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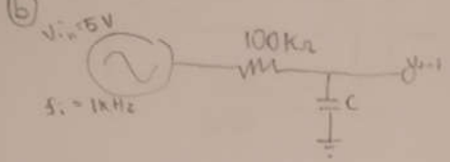
# Homework 2

# Question 1

(a) $C = \dfrac{\varepsilon_r \varepsilon_0 \cdot \text{area}}{d} = \dfrac{(20)(8.854 \times 10^{-12}\ F/m)(0.01)}{0.001} \boxed{= 1.77nF}$

(b)




$f_c = \dfrac{1}{2\pi RC} = 899.8 Hz \approx 900 Hz$

$R_c = \dfrac{1}{2\pi f_i C} = 89.9 k\Omega \approx 90 k\Omega$

$V_{out}(1kHz) = V_{in} \cdot \dfrac{R_c}{\sqrt{R^2 + R_c^2}} \boxed{= 3.718V}$

(c) $X(w) = 1 \times 10^{-3} m - 0.004 w$

$X(0) = 0.001$

$X(70kg) = 1 \times 10^{-3} m - 0.004(70) = -0.279$

$C(70kg) = C \cdot \dfrac{X(0)}{X(70kg)} = 1.77nF \cdot \dfrac{0.001}{-0.279} = -6.344 pF$

$R_c(70kg) = \dfrac{1}{2\pi f_i C(70)} = 25.01 M\Omega$

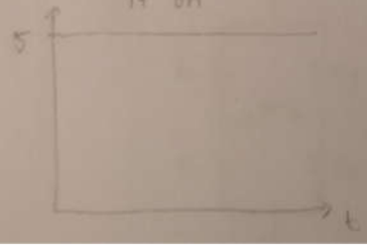
$V_{out}(1kHz, 70kg) = 5_V \cdot \dfrac{25M}{\sqrt{100k^2 + 25M^2}} \approx 5V$

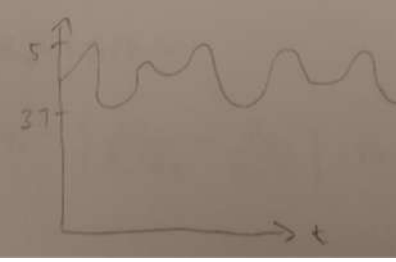
range : [3.718 , 5]

(d) If burglar is on the mat but not still, as long as one foot is on the mat and the other in air / on mat, it should still be 78kg

If burglar shuffling on / off the its going to flicker inbetween 3.718 & 5

if on



## Question 2:

$N = 1\,kg\text{-}m/s^2$

$R_o = 1K\Omega$ $\quad GF = 3$ , $E = 73.1\,GPa$ , $R_w = 1k\Omega$

$= 7310000\,N/cm^2$


$L_o = 10cm$

$t = 2cm$

$w = 4cm$

$$\varepsilon = \frac{4LF}{Ewt^2}$$

$$GF = \frac{\Delta R / R}{\varepsilon}$$

(a)

$W_L = 1kg \Rightarrow F = 1000 \cdot 9.8 = 9800N$

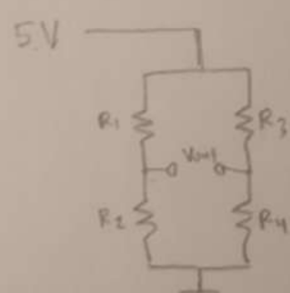
$$\varepsilon = \frac{4(10cm)(9800N)}{(7.31\times10^6\,N/cm^2)(4cm)(2cm)^2} = \frac{\cancel{4}(10)(9800)}{(7.31\times10^6 \cdot \frac{1}{cm^2})(\cancel{4})(4cm^2)}$$

$= 3.35\times10^{-3}$

$$GF = \frac{\frac{R_L - R_o}{R_o}}{\varepsilon} \Rightarrow GF = \frac{R_L - R_o}{\varepsilon \cdot R_o} \Rightarrow R_L = (GF\cdot\varepsilon\cdot R_o) + R_o$$

$$R_L = (3)(3.35\times10^{-3})(1\times10^3\Omega) + (1\times10^3\Omega) = 1.01k\Omega$$

(b)




assuming $R_1 = R_2 = R_3 = 1k\Omega$

$R_4 = 1.01k\Omega$

$$V_o = \left[\frac{R_4}{R_3+R_4} - \frac{R_2}{R_1+2}\right]\cdot V_{in}$$

## Question 3

ⓐ $f_c = 100Hz$ , $\Delta T = 0$

Noise = N

$N_o(@ f_c) = 600$

$N_n(@ f_c) = 600 \cdot 0.707 = 424.2$

$N_n(@ 1kHz) \approx 300$

ⓑ $f_c = 1Hz$

$N_o(f_c) \approx 1200$ assuming slope $\approx -\dfrac{1200 - 800}{10 - 1} = -\dfrac{400}{9}$

$N_n(@ f_c) = 848.4$

## Question 4

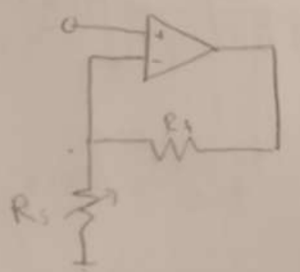
$$R = (1k\Omega)\left[1 + \frac{F}{200N}\right]$$

(a) $R_0 = 1k\Omega$ , $R_{50} = 1.25k\Omega$

Going to use $V_{in} = 5V$

Plan is to make a circuit with sensor and get some range of $V_{out_1} = V_x$ then map that range using some bias and scaling to $V_{out}$ range $0-4V$.

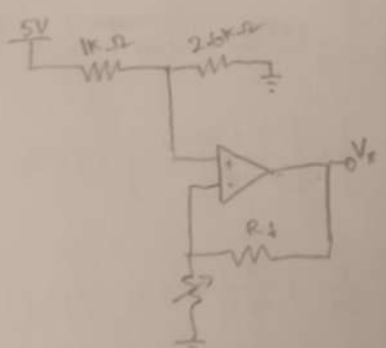
Assuming ideal op-amps and 


if $R_f$ is $1000\Omega$ ,

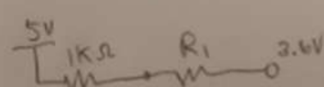
the gain from this amplifier ranges from $A \Rightarrow [1.8, 2]$

Gonna input 2V by adding voltage divider to $V_{in}$

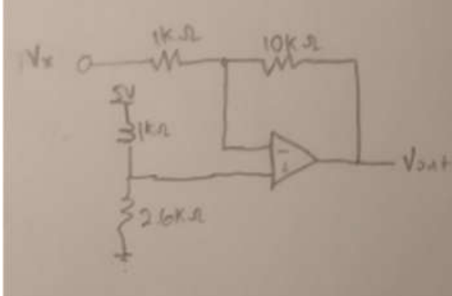



The range of $V_x$ is now $[1.8\cdot 2, 2\cdot 2]$
$= [3.6, 4]$

to create a bias of 3.6V,




I'm going to use only standard resistors so choosing $R_1 = 2.6k\Omega$ gets roughly 3.6V

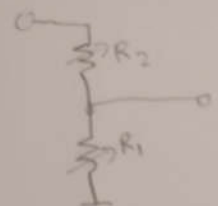



Here, if $V_x = 3.6V$ , $V_{out} \approx 3.8V$
if $V_x = 4.0V$ , $V_{out} = 0V$

if $R_1$ from earlier was $2.666k\Omega$ ,
at $V_x$ 3.6V, $V_{out} = 4V$

Question 5

$R_1 = 1k\Omega \cdot \left[1 + \frac{F}{1kN}\right]$ , $R_2 = 1k\Omega\left[1 - \frac{F}{1kN}\right]$




Basic voltage divider formula:

$$V_{out} = V_{in} \cdot \frac{R_1}{R_2+R_1}$$

(a) $V_{out}(F) = V_{in}' \cdot R(F)$

$$R(F) = \frac{R_1(F)}{R_2(F)+R_1(F)} = \frac{[1000+F]}{[1000-\cancel{F}]+[1000+\cancel{F}]} = \frac{1000+F}{2000}$$

$$R(F) = \frac{1000+F}{2000}$$

$$V_{out}(F) = 5 \cdot R(F) = \frac{1000+F}{400}$$

(b) $f(x) = f(a) + \frac{f'(a)}{1!}(x-a)^1 + \frac{f''(a)}{2!}(x-a)^2$ , $x = F$ , $a = F_0$

$$f(F) = \left[\frac{1000+F}{400}\right] + \frac{\left[0+\frac{1}{400}\right]\left[F+F_0\right]}{2} + 0$$ , $F_0 = 0$ in neutral posi

$$f(F) = 2.5 + \frac{F}{400} + \frac{F}{800} = 2.5 + \frac{3F}{800}$$