EE 462G Laboratory # 2

Non-Linear Element Characterization

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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 (I-V Curves)

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 memory-less systems. Nonlinear instantaneous systems are completely characterized by their transfer characteristic (TC or I-V curves), 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 (I-V curves) of Diode

1) Create a SPICE simulation that results in a TC of the diode you will use in the lab experiments. The simulation should contain **no resistors**.
   - Present the plot from the simulation ($\boldsymbol{I_d}$ vs. $\boldsymbol{V_d}$)
   - Comment on the validity of modeling a diode as an ideal diode with a 0.7 volt forward bias.
2) Write a Matlab function to plot the diode TC from the Shockley equation below:

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

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 typically between 1 and 2
- 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:

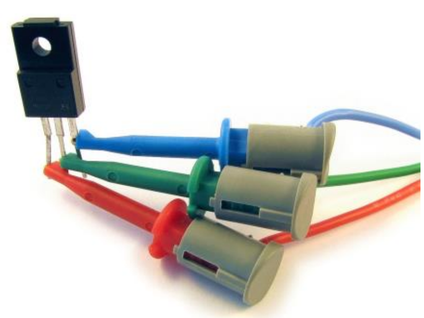
```
>> vd = [-1:.01:1.2];
>> is = 1e-17;
>> n=1.1;
>> vt = 0.026;
>> id = diodetc(vd,is,n,vt);
>> plot(vd, id);
>> xlabel('Volts')
>> ylabel('Amps')
```

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*.

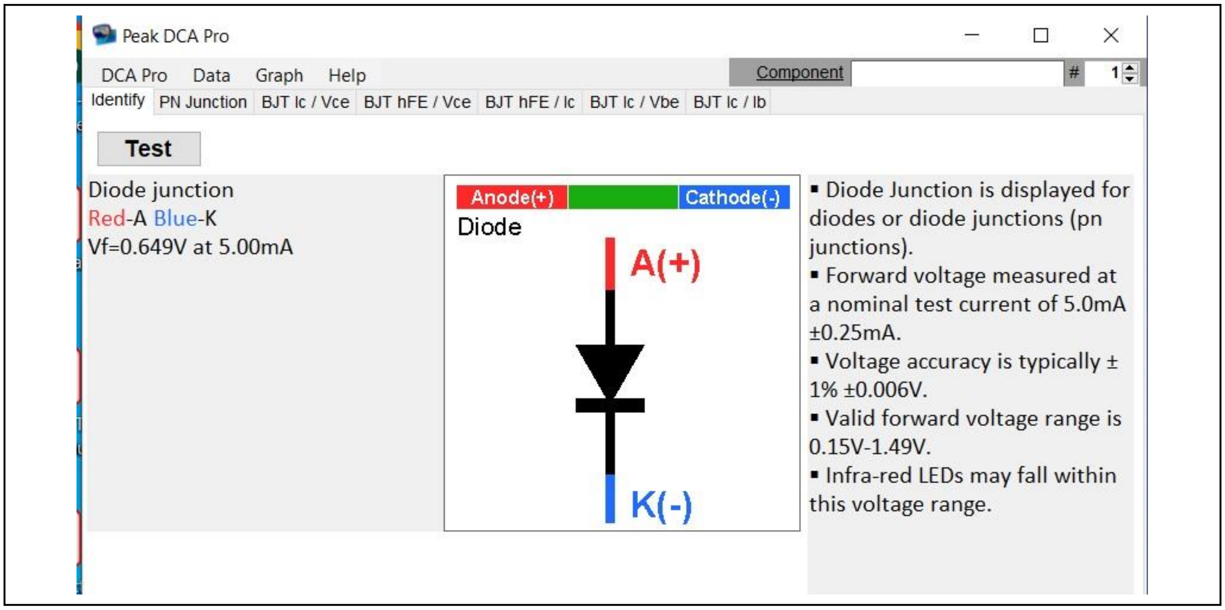
3) Use the *nmos* Matlab function from the course website to plot TC curves for the nmos FET with the following parameters: K_p specified at 0.1233 A/ V^2 , **W**=**L**=1, and V_{tr} = 1.8. Plot them on the same graph and label for V_{GS} = [.5, 1, 1.5, 2, 2.5, 3, 3.5]. Let the drain source voltage,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

IV. Laboratory Procedure

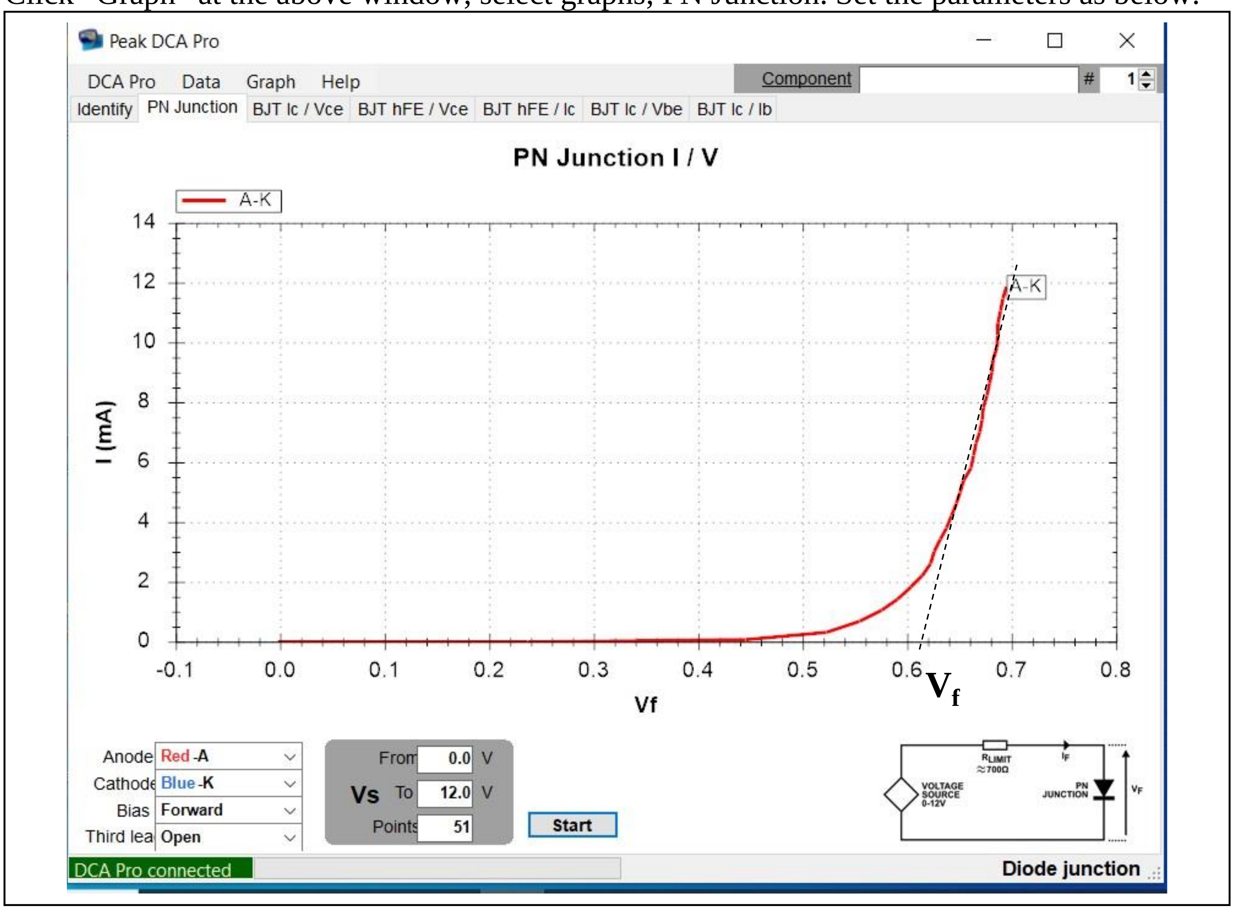
1. Measure I-V Curves of a Diode using Atlas DCA75 Pro



Connect USB from DCA75 to the lab PC. Open the software DCA Pro. Connect the diode, using Red clip on anode and Blue clip on Cathode. Click TEST. Take a photo for your lab report.



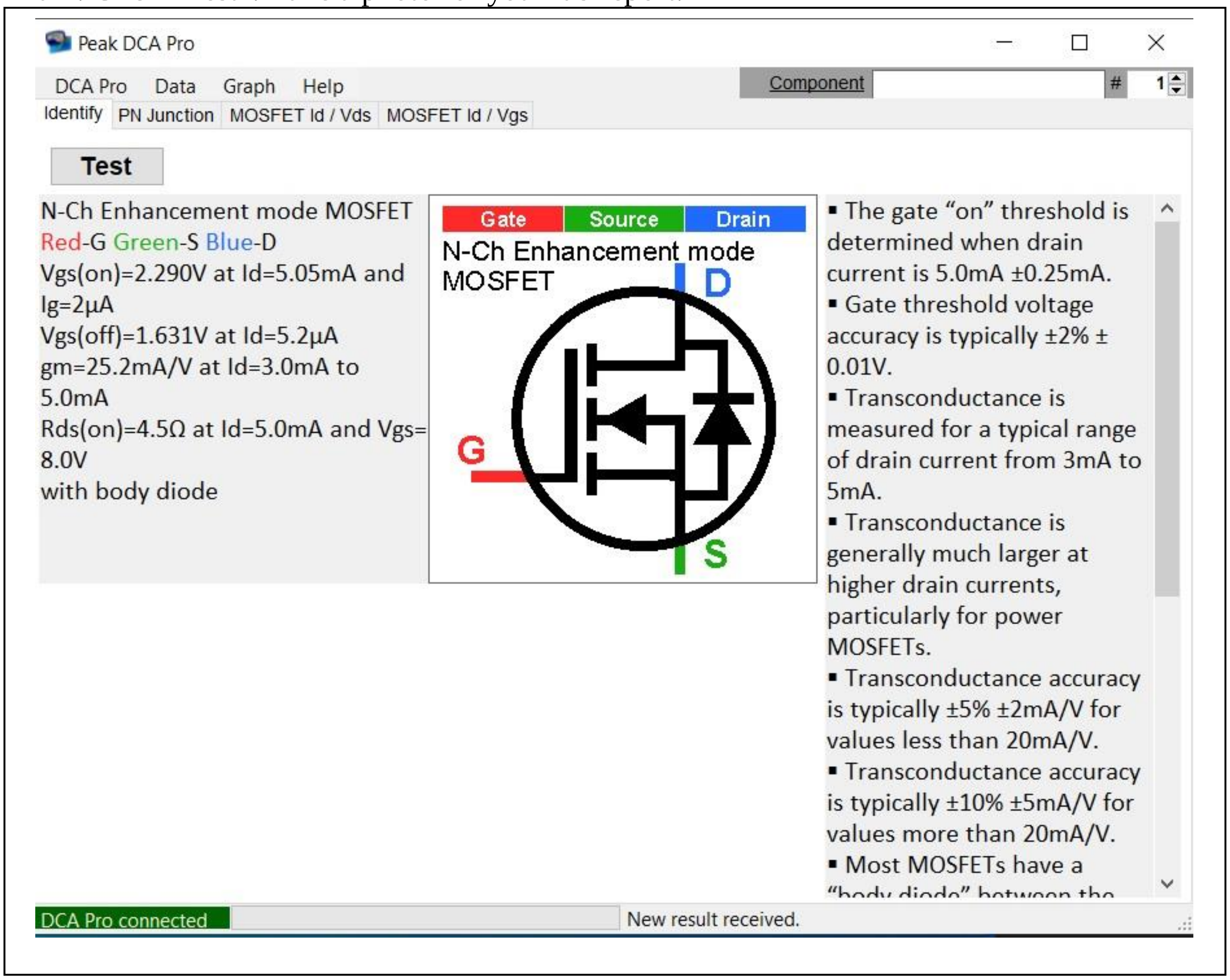
Click “Graph” at the above window, select graphs, PN Junction. Set the parameters as below.



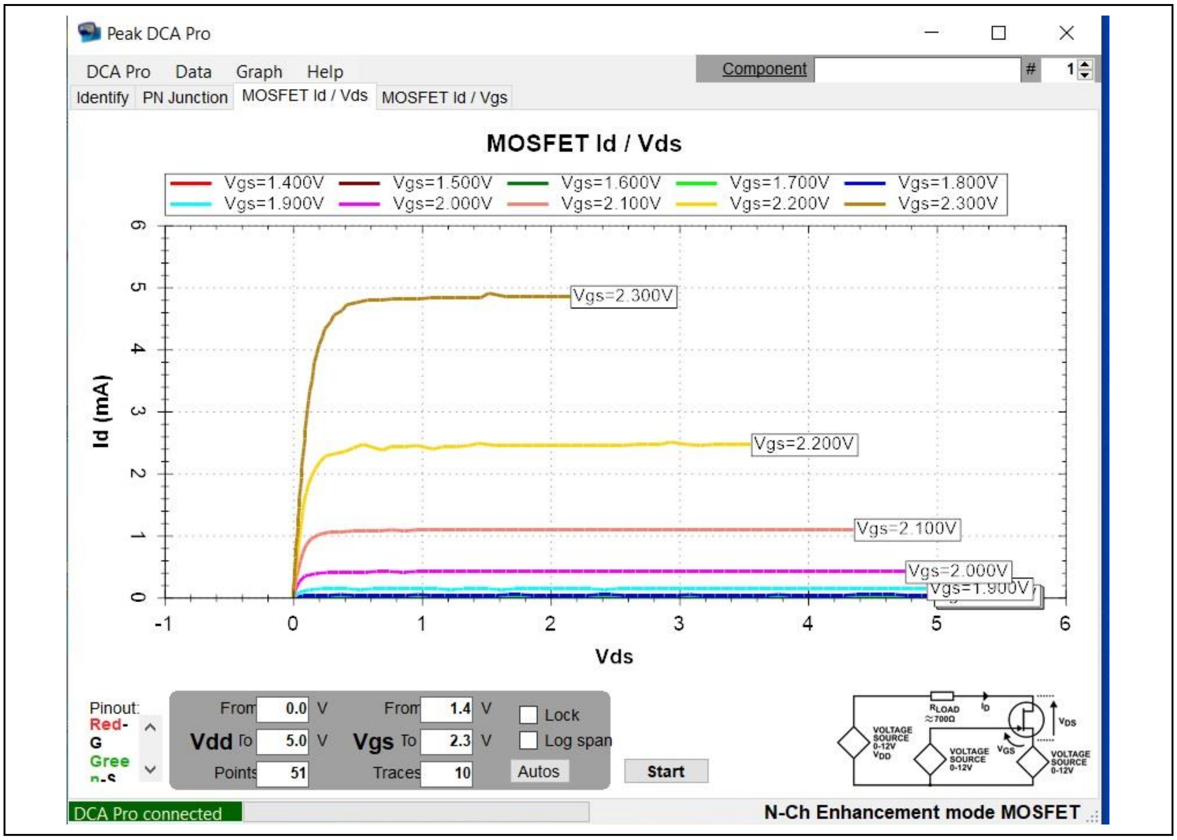
Click “Start”. Take a photo. Click “Data” and “Load Data” to save your data in txt file. Plot the I-V curve from the data. From the curve find $r_d,\ where\ \frac{1}{r_d} = \frac{\Delta I}{\Delta V} = slope$. Extrapolate the curve at the forward bias to obtain the turn-on voltage, V_f. Compare against the theoretical model using extracted features from your experiment’s plot and Matlab code written for part 2 of prelab. Is the Shockley equation a good model for current through a diode? If so, are there any differences, and if there are differences then what is the root cause of the difference?

2. Measure I-V Curves of a MOSFET using Atlas DCA75 Pro

Connect the ZVN3306A MOSFET’ as follows: Red clip on Gate, Green on Source, and Blue on Drain. Click “Test”. Take a photo for your lab report.



Click “MOSFET Id / Vds”. Set the parameters as below. Click “Start”. Take a photo. Click “Data” and “Load Data” to save your data in txt file. Plot the I_D -V_{DS} curves for various Vgs values from the data. From the curves determine the threshold voltage Vth by plotting curves at very low Id currents from 0 to 1 mA. Find the curve for Id ~0.1mA, find the Vgs, which is Vth. Find three turning point from triode to saturation. At each point, find its Vds and Id to calculate K using $I_d = KV_{ds}{}^2$. Then find K by doing average of the three K values.


Peak DCA Pro
DCA Pro Data Graph Help
Component
Identify PN Junction MOSFET Id / Vds MOSFET Id / Vgs
MOSFET Id / Vds
Vgs=1.400V Vgs=1.500V Vgs=1.600V Vgs=1.700V Vgs=1.800V
Vgs=1.900V Vgs=2.000V Vgs=2.100V Vgs=2.200V Vgs=2.300V
Vgs=2.300V
Vgs=2.200V
Vgs=2.100V
Vgs=2.000V
Vgs=1.900V
Id (mA)
Vds
Pinout:
From 0.0 V
Vdd To 5.0 V
Points 51
From 1.4 V
Vgs To 2.3 V
Traces 10
Lock
Log span
Autos
Start
DCA Pro connected
N-Ch Enhancement mode MOSFET