EE-241. Introductory Electronics Laboratory
Lab 10 Handout*

Fall 2009

Mandatory Reading

Background section in Experiment 10 of Y. Tsividis *pg.* 74 - 76.

Exercise Due Date

Week of Nov 23rd.

Prelab Problems

The following set of problems gives you a taste of what is to come in EE210: Signals and Systems and EE380: Communication Systems. Here we will look at amplitude modulation not from the point of view of electronic circuits but from the perspective of signal processing. In your lab session, you will be able to see how this type of signal analysis helps to think about communication circuits and their performance measurement.

1. Look up the terms *modulation*, *Amplitude modulation* (AM), *Frequency modulation* (FM) and *Phase modulation* (PM). For a light introduction, you may consult your lab manual and/or Wikipedia. Why do we need modulation for transmitting electrical signals?

2. In the context of AM, what is meant by *modulation index*? How does the shape of an AM wave change as we change the modulation index from 0 to 1? Show some rough sketches for various values of modulation index.

3. Use MATLAB to generate and plot a sine wave of frequency $f_c = 1$MHz and a duration of 100μsec. We will use this as a carrier. For the same duration, generate another signal of $f_b = 100$KHz. This is the signal to be transmitted. Now modulate the carrier using the formula,
$$m(t) = [1 + \alpha \sin(2\pi f_b t)] \sin(2\pi f_c t),$$
where α is the modulation index. For various values of α between 0 and 1.5, plot the graphs of $m(t)$ in MATLAB.

4. Now use a trigonometric formula $2\sin(A)\sin(B) = \cos(A - B) - \cos(A + B)$ to expand $m(t)$. How many different pure sinusoids do you see in the trigonometric expansion of $m(t)$?

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5. If you were to plot the Fourier series of $m(t)$, what type of spectrum will you get? Make a rough sketch by hand and mark frequencies of the various peaks in the Fourier spectrum.

6. Next use the MATLAB function `fft()` to get a Fourier series of $m(t)$ for a modulation index of 0.5. [1] How many peaks do you see in the graph of the series? Can you guess what these peaks correspond to?

   Hint. If `m` contains the signal vector of the modulated signal, then you can plot the spectrum using the following series of commands.

   ```
   >> M = fft(m); % Get Fourier transform of signal.
   >> M = abs(M); % Retain amplitude of complex numbers only.
   >> L = length(M); % Get length of the spectrum.
   >> plot(M(1:L/2)); % Only one half of the spectrum is enough.
   ```

7. **Bonus Question** [2]

   (a) Simulate in MATLAB the effect of rectifying $m(t)$ by replacing negative values of `m` by zeros.

   (b) Now simulate in MATLAB the effect of passing $m(t)$ through a half wave rectifier of Figure 4. of Lab #2, *Diodes and their applications*. You may assume the value of the resistance at $10k\Omega$ and capacitance at 1nF. If you have gotten this far, you have successfully simulated an AM transmitter and an AM receiver using envelope detection in MATLAB.

[1] What we actually get here is a Discrete Fourier Transform (DFT) and not a Fourier series, but both are closely related. FFT stands for Fast Fourier Transform. It is a very fast method of computing DFT.

[2] You may also submit this part separately after your lab session for a bonus 20% points on the prelab assignment.