.916·Sig → [x11] → 10x Sig

note that we now need a gain of 11.



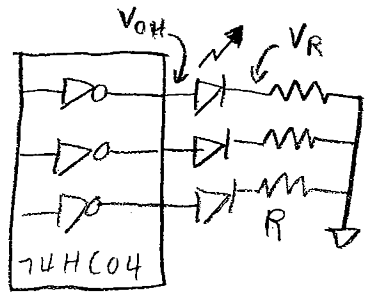
$$11 = \frac{V_{out}}{V_{In}} = 1 + \frac{R_2}{R_1}$$

Let $R_2 = 10K$
$R_1 = 1K$

Final Design

Input $\frac{Sig}{Noise}$ → [LP Filter] → $\frac{Sig \cdot 0.91}{Noise \cdot 1/30.2}$ → [gain x11] = $\frac{Sig \cdot 10}{Noise \cdot 1/3}$

#3 $V_{CC} = 5v$



Key to the problem:

The data sheet specifies $V_{OH} > 3.98v$ guaranteed for $V_{CC} = 4.5v$ @ 4mA load.

For $V_{OH} = 3.98$ and $V_f = 1.5v$, $V_R = 3.95 - 1.5 = 2.45v$

$$\therefore R = V/I = \frac{2.45v}{4mA} = 625\,\Omega$$

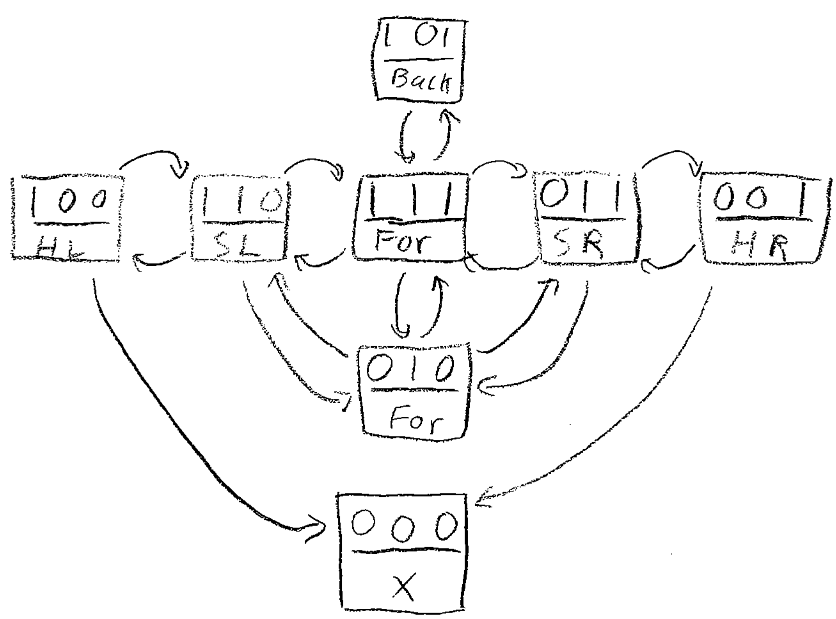
Possible resistor values are 620 and 680

In this case, though V_{OH} is guaranteed $> 3.98v$, it is 4.2v typ. $\therefore$ we expect it to in general be higher so R should be sized up.
For $R = 680\,\Omega$ and $V_{OH} = 4.2v$, $V_f = 1.48v$.

#4

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

actuation is done in response to sensor state by controlling the motors. We use the 2 motor speeds for the following actuations, Hard Left, Soft Left, Forward, Backward, Soft Right, Hard Right



6 $T_{stall} = 28\,in.oz$ $\omega_{NL} = 1160\,RPM$

$R = 2\,\Omega$

a. $V_{stall} = 12V$, $R = 2\Omega \Rightarrow I_{stall} = 6A$

$T = K_t A \Rightarrow 28\,inoz = K_t \cdot 6A \Rightarrow K_t = 4.6\,\frac{oz\,in}{A}$

b. $I_{stall} = 6A$ from part a)

parts c, d + e desired $V = 15v$, $T = 10\,inoz$, $\omega = 500\,RPM$

c. To meet speed, what current is required?

$V = I \cdot R + K_e \cdot \omega \Rightarrow 15 = I \cdot 2 + K_e \cdot 500$

$K_e = \frac{V}{\omega_{NL}} = \frac{12v}{1160rpm}$ note that V = 12 not 15 because ω_{NL} was measured @ 12V.

$\therefore I = 4.9A$ @ 15v $\Rightarrow$ 500 RPM

$T = K_t I = 4.6 \cdot 4.9 = 23\,inoz > 10\,inoz$

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

D. we desire exactly $T = 10\,inoz$.

$T = K_t \cdot I \Rightarrow 10\,inoz = 4.6\,\frac{inoz}{A} \cdot I \Rightarrow I = 2.14A$

$V = I \cdot R + K_e \cdot \omega = 2.14A \cdot 2\Omega + \frac{12v}{1160\,RPM} \cdot 500\,RPM$

$= 9.456\,V$

Duty Cycle $= \frac{9.456}{15}$

e. $I = 2.14\,A$ from part d.