EE 462G Laboratory # 2

Non-Linear Element Characterization

by
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(Lab 1 – Report and Lab Effort Plan due at beginning of lab period) (Pre-lab 2 and Lab-2 Datasheet due at the end of the lab period).

I. Instructional Objectives

- Measure input-output transfer characteristic curves of instantaneous (non-dynamic) semiconductor elements (Diodes and FETs).
- Estimate characterization parameters from transfer characteristics

II. Transfer Characteristics

Dynamic circuit responses result from energy storage elements. Dynamic systems are characterized by transfer functions, differential equations, and/or impulse responses. For linear circuits these characterizations, along with the initial conditions, completely describe the input-output relationship. Circuits containing no energy storage elements are referred to as instantaneous or memoryless systems. Nonlinear instantaneous systems are completely characterized by their transfer characteristic (TC), which describes the amplitude input-output relationship over a range of input amplitudes. Transfer characteristics for linear circuits can be expressed as an explicit mathematical function, while for most nonlinear circuits this is not possible. Thus, graphical and numerical methods are employed for analysis and design.

III. Pre-Laboratory Exercises

Transfer Characteristic of Diode

1) Create a SPICE simulation that results in a TC of the diode you will use in the lab experiments (use the "browse for parts" option to find the particular diode you will be using, or one similar to it). Include the plot from the simulation and discuss the validity of modeling a diode as an ideal diode with a 0.7 volt forward bias.
2) Write a Matlab function to plot diode TC from the Shockley equation below:

$$i_D = I_s \left[\exp\left(\frac{v_D}{nV_T} \right) - 1 \right] \qquad (1)$$

10 kΩ

V_s

V_1

where v_D is the voltage drop over diode, i_D is the current through the diode, I_s is the saturation current (on the order of 10^{-14}), n is the emission coefficient taking on values between 1 and 2, and V_T is the thermal voltage (about equal to 0.026 at 300K).

The function input should be a vector of points representing v_D and constants I_s, n, and V_T. The output will be a vector of the same size as v_D representing the corresponding points of i_D. (note that a negative v_D represents the reverse bias condition). Call your function "diodetc" and use it with the following command lines to plot an example curve:

```
>> vd = [-1:.01:1.2];
>> is = 1e-17
>>n=1.1;
>vt = 0.026;
>> id = diodetc(vd,is,n,vt);
>> plot(vd,id)
>>xlabel('Volts')
>>ylabel('Amps')
```

Hand in a copy of the resulting plot (under the edit menu for the figure you can do a *copy* figure and send it to the clipboard for pasting in a document), along with your commented code for the function file diodetc.m.

3. Use the "nmos" Matlab function from the course website to plot TC curves for the nmos FET with the following parameters: K_p specified at 0.1233 A/ V^2 , W=L=1, and V_{tr} = 1.8. Plot them on the same graph and label for V_{GS} = [.5, 1, 1.5, 2, 2.5, 3, 3.5]. Let the drain source voltage, v_{DS}, range from 0 to 5 volts. (Hint: See last part of the script openfettc.m)

IV. Laboratory Procedure

From the mfile link on the course website:
http://www.engr.uky.edu/~donohue/ee462g/mfile/Matlab for EE462G.htm
Download the follow files to you directory on the lab computer for the MSE best-fit curve exercises:
Function for extracting the CSV file data from the curve tracer to regular matrices for analysis:
getcurves.m
interpcurves.m
peakfind.m
For example scripts and data to demonstrate how these programs can be used:
openfettc.m
opendiodetc.m
E121600E.CSV
E121555E.CSV

1. **Measure Transfer Characteristic of Diode Using Curve Tracer:** Use the curve tracer in the laboratory to measure the diode characteristic for forward bias. Set I-V range limits to about either 2V and/or current of 2mA. Record the trace and estimate the diode's forward offset voltage. Save the screen image for the trace from which you

estimated the forward offset voltage. Do this by first inserting a 3.5" floppy disk and changing the sweep mode from REPEAT to SINGLE once you have the desired trace on the screen. The screen image can be saved as a BMP file by pressing the HARDCOPY/BMP FILE button while the FAST/SHIFT button is held down. Also save the trace values (I and V corresponding to the x- and y-axes) as a CSV file. The CSV file can be save by pressing the HARDCOPY/BMP FILE button while the LOCAL/ADDR button is held down. Before you press the buttons to do the save operation it is important to change the sweep mode from REPEAT to SINGLE so the programs that extract single trace data can work properly. This will put a single sweep of the I-V curve in the buffer synchronized from beginning to end or the sweep before saving. If you do not do this, the saved sweep data may start in the middle of a sweep and create problems for the Matlab extraction programs. In the **procedure section** clearly described the settings used in the curve tracer and how the forward offset voltage was estimated from the transfer characteristic on the curve tracer. Datasheet should include a sketch of TC along with parameters listed on the curve tracer screen.

2. Use the programs getcurves.m and interpcurves.m to open the CSV file for the diode (see opendiodetc script for an example of using these functions). Then write a script using the diode function developed in the prelab to fit the measured diode curve to the parametric one that the Matlab function produces (very similar to the lecture notes example). Fix V_T to a constant .026 value and let n and I_s vary. The emission coefficient should cover the range between 1 and 2 (it is a good idea to go a little beyond these limits), and the for the saturation current try about 10 to 100 values equally spaced on a log scale, see help logspace in Matlab for generating these points. (**Discussion: Compare the SPICE simulation and Matlab plot using the MSE best-fit parameters. What would the forward bias voltage be if estimated from the SPICE graph and Matlab Graph using the best fit parameters? How consistent are the forward bias voltages to each other. Which do you put the most confidence it?**). The procedure section must describe the program you used to obtain the final curve from the data. Include your commented code as an appendix to the lab report. The data sheet should include sketches or printouts of the raw TC curve and the best-fit parametric curve.

3. **Obtain MOSFET family of transfer characteristics curves with curve tracer**: Use the curve tracer to measure the ZVN3306A MOSFET's drain characteristic curves. Using the OFFSET button on the STEP GENERATOR find the threshold voltage (i.e. increase and decrease the offset voltage to determine voltage for which the bottom curve leaves the 0 axis of the trace). After determining V_{tr} from your manual adjustments, set the offset set voltage below the threshold voltage, and set the step voltage increments along with number of steps so that several (at least 3) transitions from the triode to saturation regions are visible (see lecture notes). When the desired set of drain current characteristics curves are on the display, change the sweep mode from REPEAT to SINGLE. Save the screen image for the curves used to determine the MOSFET's K_p (i.e. using the methods described in the lecture notes based on the visual determination of the transition between the saturation and triode regions). Also save the trace as a CSV file. TAKE SPECIAL NOTE OF THE OFFSET, STEP VOLTAGES, AND NUMBER OF STEPS APPLIED TO THE GATE-SOURCE VOLTAGE. You will need this