# Lab 2

# Signal construction and time-domain response of LTIC systems

**EECS3451**

**Name: Chethana Wickramasinghe**

**Student Number: 214866511**

**Professor: Peter Lian**

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**1. Introduction:**

Using MATLAB to answer questions provided. Questions leads to create formulas and graph plots to get a better understanding of signal construction and Time-domain response of LTIC systems. This report is mainly answering the provided questions using MATLAB. Results will demonstrate the use of MATLAB properly in analysing Amplitude modulation and Time-domain response.

**2. Equipment:** MATLAB

**3. Results and discussion:**

The answers to provided question are as follows,

## Part I) Amplitude modulation of baseband signals

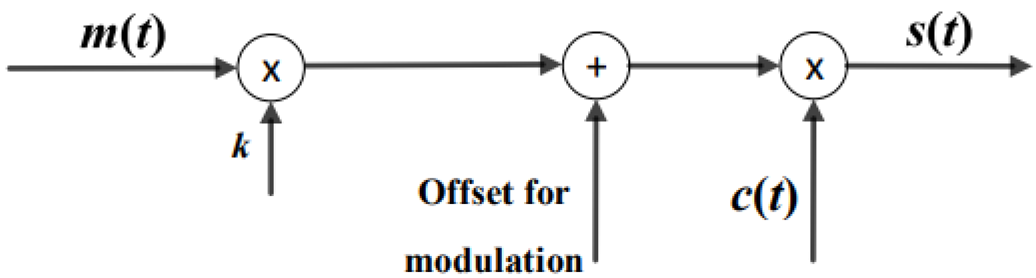



Fig. 1 Schematic diagram of the modelling of amplitude modulation

a) **Assume that the sinusoidal tone: $m(t) = 3\cos(2\pi f m t)$ where fm is 1kHz, is modulated by the carrier $c(t) = 10\cos(2\pi f c t)$, where fc is 20kHz. If k = 0.2 and the DC offset is 1. Construct the output signal s(t) from Fig. 1, plot m(t) and s(t) on the same figure in MATLAB but display them in different plots. You must plot for a few low frequency cycles to see the complete s(t).**

$$s(t) = \mathrm{A}[1 + \mathrm{km(t)}]\cos(2\pi\ \mathrm{fct}) = 10[1 + 0.2 * 3\cos(2\pi * 1 * t)]\cos(2\pi * 20 * t)$$

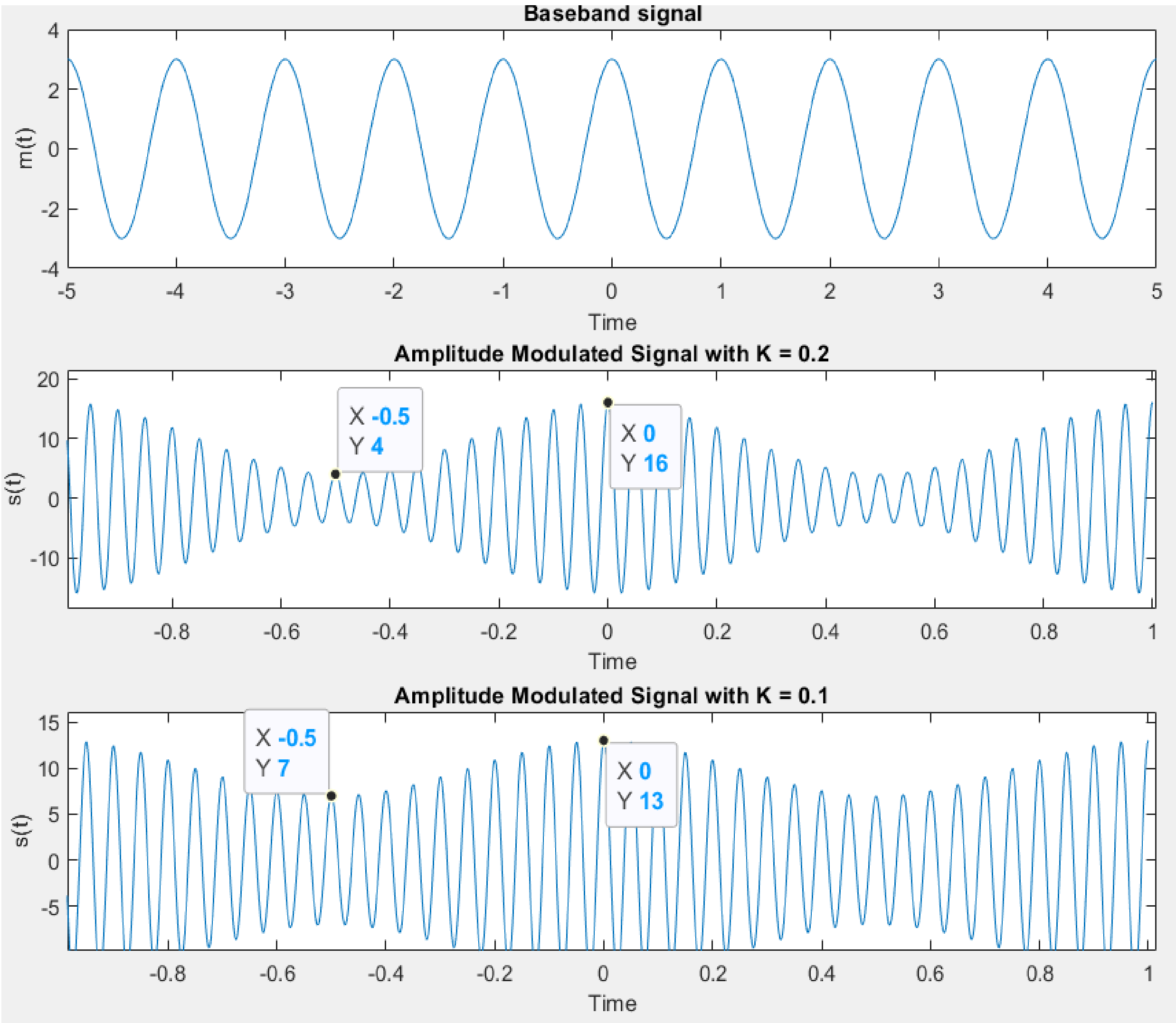
$$s(t) = 10[1 + 0.6\cos(2\pi t)]\cos(40\pi t)$$

<u>CODE</u>

```
t = -5:0.01:5;
m = 3 * cos(2 *pi*t) ;
t2 = -1:0.001:1;
s = 10* (1 + 0.6 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =0.2

subplot(3,1,1); % 3 rows, 1 column, 1st spot
plot(t,m);
xlabel('Time');
ylabel('m(t)');
title('Baseband signal');
```

```
subplot(3,1,2); % 3 rows, 1 column, 2nd spot
plot(t2,s);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = 0.2');

s = 10* (1 + 0.3 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =0.1


subplot(3,1,3); % 3 rows, 1 column, 3rd spot
plot(t2,s);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = 0.1');
```

<u>PLOTS</u>



Name: Chethana Wickramasinghe Student #: 214866511

**b) If k is decreased to 0.1, repeat a). How does s(t) vary as k decreases?**

New s(t) with k= 0.1 is plotted above. As the K decreased the modulation index decreased as well.

<u>EXTRA</u>

Plots for k = -1(for curiosity), 0.1,0.2,1 and 3. K=1 -> 100% modulation, K=0.2 -> 20% modulation and so on.

An AM modulation index of 0.2 means the signal increases by a factor of 0.2, and decreases to 0.2, centered around its unmodulated level.

As k increases, the modulation index increases, therefore the factor of increasing and decreasing of the of signal around the unmodulated level increase.

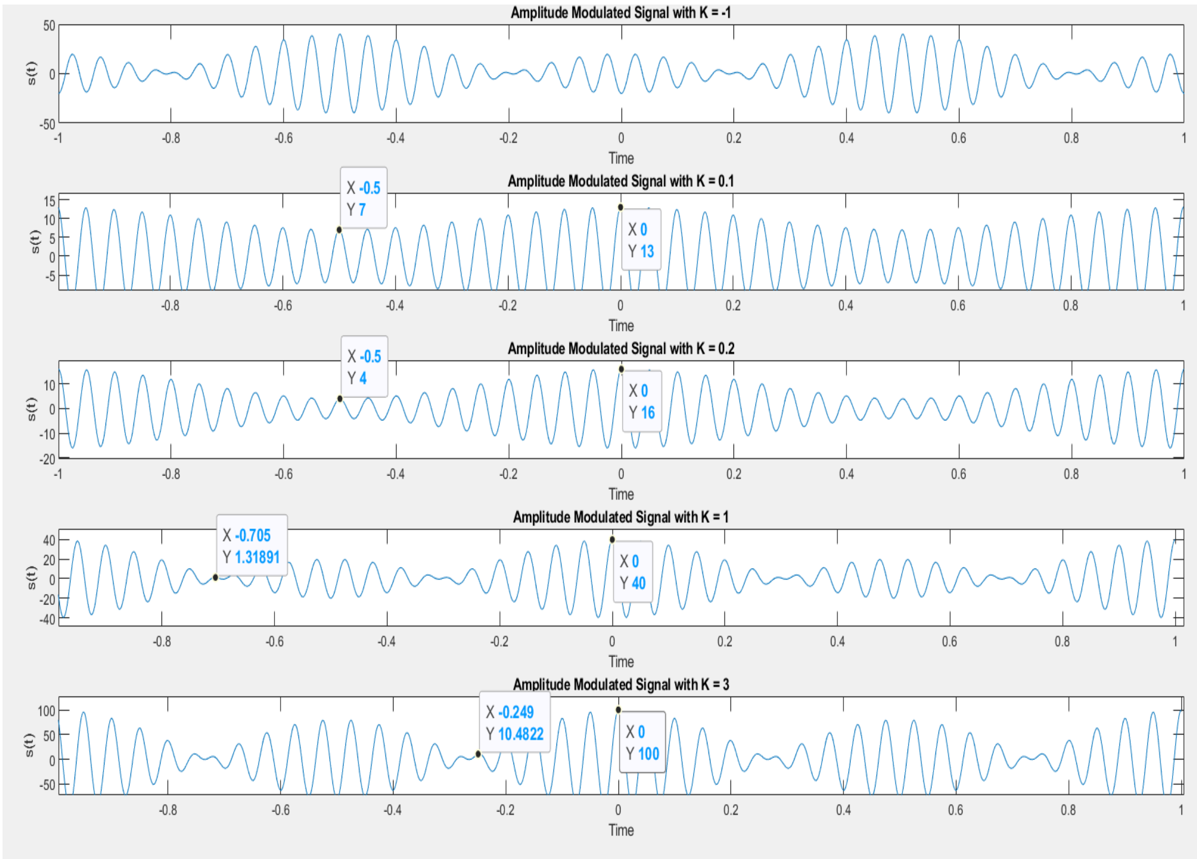
As k decreases, the modulation index decreases, therefore the factor of increasing and decreasing of the of signal around the unmodulated level decreases.

<u>CODE</u>

```
t = -5:0.01:5;
m = 3 * cos(2 *pi*t) ;
t2 = -1:0.001:1;
s = 10* (1 + 0.6 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =0.2
s2 = 10* (1 + 0.3 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =0.1
s3 = 10* (1 + 3 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =1
s4 = 10* (1 + 9 * cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =3
s5 = 10* (1 + (-3)* cos(2 *pi*t2) ) .* cos(40*pi*t2); %k =-1

subplot(5,1,1); % 5 rows, 1 column
plot(t2,s5);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = -1');

subplot(5,1,3); % 5 rows, 1 column
plot(t2,s);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = 0.2');

subplot(5,1,2); % 5 rows, 1 column
plot(t2,s2);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = 0.1');

subplot(5,1,4); % 5 rows, 1 column
plot(t2,s3);
xlabel('Time');
ylabel('s(t)');
```

```
title('Amplitude Modulated Signal with K = 1');

subplot(5,1,5); % 5 rows, 1 column
plot(t2,s4);
xlabel('Time');
ylabel('s(t)');
title('Amplitude Modulated Signal with K = 3');
```

PLOTS




**c) If m(t) is the input signal and s(t) is the output signal, is this a time-invariant system? Explain.**

"A system is said to be time-invariant (TI) if a time delay or time advance of the input signal leads to an identical time-shift in the output signal."

$$s(t) = \mathrm{A}[1 + \mathrm{km(t)}]\cos(2\pi\,\mathrm{fct})$$

$$\mathrm{m(t - to)} = \mathrm{A}[1 + \mathrm{km(t - to)}]\cos(2\pi\,\mathrm{fct})$$

$$s(t - to) = \mathrm{A}[1 + \mathrm{km(t - to)}]\cos(2\pi\,\mathrm{fc(t - to)})$$

$$\mathrm{m(t - to)} \neq s(t - to)$$

Therefore, it is a time-varying system

Name: Chethana Wickramasinghe Student #: 214866511

# Part II) Time-domain response of LTIC systems

## Exercise 2: Consider the below CR circuit

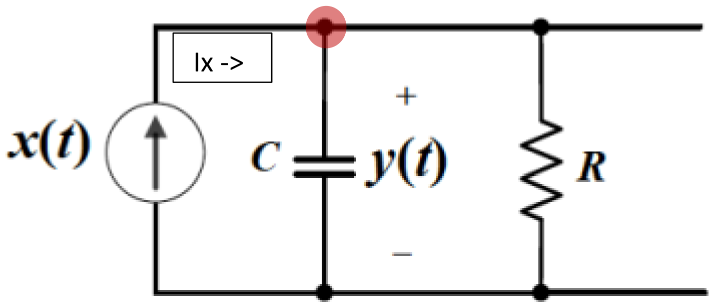



Fig. 2 CR circuit network

**1) Determine the differential equation relating x(t) and y(t), if C = 0.2F, R = 5Ω**

KCL at the red node,

$$I_x = \frac{x(t)}{Rt} \quad , Total\ Resistnace(Rt)$$

Ideally capacitor has no resistance therefore Ix can also be written as $I_x = x(t)/R$

$$-\frac{x(t)}{Rt} + \frac{Cdy}{dt} + \frac{y(t)}{R} = 0$$

$$\frac{Cdy}{dt} + \frac{y(t)}{R} = \frac{x(t)}{Rt}$$

$$\frac{dy}{dt} + \frac{y(t)}{CR} = \frac{x(t)}{CR*Rt}$$

$$\frac{dy}{dt} + \frac{y(t)}{(0.2*5)} = \frac{x(t)}{0.2*5*Rt}$$

$$\frac{dy}{dt} + y(t) = \frac{x(t)}{Rt}$$

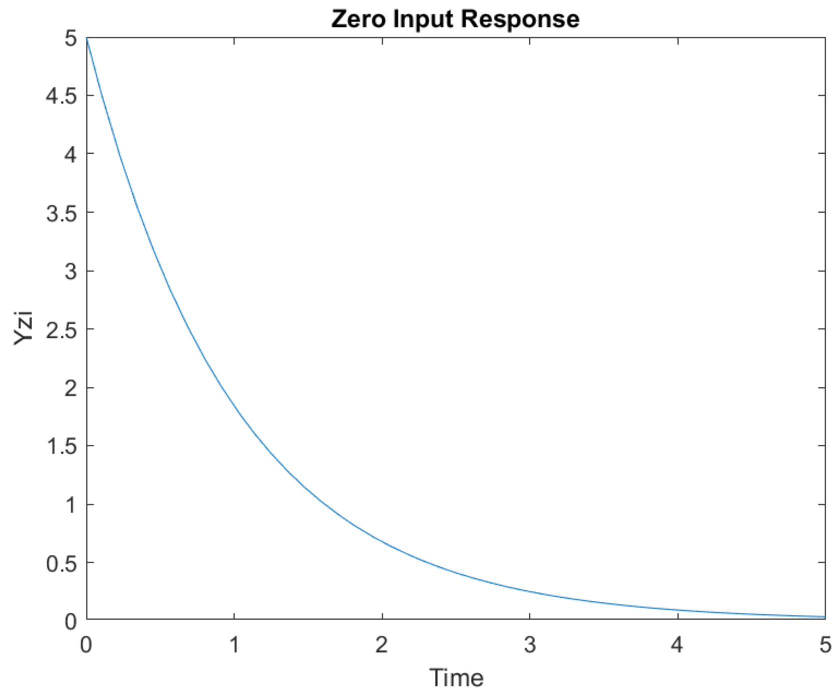
2) **Plot the following responses within t=[0,5s]:**

i. **the zero-input response if the initial voltage in C is 5V;**

<u>CODE</u>

```
syms y(t) x
eqn =  diff(y,t) +y == 0;
Dy = diff(y,t);
cond = [y(0)== 5];
f = dsolve(eqn,cond);
fplot(f, [0,5])
xlabel('Time');
```

```
ylabel('Yzi');
title('Zero Input Response');
```

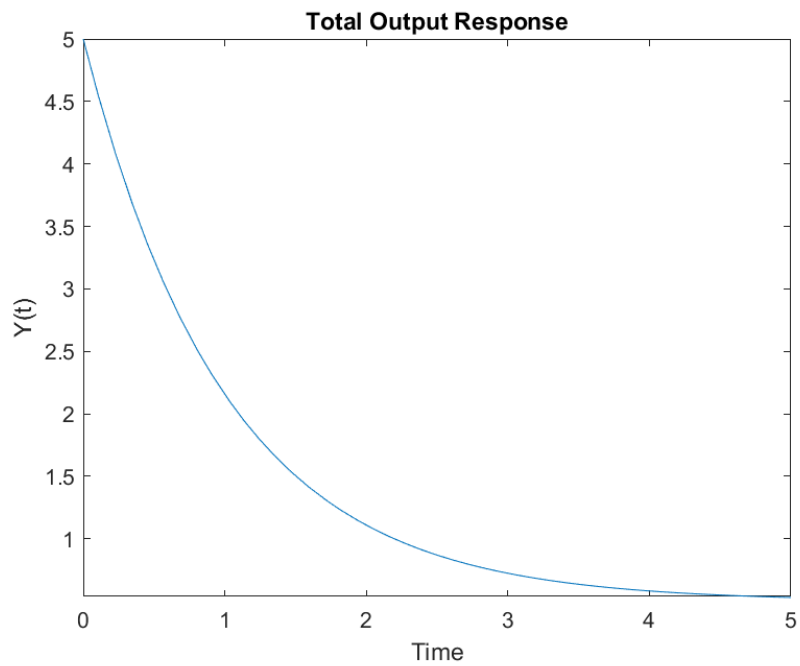



**ii. the total output response y(t) if the input signal is 0.5u(t) and the initial voltage in C is 5V;**

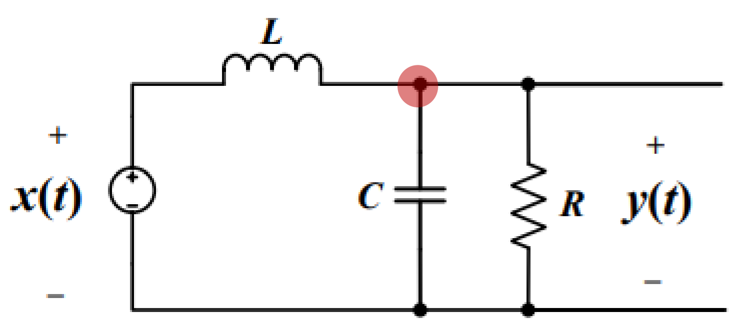
<u>CODE</u>

```
syms y(t) x
eqn =  diff(y,t) +y == 0.5.*heaviside(t);
Dy = diff(y,t);
cond = [y(0)== 5];
f = dsolve(eqn,cond);
fplot(f, [0, 5])
xlabel('Time');
ylabel('Y(t)');
title('Total Output Response');
```

<u>PLOT</u>




## Exercise 3: Consider the below RLC circuit




**1) Determine the differential equation relating x(t) and y(t) if L = 2.0H, C = 0.5F and R = 1Ω**

KCL at the red dot,

$$\frac{1}{L}\int y(t) - x(t)dt\ + \frac{y(t)}{R} + \frac{Cdy(t)}{dt} = 0$$

Reduced to,

$$\frac{y(t)}{L} - \frac{x(t)}{L} + \frac{dy(t)}{R\,dt} + C\frac{d^2y(t)}{dt} = 0$$

$$\frac{y(t)}{L} + \frac{dy(t)}{R\,dt} + C\frac{d^2y(t)}{dt} = \frac{x(t)}{L}$$

$$y(t) + \frac{L\,dy(t)}{R\,dt} + CL\frac{d^2y(t)}{dt} = x(t)$$

$$\frac{y(t)}{CL} + \frac{dy(t)}{RC\,dt} + \frac{d^2y(t)}{dt} = \frac{x(t)}{CL}$$

$$\frac{d^2y(t)}{dt} + \frac{dy(t)}{(0.5*1)\,dt} + \frac{y(t)}{(0.5*2)} = \frac{x(t)}{(0.5*2)}$$

$$\frac{d^2y(t)}{dt} + \frac{dy(t)}{0.5\,dt} + y(t) = x(t)$$

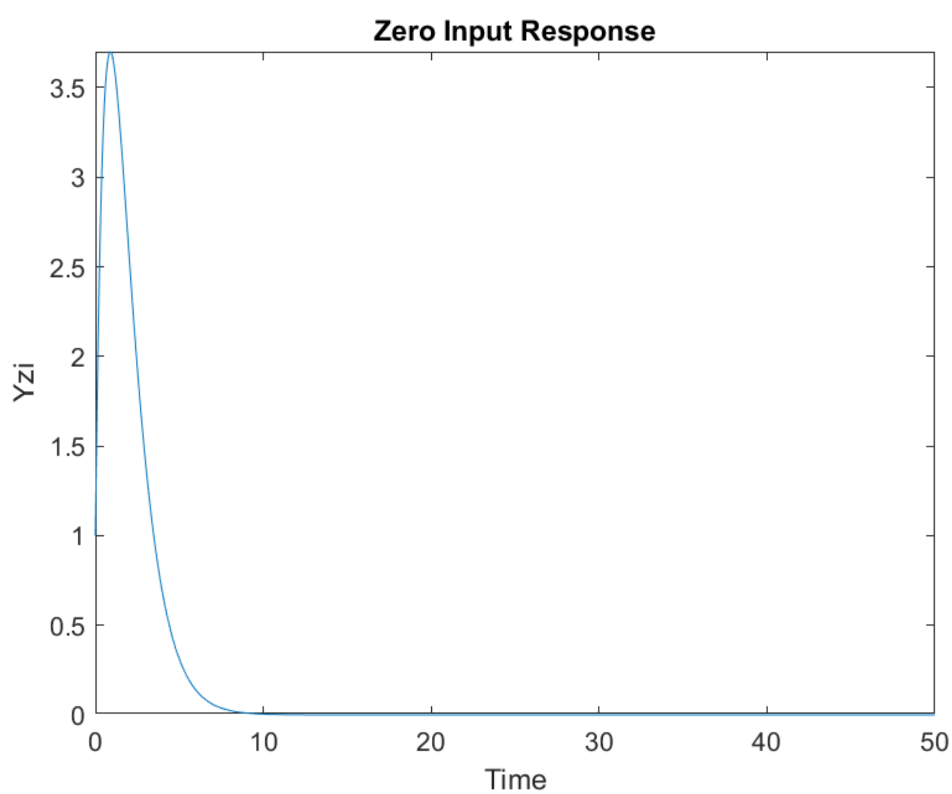
**2) Plot the following responses within t=[0,50s]:**

**i. the zero-input response if y(0) = 1 and y'(0) = 8**

CODE

```
syms y(t) x
eqn =  diff(y,t,2) + 2*diff(y,t) + y == 0;
Dy = diff(y,t);
cond = [y(0)== 1, Dy(0)  == 8];
f = dsolve(eqn,cond);
fplot(f, [0,50])
xlabel('Time');
ylabel('Yzi');
title('Zero Input Response');
```

PLOT

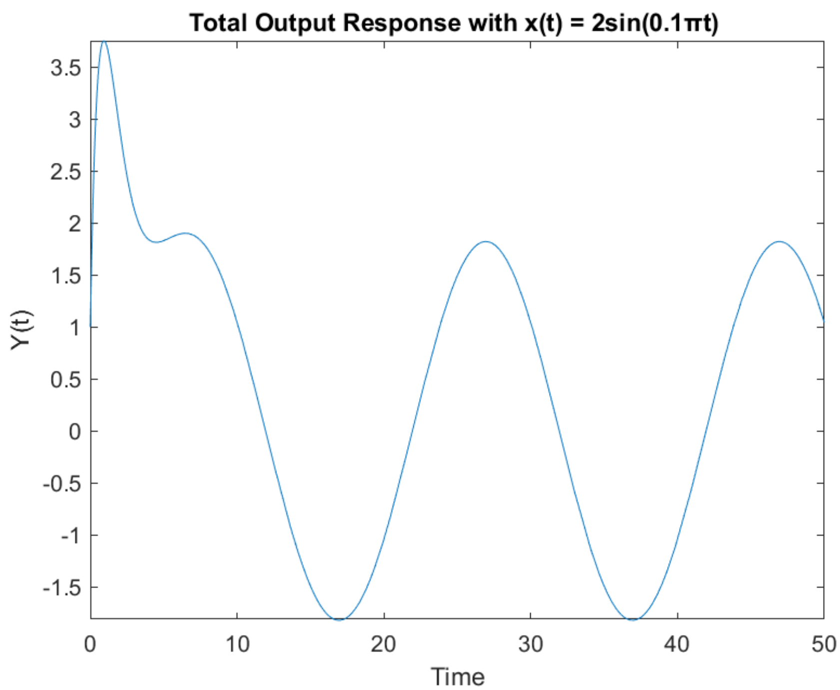


**ii. the total output responses y(t) if the input signal is 2sin(0.1πt) with y(0) = 1 and y'(0) = 8**

CODE

```
syms y(t) x
eqn =  diff(y,t,2) + 2*diff(y,t) + y(t)== 2*sin(0.1*pi*t);
Dy = diff(y,t);
cond = [y(0)== 1, Dy(0) == 8];
f = dsolve(eqn,cond);
fplot(f, [0, 50])
xlabel('Time');
ylabel('Y(t)');
title('Total Output Response with x(t) = 2sin(0.1πt) ');
```

PLOT



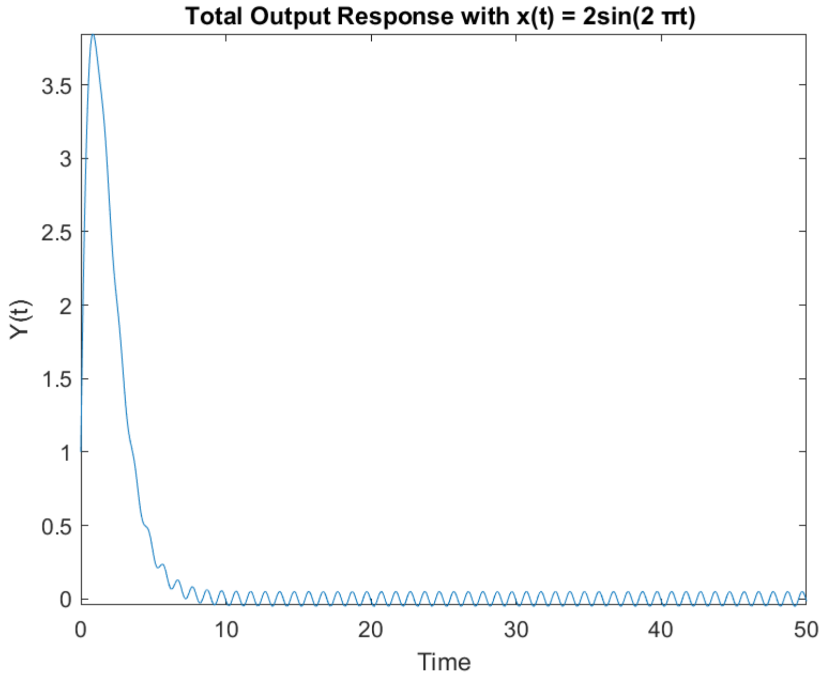

**iii. the total output responses y(t) if the input signal is 2sin(2 πt) with y(0) = 1 and y'(0) = 8;**

CODE

```
syms y(t) x
eqn =  diff(y,t,2) + 2*diff(y,t) + y(t) == 2*sin(2*pi*t);
Dy = diff(y,t);
cond = [y(0)== 1, Dy(0) == 8];
f = dsolve(eqn,cond);
fplot(f, [0, 50])
xlabel('Time');
```

```
ylabel('Y(t)');
title('Total Output Response with x(t) = 2sin(2 πt) ');
```

PLOT




**4. Conclusion: state what you learn from this lab, lab objectives you achieved, and any difficulties you met.**

Learned how to use "dsolve" function in MATLAB to investigate time-domain response of the provided LTIC systems and how the factor "k" (modulation index) effect the output signal.

All the questions were answered using MATLAB and was able to get a better understanding of signal construction and Time-domain response of LTIC systems by observing the generated plots.

Had to spent time to review on how to build KCL equations, took some time to find out how to use "dsolve" function to generate response plots and also understand the role of modulation index.

REFERENCES

Web.sonoma.edu. 2021. [online] Available at: <https://web.sonoma.edu/esee/courses/ee442/archives/sp2018/lectures/lecture06_am_modulation.pdf> [Accessed 18 February 2021].