Laboratory 2 – Signal construction and time-domain response of LTIC systems

(Deadline: February 1 at 3pm)

Introduction:

There are _two parts_ in this lab:

1. Signal construction
2. Time-domain response of LTIC systems

In the first part of the lab, you will look at how to construct signals in radio communications with MATLAB. In the second part of this lab, you will use the "**ode**" function in MATLAB to investigate time-domain response of several LTIC systems. There are <u>5</u> exercises in this lab.

Note: You are encouraged to complete the pre-lab exercises before you start part II of this lab.

Part I: Amplitude modulation of baseband signals

Amplitude modulation (AM) is a popular technique used for broadcasting radio stations within a local community. Modulation is the process used to shift the frequency content of an information bearing signal such that the resulting modulated signal occupies a higher frequency range. Modulation leads to two main advantages in communications. First, since the length of the antenna is inversely proportional to the frequency of the information signal, transmitting information bearing low-frequency baseband signals directly leads to antennas with impractical lengths. Secondly, modulation leads to frequency division multiplexing, where multiple signals are coupled together by shifting them to a range of different frequencies and are then transmitted simultaneously.   This provides considerable savings in the transmission time and the consumption power.

A schematic diagram of an AM system is shown in Fig. 1, where $m(t)$ is a baseband signal. The multiplication term $c(t)$ represents the sinusoidal carrier, with amplitude A, and the radian frequency is given by $\omega_c = 2\pi f_c$. The factor k is referred to as the modulation index, which is adjusted such that the intermediate signal is always positive for all $t \geq 0$.
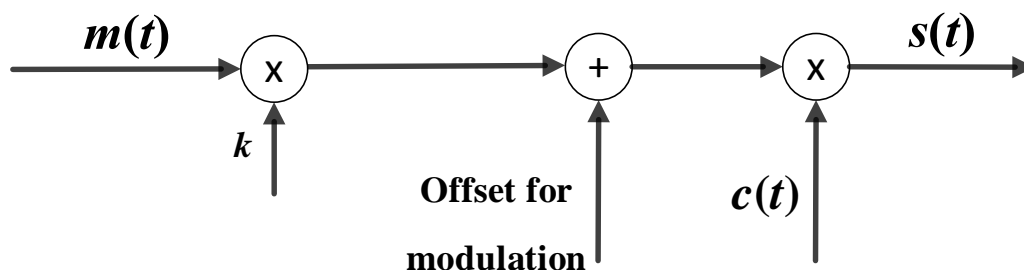

Fig. 1 Schematic diagram of the modelling of amplitude modulation

Laboratory exercise 1.

a) Assume that the sinusoidal tone: $m(t) = 3\cos(2\pi f_m t)$, where f_m is 1kHz, is modulated by the carrier $c(t) = 10\cos(2\pi f_c t)$, where f_c 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 $s(t)$.

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

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

d) A special case of amplitude modulation, referred to as the quadrature amplitude modulation (QAM), which modulates two information-bearing signals $x_1(t)$ and $x_2(t)$ simultaneously. A schematic of the QAM process is shown in Fig. 2, where the two carriers $c_1(t)$ and $c_2(t)$ are **_90°_** **_phase shifted_**.
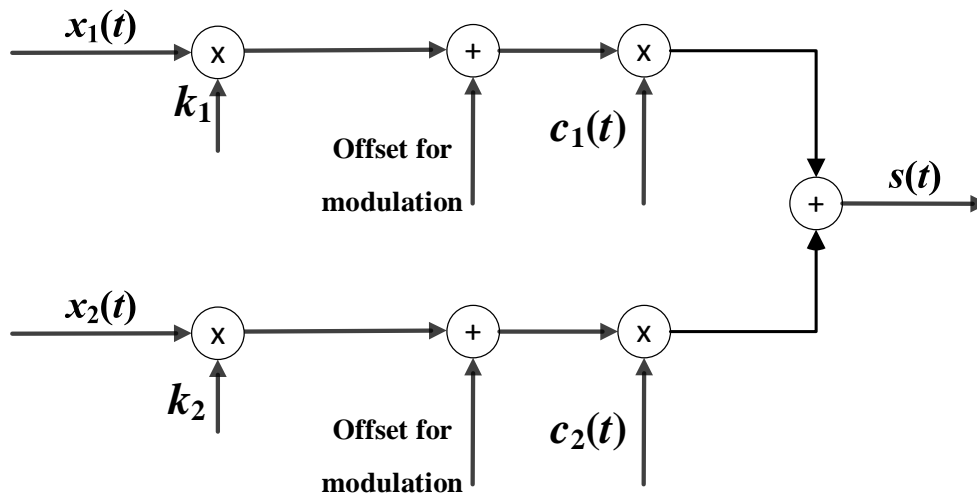

Fig. 2 Schematic diagram of the modelling of quadrature amplitude modulation

If: $x_1(t) = 3\cos(2\pi f_{m1} t)$, where f_{m1} is 3kHz, and $x_2(t) = 5\cos(2\pi f_{m2} t)$, where f_{m2} is 2kHz. The two carriers have the same frequency 20kHz, with carrier $c_1(t) = 5\cos(2\pi f_c t)$ and the amplitude of the second carrier is 10. If $k_1 = 0.2$ and $k_2 = 0.3$, the DC offset is 1, construct the output signal $s(t)$ from Fig. 2. Then plot $s(t)$ in MATLAB up to 2.5ms. How is the output signal in this case different from the output signal of the amplitude modulation?

Part II: Time-domain response of LTIC systems

The analytical method of solving a LTIC system with a differential equation relating the input and output signals has been discussed in the lecture. In the second part of this lab, you will use MATLAB to plot the dynamic output response of several LTIC circuit systems.

MATLAB provides several M-files for solving differential equations with known initial condition. The list includes: ode23, ode45, ode113. Each of these functions uses a finite difference-based scheme for discretizing a CT differential equation and iterates the resulting discrete-time finite-difference equation for the solution.

One way to plot the solution of a differential equation using **ode 23** is first to create a function (or M-file) that contains the differential equation. For example, the 1st order non-homogeneous differential equation given in (1) can be implemented in the M-file as follows:

$$\frac{dy}{dt} + 2y(t) = 3t \qquad (1)$$

```
function [dy] = DE1(t,y)
% DE1 computes the first derivative of y(t) given the value of the signal
% y(t) and time t

dy = -2*y + 3*t;
end
```

The above function is saved in a file named "DE1.m" and placed in a directory included within the defined paths of the MATLAB environment. Then in your main M-file, call the function 'DE1' using the built-in function **ode23**, and then plot the resulting $y(t)$.

In the MATLAB command window, enter **>> help ode23** for details on how to use **ode23** to call the function that contains the differential equation.

Laboratory exercise 2.

Consider the LR circuit network in Fig. 3, based on the differential equation relating $x(t)$ and $y(t)$ that you obtained from the pre-lab exercise, if $L = 0.5$H, $R = 10\Omega$, perform the following:

     i.   Plot the zero-input response if the initial current in L is 5A;
    ii.   Plot the total output response $y(t)$ if the input signal is a unit-step signal and the initial current in L is 5A;
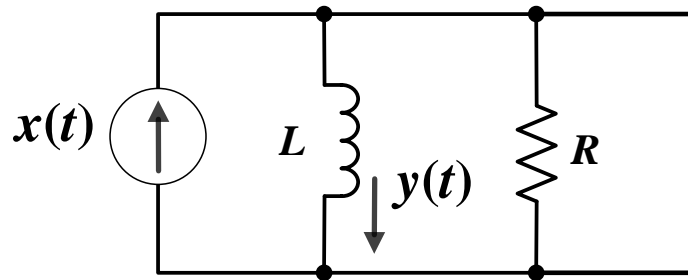
Label your plots properly.

Fig. 3 LR circuit network

Laboratory exercise 3.

Consider the RRC circuit network in Fig. 4, based on the differential equation relating $x(t)$ and $y(t)$ that you obtained from the pre-lab exercise, if $C = 0.2$F, $R_1 = 5\ \Omega$, $R_L = 10\Omega$, perform the following:

     i.   Plot the zero-input response if the initial voltage across C is 3V;
    ii.   Plot the total output response $y(t)$ if the input signal is a $0.4u(t)$ and the initial voltage across C is 3V;

    iii.   Plot the output response $y(t)$ if the input signal is $0.4\cos\left(\frac{1}{2}\pi t\right)u(t)$ and the initial

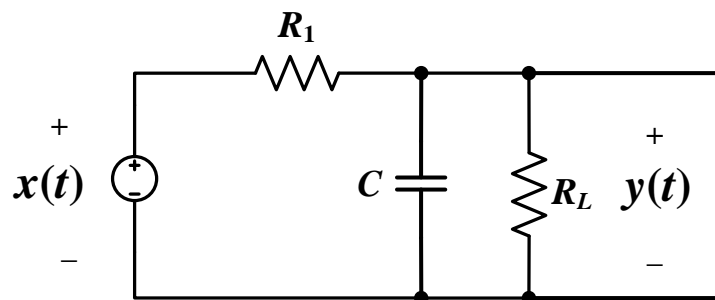   voltage across C is 3V.

Label your plots properly.

Fig. 4 RRC circuit network

Laboratory exercise 4.

Consider the RLC circuit in Fig. 5, based on the differential equation relating $x(t)$ and $y(t)$ that you obtained from the pre-lab exercise, if $L = 0.2$H, $C = 0.4$F and $R = 5\Omega$,

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

      ii.   Plot the total output response $y(t)$ if the input signal is $[3\sin(\pi) + 2\cos(\pi)]u(t)$, with $y(0)$ = 1 and $y'(0) = 8$;
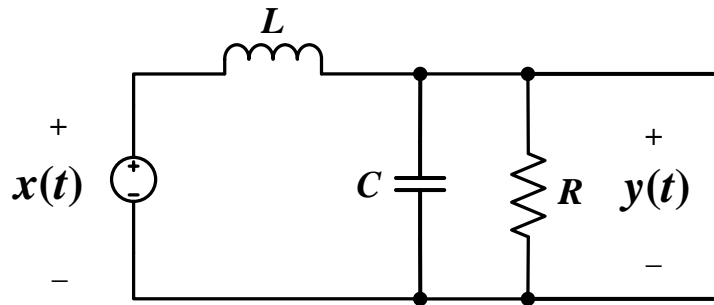
Label your plots properly.

Fig. 5 RLC circuit network with a shunt capacitor

Laboratory exercise 5.

If a resistor R_s is now connected in series with L in the circuit shown in Fig. 5, plot the output response $y(t)$ if $R_s = 0.2\Omega$ and the input signal is $[3\sin(\pi) + 2\cos(\pi)]u(t)$ with the same initial conditions in exercise 4. Plot the new $y(t)$ and the $y(t)$ that you obtained from exercise 4 on the same figure. (***Hint: You should obtain the new differential equation relating $y(t)$ and $x(t)$ first***)

Label your plots properly.

Submitting your M-files and published report using the EECS submit service:

You can submit multiple files stored on your computer using the web-based submit service: https://webapp.eecs.yorku.ca/submit/index.php .

You will need to provide your EECS login credentials to submit your file(s). Once you have logged in, select "2015 - 16" for Academic Year, then choose the Course (2602) and the Assignment (lab2_M). Browse for your file or files, and press the Submit Files button. You may submit files as many times as you like. The most recent submission overwrites all previous submissions.

Files to be submitted:

1. Main M-file: the main file should contain your solutions to exercise 1, your scripts in exercise 2 – 5 to call the corresponding functions that contain the differential equations.
2. M-file for each differential equation in exercise 2, 3, 4 and 5.
3. Published report of the main M-file in pdf (in your M-file, select the "PUBLISH" Tab and click)