ENSC 180: Introduction to Engineering Analysis

Assignment 8

Due: 6.00 p.m., April 11, 2018

Note: *MATLAB codes should include definition of all variables; headings to identify the program structure plan; and appropriate captions and labels for tables and figures. Submit a .pdf report documenting your inputs and outputs in addition to a separate zip-file containing all M-files. Marks will be deducted for solutions that are unrealistic/impractical (as future engineers student should learn to think practically) and poorly documented.*

1. When broadcasting radio waves, different signals can intermix during transmission, and the receiver will need to know how to differentiate between them. Amplitude Modulation (AM) and Frequency Modulation (FM) are two methods of differentiating the signals so that they can be transmitted and then recovered. In both, a sinusoidal carrier signal is used to modify the message. The carrier signal is of the form;

   $$S(t) = A_c \cos(2\pi f_c t)$$

   with A_c =carrier amplitude and f_c = carrier frequency (Hz)

   The carrier will modulate a modulating/message signal *m(t)*;

   $$m(t) = A_m \cos(2\pi f_m t)$$

   with A_m = message amplitude and f_m = message frequency (Hz) << f_c

   AM modulation is defined by;

   $$S_{AM}(t) = A_c[1 + m(\mathrm{t})]\cos(2\pi f_c t)$$

   while FM modulation is defined by;

   $$S_{FM}(t) = A_c \cos(2\pi f_c t + 2\pi k_f A_m \int_0^t m(\tau) d\tau)$$

   where k_f = the frequency sensitivity.

   Write a MATLAB program that takes a carrier frequency $f_c >> f_m$ in Hz (assume the amplitudes and k_f are all 1). Create a message signal with frequency f_m = 0.02 Hz and modulate it via each method, then output a figure with four separate subplots stacked on top of each other; the first is the message, the second is the carrier signal, the third is the AM wave and the fourth the FM wave. Comment on the results. (Hint: Keep the frequency values in the mHz or Hz ranges to better display the signal features) (20 marks)

2. Diode is a two-terminal component widely used in electronic design. The relationship between diode forward current I_D and diode forward voltage V_D can be modeled as:

   $$I_D = I_S(e^{\frac{V_D}{nV_T}} - 1)$$

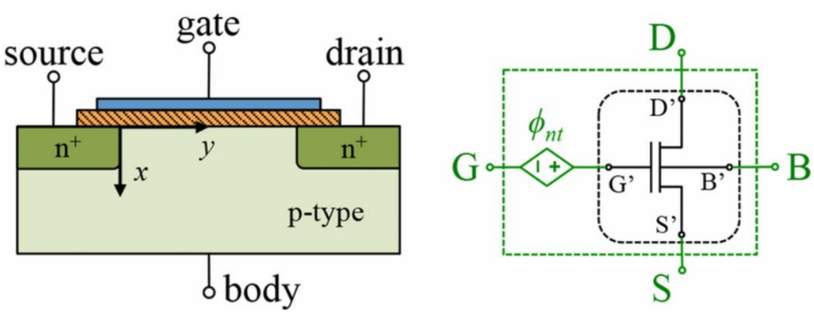
where I_S is the reverse current, *n* is a quality factor and V_T is thermal voltage. Thermal voltage V_T is given by:

$$V_T = \frac{kT}{q}$$

where k = 1.38×10^{-23} J/K and q = 1.6×10^{-19} C. T is the temperature in Kelvin (0 C = 273K).

Consider a case where n = 1, $I_S = 10^{-12}$ A and plot the forward diode current (I_D) *vs* diode voltage (V_D) at -75C, 25C and 75C. For plotting, use voltage as the horizontal axis and current as the vertical axis with V_D from 0 to 0.8V. Plot the 3 curves corresponding to the 3 temperatures in separate figures aligned vertically in one page. Comment on the behavior current-voltage relationship at different temperatures. (20 marks)

3. In electronics, a MOSFET is a voltage-controlled field effect transistor. A MOSFET is a three-terminal device containing a drain (D), a gate (G) and a source (S), body is always connected to the lowest voltage in the circuit. Consider a N-channel MOS as shown in the following diagram:



The Current-Voltage curve of a MOSFET has three regions: cut-off, linear and saturation, and they are defined by:

$$\text{cut-off: } I_D = 0 \text{ for } V_{GS} < V_T$$

For V_{GS} > VT, the gate can be turned on which allows the MOSFET enters into linear and saturation regions defined by:

$$\text{linear: } I_D = \frac{1}{2}K_n\frac{W}{L}\left[2(V_{GS} - V_T)V_{DS} - {V_{DS}}^2\right] \text{ for } V_{DS} \le V_{GS} - V_T$$

$$\text{Saturation: } I_{D=}\frac{1}{2}K_n\frac{W}{L}(V_{GS} - V_T)^2(1 + \lambda V_{DS}) \text{ for } V_{DS} > V_T$$

where K_n is the transconductance parameter, W/L is the aspect ratio between width and length, V_T is the threshold voltage, V_{GS} is the voltage difference between Gate and Source, V_{DS} is the voltage difference between Drain and Source.

Given: K_n = 100u (unit: A/V^2), W/L = 5 (unitless), V_T = 1V, lambda = 0.01

Plot I_D vs. V_{DS} for different gate to source voltages V_{GS}. Vary V_{GS} starting from 0V with increments of 0.5V each time to generate 10 characteristic curves. (20 marks)

4. The following model describes the motion of a 2-DOF system described by the generalized coordinates x_1 and x_2 under an external excitation *f(t)*.

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -5 & -2 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 \\ 1 \end{bmatrix} f(t)$$

a. Use the *initial* function to plot the position x_1 of the mass if the initial position is 5 and the initial velocity is 3.
b. Use the *step* function to plot the response of the system for zero initial conditions and a step function excitation with magnitude equal to 10.

Note: use the control system toolbox to solve this problem. (20 marks)

5. When images are scaled or resized, the values between pixels need to be guessed/interpolated in order to fill in the missing gaps. Write a function that takes a grayscale image and a scaling factor (any positive decimal value) as input and resizes the image using the following methods;
   a) Nearest neighbouring pixel
   b) Linear interpolation
   c) Spline interpolation

   Use the test image provided (a8_img.jpg), read in the image and output the resulting image for each of the three methods. Test out your function with 1.5 scaling, 3.1 scaling, and for 0.3 scaling (9 images total). You cannot use the built-in MATLAB function imresize(), but any other MATLAB built-in functions are acceptable.

   (Hint: the image is in uint8 format, with values between 0 and 255, but in order to process and display properly, MATALB requires images to be in double format with values between 0 and 1) (20 marks)