Faculty of Engineering & Technology Electrical & Computer Engineering Department

Interfacing Techniques – ENCS4380

HW #2

Prepared by:

Maha Maher Mali 1200746

Instructor: Dr. Wasel Ghanem

Section: 1

Date: 8-12-2023

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Question 1

```
% Maha Mali 1200746
% System Parameters
m = 1;      % Mass of the sensor
b = 0.2;    % Damping coefficient
% Transfer Function
numerator = 1;
denominator = [m, b, 0];
sys = tf(numerator, denominator);
% Step Response
figure;
step(sys, 'r'); % Adds 'r' to specify red color
title('Step Response of Acceleration Sensor Model');

% Ramp Response
figure;
impulse(sys, 'r'); % Adds 'r' to specify red color
title('Impulse Response of Acceleration Sensor Model');
% Frequency Response
figure;
bode(sys, 'r'); % Adds 'r' to specify red color
title('Frequency Response of Acceleration Sensor Model');
```

Figure 1: Question 1 MATLAB Code

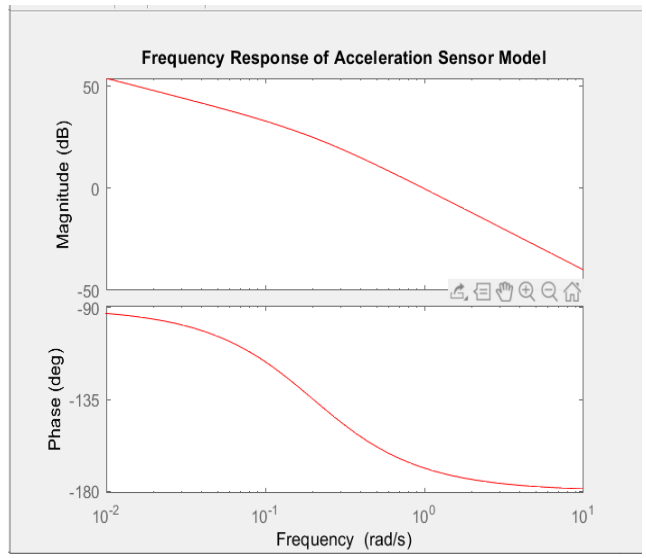


Figure 2:Freqancy Response

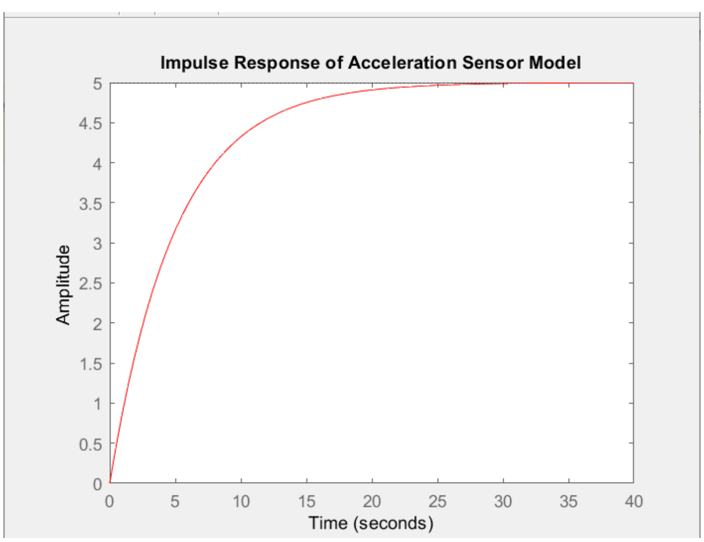


Figure 3:Impulse Response

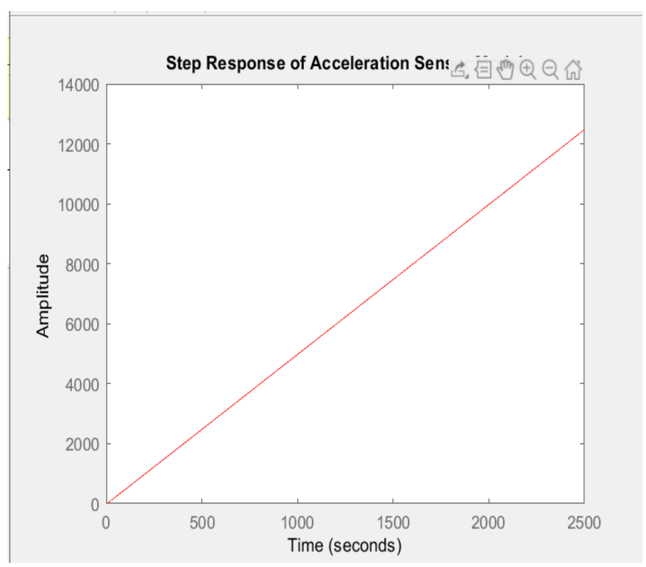


Figure 4:Step Response

- **The Effect Of B/M On the System Response:**

Unit step Response: if we increase the B/M accelerates damping yielding fast response, also high B/M may cause overshooting and oscillations. On the other hand, decreasing B/M slows damping resulting in a more gradual response, this can reduce overshoot, but response may be slower.

Ramp Response: if we increase the B/M values this will lead to faster response to ramps. On the other hand, lower B/M values this will result in a slower response with clear oscillations.

- **The Effect Of B/M On the Frequency Response:**

Bandwidth: if we increase the B/M values the system can respond to a wider range of frequencies. On the other hand, decreasing B/M values leads to a narrower bandwidth and the system has a more specific frequencies value.

Response Frequency: if we increase the B/M values the system is more affected to resonance at lower frequencies. On the other hand, lower B/M values the system is less open to resonance at higher frequencies.

Question 2

- **Accelerometer**

  - **Concept of Operation**: the accelerometer in smartphone measures the linear acceleration of the device. When at rest position in whatever orientation.

  - **Technology Used in Manufacturing: MEMS** (Micro – Electro -Mechanical Systems.

  - **Static and dynamic characteristics:** the static characteristics: sensitivity which is ratio of the output signal to applied acceleration, resolution which is the smallest detectable change in acceleration. The dynamic characteristics: bandwidth which is range of frequencies for accurate measurements, frequency response which is describe how well the accelerometer responds to change in acceleration over time.

  - **Simple interface**: using APIs.

- **Gyroscope**

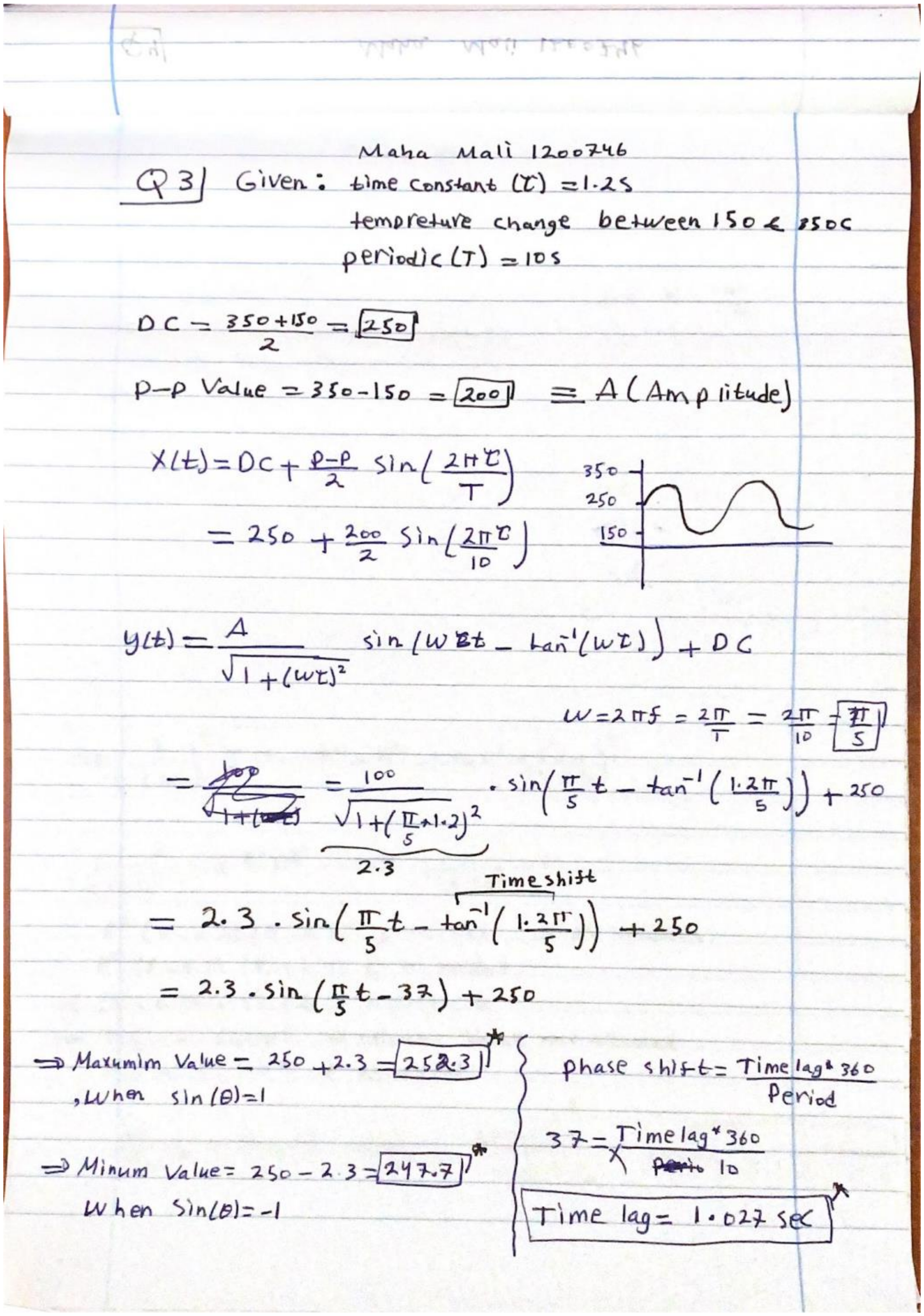
  - **Concept of Operation**: The gyroscope sensor is responsible for the autorotation of the screen and view on the screen whenever a phone is rotated.

  - **Technology Used in Manufacturing: MEMS** (Micro – Electro -Mechanical Systems.

  - **Static and dynamic characteristics:** the static characteristics: sensitivity and zero rate output which is the gyroscope output when there is no rotation. The dynamic characteristics: dynamic range the range of angular velocities that the gyroscope can accurately measure.

- **Finger print:** it can read and store biometric data of our fingers and can be used to unlock the phone. Also, it can use the capacitance of the finger to detect that the thing which touches the button is a humanly thing.

Question 3



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Q3 Given: time constant $(\tau) = 1.2s$

tempreture change between 150 & 350C

periodic $(T) = 10s$

$$DC = \frac{350+150}{2} = \boxed{250}$$

$$P\text{-}P \text{ Value} = 350-150 = \boxed{200} = A \text{ (Amplitude)}$$

$$X(t) = DC + \frac{P-P}{2}\sin\left(\frac{2\pi\tau}{T}\right)$$

$$= 250 + \frac{200}{2}\sin\left(\frac{2\pi\tau}{10}\right)$$

$$y(t) = \frac{A}{\sqrt{1+(\omega\tau)^2}}\sin\left(\omega t - \tan^{-1}(\omega\tau)\right) + DC$$

$$\omega = 2\pi f = \frac{2\pi}{T} = \frac{2\pi}{10} = \boxed{\frac{\pi}{5}}$$

$$= \underbrace{\frac{100}{\sqrt{1+\left(\frac{\pi}{5}\cdot 1.2\right)^2}}}_{2.3} \cdot \sin\left(\frac{\pi}{5}t - \tan^{-1}\left(\frac{1.2\pi}{5}\right)\right) + 250$$

$$= 2.3 \cdot \sin\left(\frac{\pi}{5}t - \overbrace{\tan^{-1}\left(\frac{1.2\pi}{5}\right)}^{\text{Time shift}}\right) + 250$$

$$= 2.3 \cdot \sin\left(\frac{\pi}{5}t - 37\right) + 250$$

$\Rightarrow$ Maxumim Value $= 250 + 2.3 = \boxed{252.3}$, When $\sin(\theta) = 1$

$\Rightarrow$ Minum Value $= 250 - 2.3 = \boxed{247.7}$, When $\sin(\theta) = -1$

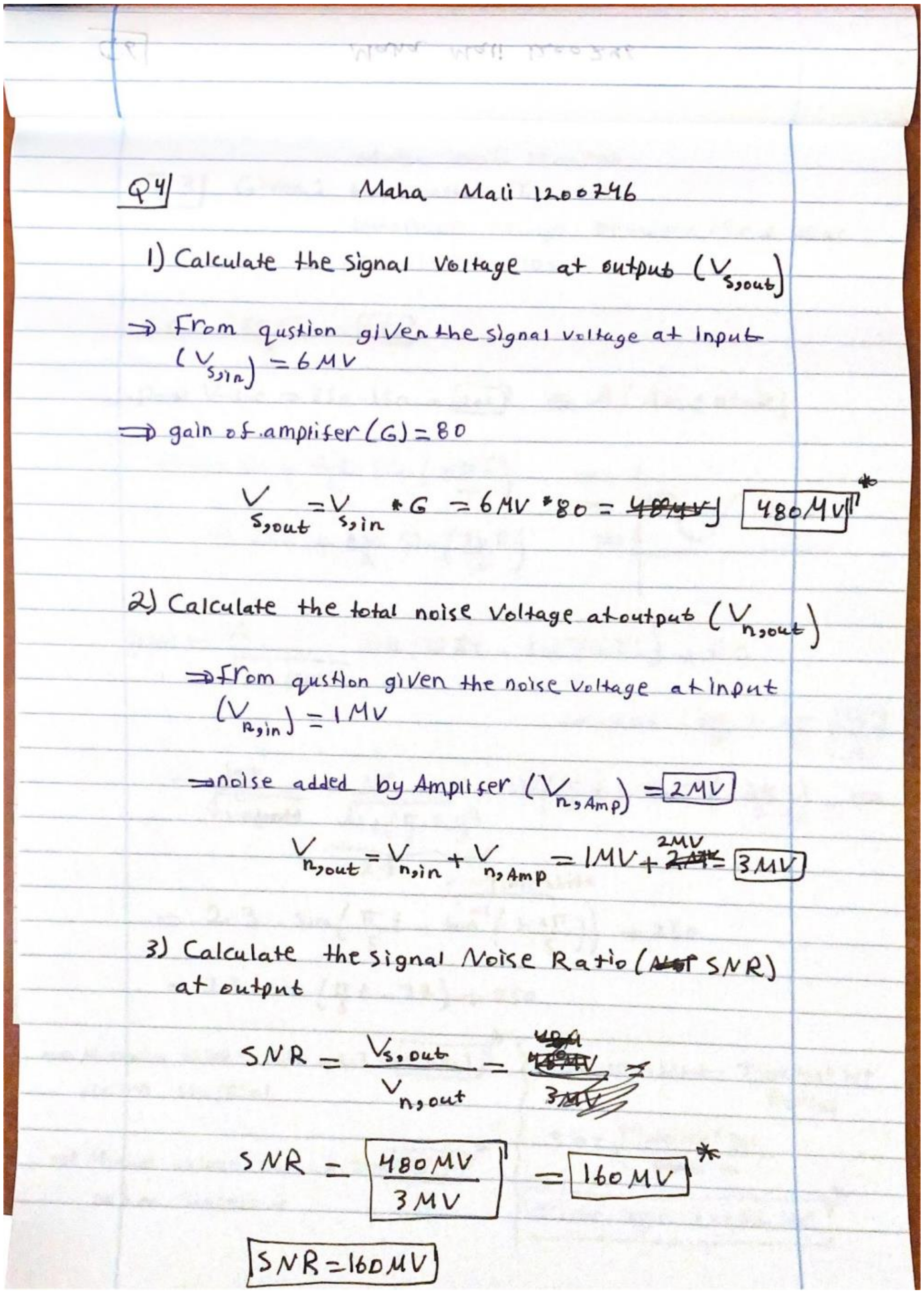
$$\text{phase shift} = \frac{\text{Time lag} * 360}{\text{Period}}$$

$$37 = \frac{\text{Time lag} * 360}{10}$$

$$\boxed{\text{Time lag} = 1.027 \text{ sec}}$$

Figure 5:Question 3 Solution

Question 4



Q4/ Maha Mali 1200746

1) Calculate the Signal Voltage at output ($V_{s,out}$)

⇒ From qustion given the signal voltage at input ($V_{s,in}$) = 6MV

⇒ gain of amplifer (G) = 80

$$V_{s,out} = V_{s,in} * G = 6MV * 80 = \cancel{480MV} \boxed{480MV}$$

2) Calculate the total noise Voltage at output ($V_{n,out}$)

⇒ From qustion given the noise voltage at input ($V_{n,in}$) = 1MV

⇒ noise added by Ampliser ($V_{n,Amp}$) = $\boxed{2MV}$

$$V_{n,out} = V_{n,in} + V_{n,Amp} = 1MV + \cancel{2MV}\;2MV = \boxed{3MV}$$

3) Calculate the signal Noise Ratio (~~Not~~ SNR) at output

$$SNR = \frac{V_{s,out}}{V_{n,out}} = \frac{\cancel{480MV}}{\cancel{3MV}}$$

$$SNR = \boxed{\frac{480MV}{3MV}} = \boxed{160MV}$$

$\boxed{SNR = 160MV}$

Figure 6:Question 4 Solution

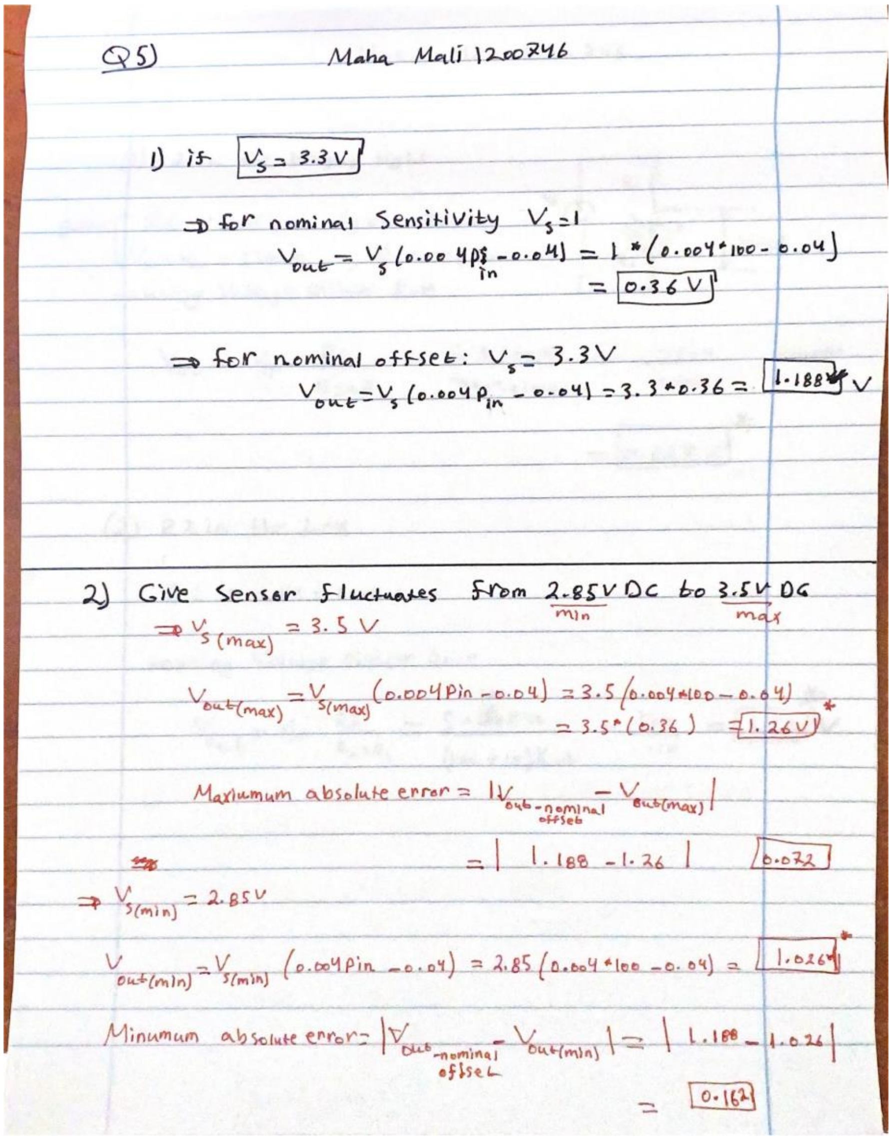
Question 5

The below equation given from question, also given $Vs = 3.3\ V$ and $Pin = 100$ kPa

$$Vout = Vs * (0.004 * Pin - 0.04)$$

Nominal sensitivity: This is the change in output voltage per unit change in pressure at the nominal supply voltage.

Nominal offset: This is the output voltage at zero pressure.



Q5) Maha Mali 1200746

1) if $\boxed{V_s = 3.3V}$

⇒ for nominal Sensitivity $V_s = 1$

$V_{out} = V_s(0.004P_{in} - 0.04) = 1*(0.004*100 - 0.04) = \boxed{0.36V}$

⇒ for nominal offset: $V_s = 3.3V$

$V_{out} = V_s(0.004P_{in} - 0.04) = 3.3*0.36 = \boxed{1.188}V$

2) Give Sensor fluctuates from $\underset{min}{2.85V}$ DC to $\underset{max}{3.5V}$ DC

⇒ $V_{s(max)} = 3.5V$

$V_{out(max)} = V_{s(max)}(0.004Pin - 0.04) = 3.5(0.004*100 - 0.04) = 3.5*(0.36) = \boxed{1.26V}$

Maximum absolute error $= |V_{out-nominal\ offset} - V_{out(max)}| = |1.188 - 1.26| = \boxed{0.072}$

⇒ $V_{s(min)} = 2.85V$

$V_{out(min)} = V_{s(min)}(0.004Pin - 0.04) = 2.85(0.004*100 - 0.04) = \boxed{1.026}$

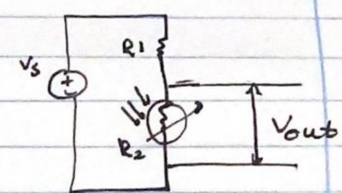
Minumum absolute error $= |V_{out-nominal\ offset} - V_{out(min)}| = |1.188 - 1.026| = \boxed{0.162}$

Figure 7:Question 5 Solution

Question 6

Q6 | Maha Mali 1200746

(1) R2 in the bright light



given: $R2$ in Bright light $= 700\Omega$

$V_s = V_{in} = 5$ Volt, $R_1 = 10K\Omega$

⇒ using Voltage Divider Role

$$V_{out} = V_{in} \cdot \frac{R2}{R_2+R_1} = \frac{5 * 700\Omega}{700\Omega + 10000\Omega} = \frac{3500}{10700}$$

$$= \boxed{0.327\,V} *$$

(2) R2 in the dark

$R2$ in dark $= 100K\Omega$

⇒ using Voltage Divider Role

$$V_{out} = V_{in} \cdot \frac{R2}{R_2+R_1} = \frac{5 \times 100\,K\Omega}{(100+10)K\Omega} \Rightarrow \frac{500}{110} = \boxed{4.54}\,V *$$

Figure 8: Question 6 Solution

Question 7

Q7] $\tau = 38\text{ sec}$, $f = 3\text{ time/minute}$, $T = 20\text{ sec}$

$f = \frac{3}{60} = \boxed{\frac{1}{20}}$

$$\tau_d = \frac{\tan^{-1}(\omega\tau)}{\omega} = \frac{\tan^{-1}(2\pi f \tau)}{2\pi f}$$

$$= \frac{\tan^{-1}\left(2\pi * \frac{1}{20} * 38\right)}{2\pi * \frac{1}{20}}$$

$$= \frac{\tan^{-1}\left(2\pi \left(\frac{38}{20}\right) \text{ rad}\right)}{2\pi \left(\frac{1}{20}\right) \text{ rad/s}}$$

$$= \frac{\tan^{-1}\left(\left(\frac{38}{20}\right)(\cancel{2\pi})\left(\frac{360}{\cancel{2\pi}}\right) \text{ degree}\right)}{\left(\frac{1}{20}\right)(\cancel{2\pi})\left(\frac{360}{\cancel{2\pi}}\right) \text{ degree/s}}$$

$$= \frac{\tan^{-1}(684^\circ)}{18} \text{ seconds}$$

$\cancel{\tau_d = 6.91}$ seconds

$$\boxed{\tau_d = 4.99534 \text{ seconds}}$$

Figure 9: Question 7 Solution

Question 8

The resistance changes in a strain gauge we can find it using this equation:

$$\boldsymbol{\Delta R = R_n . GF . \varepsilon}$$

Where:

- ΔR : Resistance Change.
- R_n : Nominal resistance.
- GF : Gauge Factor.
- ε : Strain Applied.

From question given:

- $\varepsilon = 160\ \mu m/m = 160\ x\ 10^{-6}\ m/m$
- GF_Metal = 2.13
- GF_Semiconductor = -161
- R_n = 120 Ω

Now I will find the resistance change for metallic gauge:

$$\boldsymbol{\Delta R\_Metal = R_n\ x\ GF\_Metal\ x\ \varepsilon}$$

$$\boldsymbol{= 120\ x\ 2.13\ x\ 160\ x} 10^{-6}\ \boldsymbol{m/m}$$

$$\boldsymbol{= 0.040896\ \Omega}$$

Then I will find the resistance change for semiconductor gauge:

$$\boldsymbol{\Delta R\_Semiconductor = R_n \ x \ GF\_Semiconductor \ x \ \varepsilon}$$

$$\boldsymbol{= 120 \ x \ -161 \ x \ 160 \ x} 10^{-6} \ \boldsymbol{m/m}$$

$$\boldsymbol{= -3.0912 \ \Omega}$$

Now, to find the absolute values of the resistance change we can use this equation:

$$\frac{\boldsymbol{|\Delta R\_Semiconductor|}}{\boldsymbol{|\Delta R\_Metal|}} = \frac{\boldsymbol{3.0912 \ \Omega}}{\boldsymbol{0.040896 \ \Omega}} \boldsymbol{= 75.61}$$

From this result I can notice some points:

- Resistance change for metallic gauge is positive, this means the resistance increases approximately $0.040896 \ \Omega$ with strain.
- Resistance change for semiconductor gauge is negative, this means the resistance decrease approximately 3.0912 Ω with strain.
- The semiconductor gauge much sensitive to strain than the metallic gauge for the given parameters.
- The resistance change in semiconductor gauge is 75.61 times larger than the resistance change in metallic gauge.

Question 9

From question given this value:

- Finger length (l_f) = 300 μm
- Mass length (l_m) = 280 μm
- Number of fingers (n) = 100
- Air gap (d_f) = 1 μm
- Relative Permittivity (ε_r) = 7
- Measured capacitance change (ΔC) = 50.34pF

In this question is required to find the value of angle θ . I will use this equation to find the angle:

$$\theta = \frac{n \, . l_f . \Delta C}{\varepsilon_r \, . l_m . d_f}$$

$$= \frac{100 \ x \ 300 \ x 10^{-6} \ x \ 50.34 \ 10^{-12}}{7 \ x \ 280 \ x \ 10^{-6} \ x \ 1x \ 10^{-6}}$$

$$= 7.705 \ x \ 10^{-4} \ degree$$

Question 10

From the question given:

- Input signal frequency (f) = 200 Hz
- Dynamic error $= \pm$ 5%
- Damping ratio (ζ) = 0.6

At first, I will convert the input frequency to angular frequency:

$$\omega = 2\,.\,\pi.\,f$$

= 1256 rad/sec

Calculation by hand shown in figure 10

Q 10 | Maha Mali 1200746

$f = 200Hz$, $\delta = 0.6$, |Daynamic error $= \pm 5\%$|

$$B(w) = \frac{A}{\sqrt{\left(1-\left(\frac{w}{w_n}\right)^2\right)^2 + \left(2\delta\frac{w}{w_n}\right)^2}}$$, let $R = \frac{w}{w_n}$

$$B(w) = \frac{A}{\sqrt{(1-R^2)^2 + (1.2R)^2}}$$, with daynimc error $= \pm 5\%$

$$0.95A \le \frac{A}{\sqrt{(1-R^2)^2 + (1.2R)^2}} \le 1.05A \Rightarrow \frac{1}{1.05} \le \sqrt{(1-R^2)^2 + (1.2R^2)} \le \frac{1}{0.95}$$

$$\Rightarrow \left(\frac{1}{1.05}\right)^2 \le 1 - 2R^2 + R^4 + 1.44R^2 \le \left(\frac{1}{0.95}\right)^2$$

$$\left(\frac{1}{1.05}\right)^2 - 1 \le R^4 - 0.56R^2 - 0.108033 \le \left(\frac{1}{0.95}\right)^2 - 1$$

$R^4 - 0.56R^2 - 0.108033 = 0 \Rightarrow$ solve this using pabiic law, and let $R^2 = y$

$y^2 - 0.56y - 0.10833 = 0$

$y = 0.79589$

$y = R^2 \Rightarrow R = \sqrt{0.79589} = \boxed{0.844}$

$$\frac{w}{w_n} \le 0.844 \Rightarrow w_n \ge \frac{2\pi(200)}{0.844} \Rightarrow \boxed{w_n \ge 1488 \text{ rad/sec}}$$

Figure 10:Question 10 Solution

```
% Maha Maher Mali 1200746
zeta = input('Enter the value of damping ratio(zeta): ');
wn=input('Enter the value of wn in rad/sec : ');
numerator=[wn^2];
denominator=[1 2*zeta*wn wn^2];
Fun = tf(numerator,denominator)
ltiview(Fun)
```

Figure 11:MATLAB Code

```
>> Untitled
Enter the value of damping ratio (zeta): 0.6
Enter the value of wn in rad/sec: 1488

Fun =

        2.214e06
  ----------------------
  s^2 + 1786 s + 2.214e06
```

Figure 12:MATLAB Result

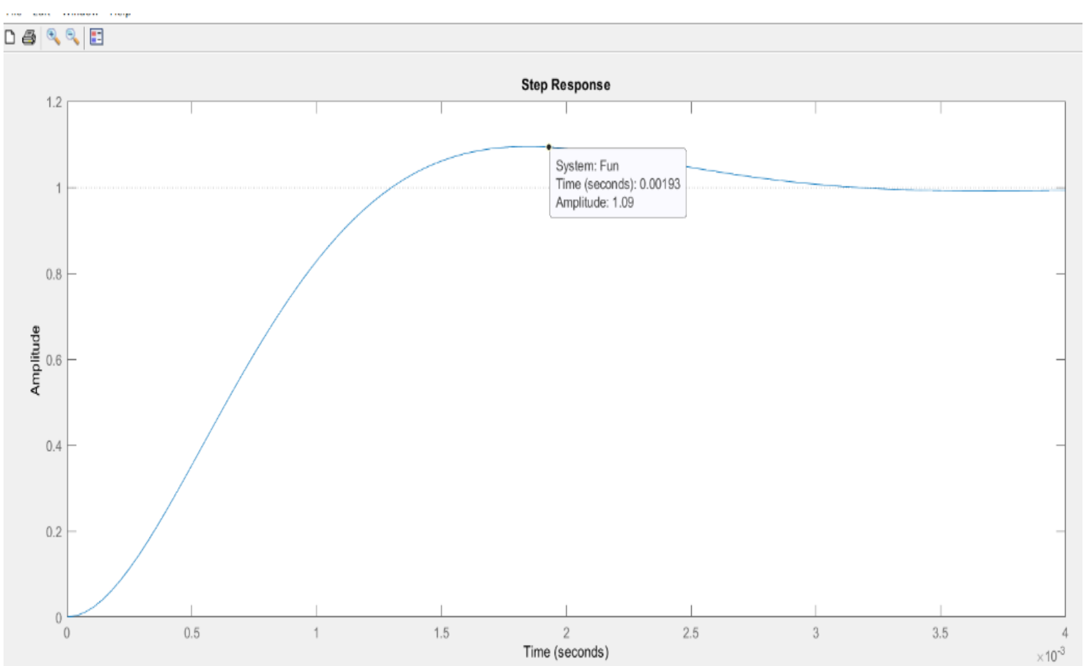


Figure 13: Step Response

Question 11

- **What is Load cell?**

A load cell is a transducer that is used to create an electrical signal whose magnitude is directly proportional to the force being measured. It is basically a device that measures strain and then converts force into electric energy which serves as a measurement for scientists and workers.[1]

- **HX711 Load Cell Amplifier**

The Load Cell Amplifier is a small breakout board for the HX711 IC that allows you to easily read load cells to measure weight. By connecting the amplifier to your microcontroller, you will be able to read the changes in the resistance of the load cell, and with some calibration, you'll be able to get very accurate weight measurements.[1]

- **Circuit Diagram**

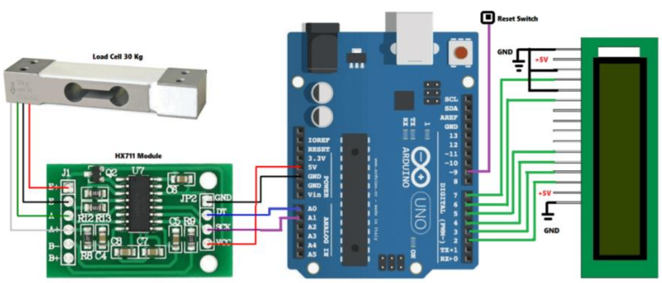


Figure 14: Scale using strain gauge load cell [1]

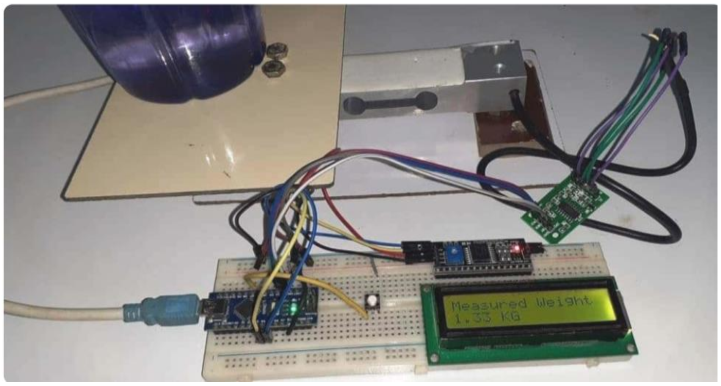


Figure 15:Scale [2]

❖ Connection on the Proteus

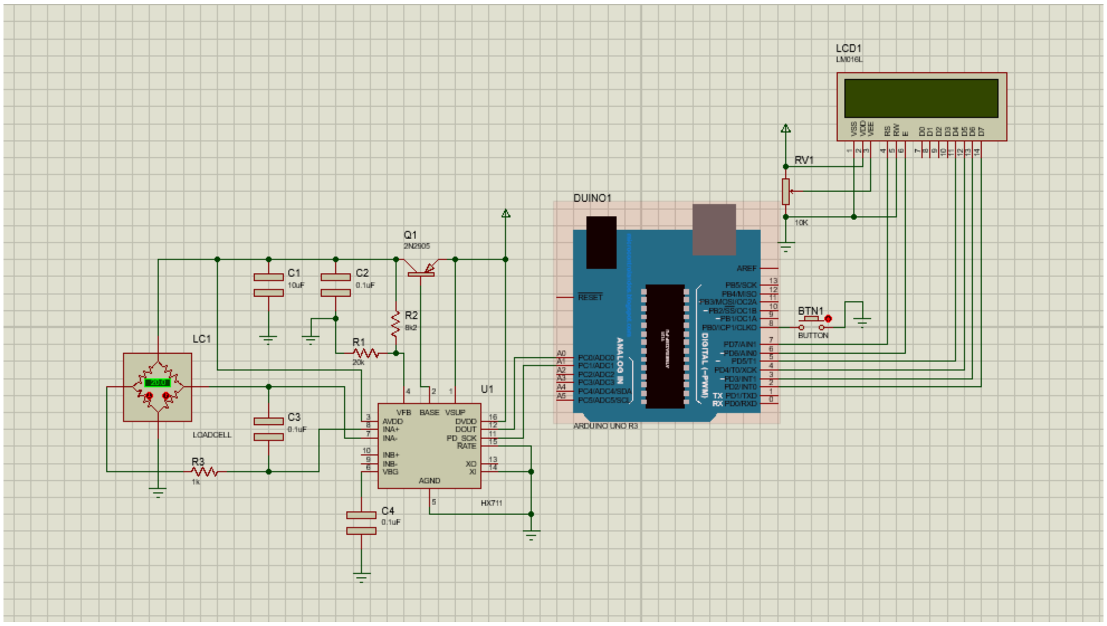


Figure 16:Connection on the Proteus [3]

❖ Components Required for this Weighing Scale Project

S.N.	Components Name	Quantity
1	Arduino Nano	1
2	16x2 LCD Display	1
3	Load Cell	1
4	HX711	1
5	Push Button	1
6	Connecting Wires	10
7	Breadboard	1

Figure 17:Components

- **Code**

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(7, 6, 5, 4, 3, 2);

#define DT A0
#define SCK A1
#define sw 9

long sample=0;
float val=0;
long count=0;

unsigned long readCount(void)
{
unsigned long Count;
unsigned char i;
pinMode(DT, OUTPUT);
digitalWrite(DT,HIGH);
digitalWrite(SCK,LOW);
Count=0;
pinMode(DT, INPUT);
while(digitalRead(DT));
for (i=0;i<24;i++)
{
digitalWrite(SCK,HIGH);
Count=Count<<1;
digitalWrite(SCK,LOW);
if(digitalRead(DT))
Count++;
}
digitalWrite(SCK,HIGH);
Count=Count^0x800000;
digitalWrite(SCK,LOW);
return(Count);
}

void setup()
{
pinMode(SCK, OUTPUT);
pinMode(sw, INPUT_PULLUP);
lcd.begin(16, 2);
lcd.print(" Weight ");
lcd.setCursor(0,1);
lcd.print(" Measurement ");
```

```
delay(1000);
lcd.clear();
calibrate();
}

void loop()
{
count= readCount();
int w=(((count-sample)/val)-2*((count-sample)/val));
lcd.setCursor(0,0);
lcd.print("Measured Weight");
lcd.setCursor(0,1);
lcd.print(w);
lcd.print("g ");

if(digitalRead(sw)==0)
{
val=0;
sample=0;
w=0;
count=0;
calibrate();
}
}

void calibrate()
{
lcd.clear();
lcd.print("Calibrating...");
lcd.setCursor(0,1);
lcd.print("Please Wait...");
for(int i=0;i<100;i++)
{
count=readCount();
sample+=count;
}
sample/=100;
lcd.clear();
lcd.print("Put 100g & wait");
count=0;
while(count<1000)
{
count=readCount();
count=sample-count;
}
```

```
lcd.clear();
lcd.print("Please Wait....");
delay(2000);
for(int i=0;i<100;i++)
{
count=readCount();
val+=sample-count;
}
val=val/100.0;
val=val/100.0; // put here your calibrating weight
lcd.clear();
}
```

References

[1] https://how2electronics.com/weighing-machine-arduino-load-cell-hx711/ .
Accessed on 7-12-2023 at 11:50 AM.

[2] https://how2electronics.com/weighing-scale-40kg-load-cell-hx711-arduino/ .
Accessed on 7-12-2023 at 12:50 PM.

[3] https://www.youtube.com/watch?v=gpofOo4_PtA .
Accessed on 7-12-2023 at 12:50 PM.