ECE3424 Electronic Circuits Laboratory

Experiment #2: **Junction diode forward conductance characteristics** **vers 1.10**

OBJECTIVE: Assess and evaluate conductance characteristic of one or more junction diodes.

Commentary: Diodes are a two-terminal component with nonlinear characteristics as represented by the I-V plot of figure 3-1a. The plot is approximately consistent with the ideal diode equation

$$I = I_S \left[e^{V / nV_T} - 1 \right] \qquad (2\text{-}1)$$

A logarithmic plot of the forward I-V characteristic shows that the characteristics are approximately exponential from 10nA to 10mA, consistent with equation (2-1).

The parameter I_S is called the *reverse-saturation current*. The parameter n is called the *emission coefficient*. The voltage V_T may be assumed to be .02585V (= thermal voltage at 300°K) inasmuch as the forward diode current is defined by thermodynamic processes.

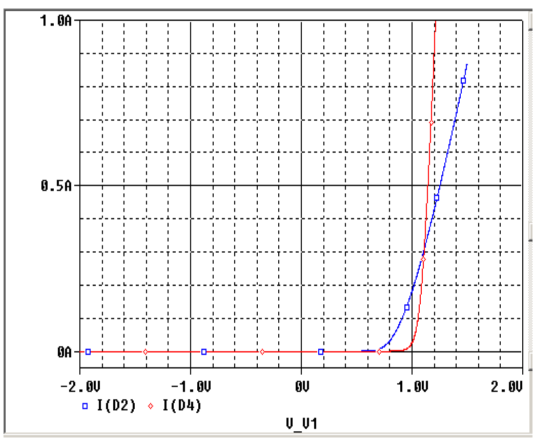


Figure 2-1a: Diode characteristics

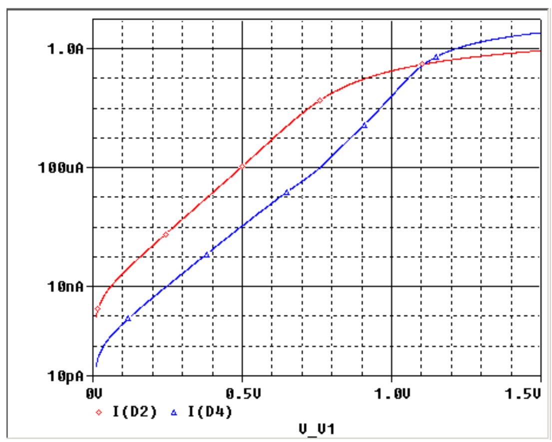


Figure 2-1b: Diode forward conductance characteristics

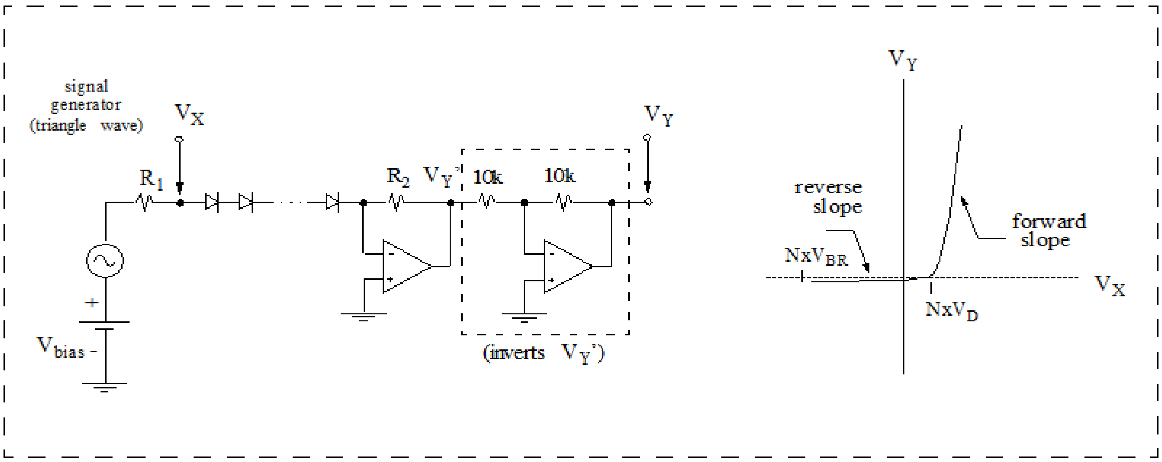
There are considerable variations in these characteristics, depending on the type of semiconductor and the manufacturing factors. Most diodes are *pn* junction silicon diodes. Some are LEDs (light-emitting diodes), consisting of multiple layers and usually made from GaAs. Some are crafted for low reverse-breakdown voltage (V_{BR}) and are called Zener diodes. Some are power diodes, designed to handle a relatively high reverse breakdown. And there are others. We will endeavor to undertake an assessment of some few of these types and undertake the extraction of (1) forward conductance parameters n and I_S.

Diodes to be evaluated:

(1) 1n4148 (or 1n914 if not available)
(2) 1n4732 Zener
(3) LED (red)

PROCEDURE:

A-1: Forward conductance characteristics: Figure 2A-1 shows the test setup. The resistances $R_1 = R_2$ define the level of current I_D through the diode. In concurrence with the exponential behavior indicated by figure 2-1b the *I* vs *V* measurements need to be accomplished over several decade levels for the current.



(Figure 2A-1a: Diode test circuit) (**Figure 2A-1b:** Output expectation)

In figure 2-1 the O-scope is set in the X-Y mode for which (ideally) an output something like figure 2A-1b should be expected, except inverted.

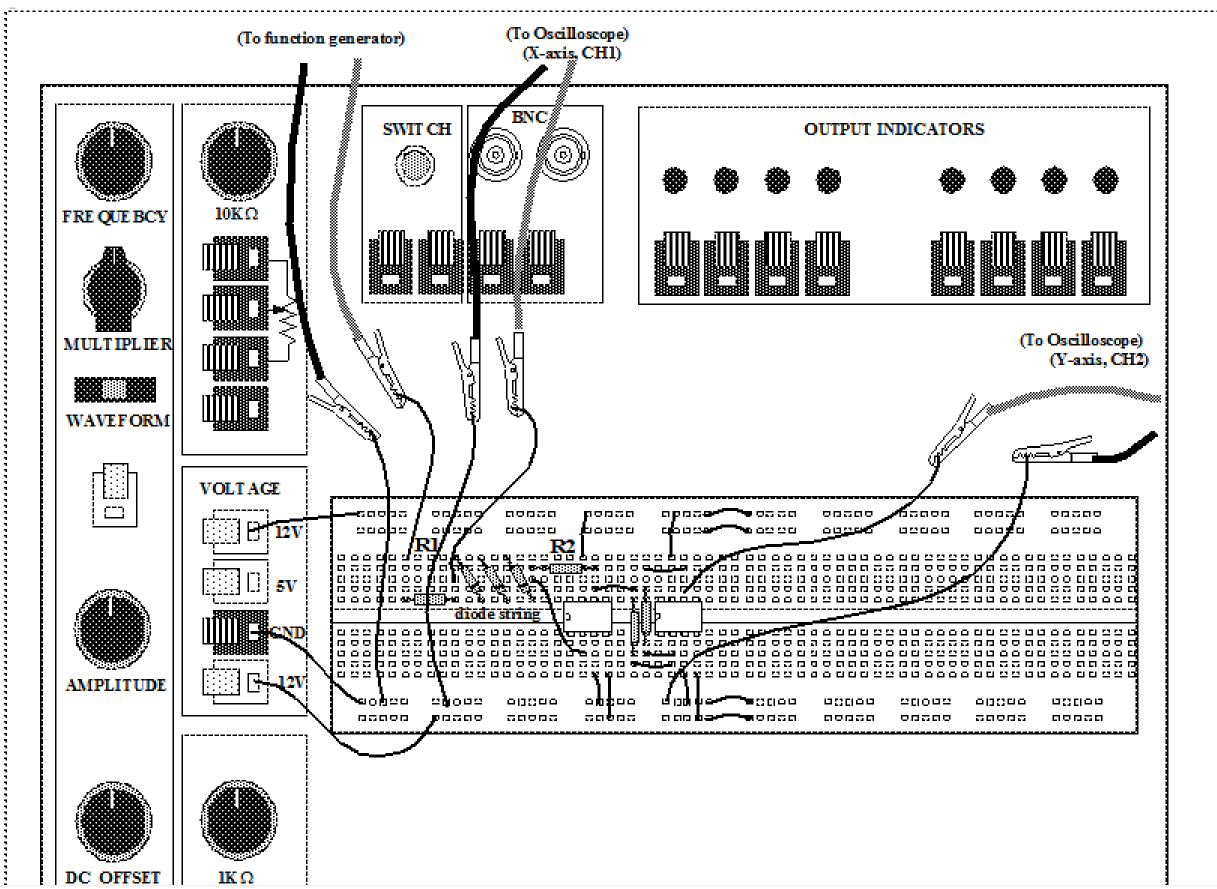


Figure 2A-2a: Suggestions for the placement and wiring for figure 2A-1. The dark wires (black) indicate leads that are usually connected to ground.

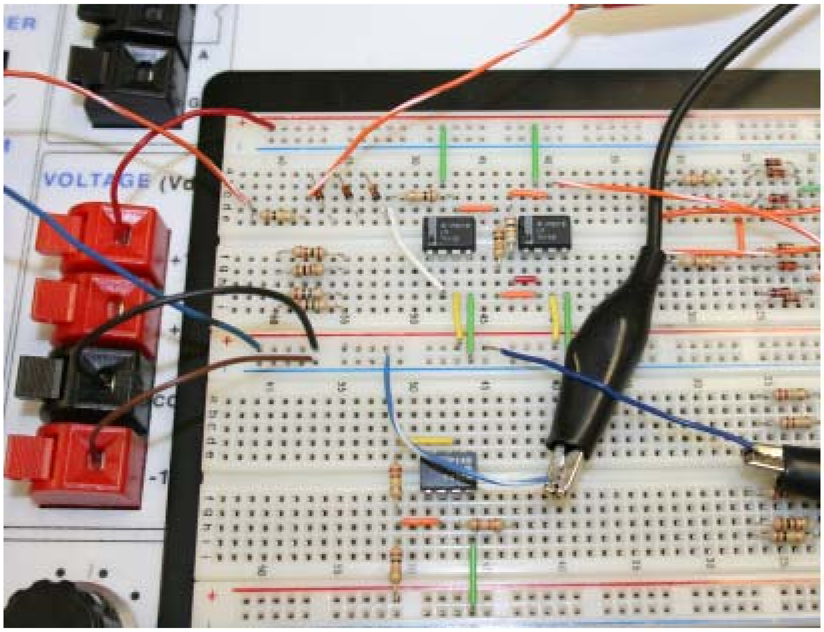


Figure 2A-2b: Photo of figure 2A-2a for placement and wiring suggestions.

A-3. Set up the test circuit of figure 2A-1 using three 1n4148 diodes (use 1n914 if the 1n4148 is not available) with figures 2A-2a and 2A-2b as a guide for placement and wiring. Let $R_1 = R_2 = 1\text{M}\Omega$. Set the triangle wave input to 3.0Vp-p at 1kHz and zero offset. The output of the first opamp relates to current but is inverted. So the second opamp (inverting configuration) is used to return output V_Y to normal perspective.

With CH-1 in the X-T mode confirm the triangle wave *V* vs *t* behavior is as you specified. You may have to negotiate with the signal generator if it defines its signal characteristics by menus and internal software.

The diode string is of arbitrary length, and its sole purpose is to multiply the small diode voltage by a factor of *N*. When mathematically assessing the diode characteristics $V(diode) = V_X/N$ and $I_D = V_Y/R2$.

Before you make measurements you will need to align your oscilloscope traces to the fiducial axes as follows:

1) Set CH1: mode = GND. And then align (horizontal) trace to axis.
2) Set CH2: mode = GND. Then align (horizontal) trace to axis.
3) Reset both CH1 and CH2 to mode = DC
4) Set display to XY mode.

A-4. With the settings as given you should see a trace that resembles figure 2-1. Figure 2A-3 shows a photo of the expected scope trace.

You should be able to take at least 3 data point measurements of V_Y vs V_X. You do not have the benefit of cursors in the X-Y mode. Regrets.

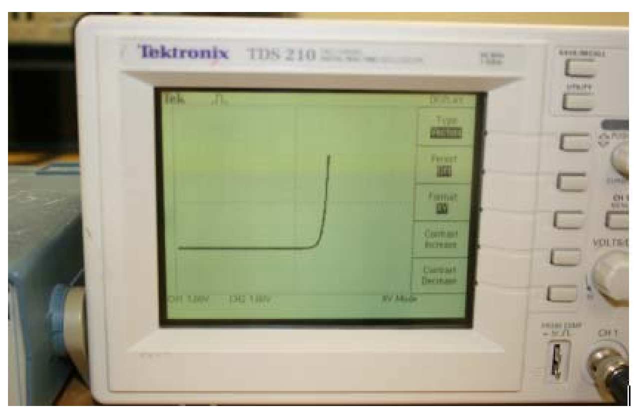


Figure 2A-3. XY output trace for the 2A-1a test circuit.

A-5. Your requirement is to extract enough data to identify ideal diode parameters n and I_S. Therefore you will need to make measurements over several decades of current. To do so you will need to reset $R_1 = R_2$ successively to 100kΩ, 10kΩ, and 1kΩ, and repeat the measurement process of part A-4, at least 3 measurements per each setting for the part of the curve for which V > 0. Make measurements along the rising part of the curve.

For each case you should see an exponential response with little change in the V_Y amplitudes but some shifts in the curve. This behavior is consistent with equation (2-1).

Be sure to include measurement accuracy assessments in your data-gathering process.

B-1. Repeat part A for a single 1n4732 Zener (which should be in your extended kit). You may encounter some problems with hysteresis (separated forward and reverse traces) due to carrier recombination times. In order to reduce this effect, reduce the sweep frequency. You may have to take measurements at frequencies as low as 50Hz in order to overcome hysteresis.

C-1. Repeat part B for a single LED (which should be in your extended kit). If you are not sure about the diode orientation be aware that LEDs are photo-emissive in the forward bias mode which you can test with your power supply at approx 1.7V. The short lead usually corresponds to the p-side of the LED *pn* junction. You should find that its characteristics are diode form, but distinctly different, and you may not be able to get as many measurements as for the simple junction diode. LEDs are multilayer diodes and are usually made from Gallium Arsenide (GaAs). The enhanced photoemissive effects will also demand more complex physics and make the ideal diode form must less accurate.

REPORT and ANALYSIS:

A. Transfer your measurement and accuracy data to your **Excel** database if not done so during the measurement process. By means of curve-fitting applied to the database and to formulae, i.e. equation (3-1) extract diode parameters I_S = reverse saturation current and n = emission coefficient (assuming V_T = .02585V) for each of the diodes tested.

Example Excel spreadsheet usage for extraction of parameters by curve fitting is provided by the support documents. Parameters are extracted by overlaying the equation against the measurements and varying parameters until the plots match
(see \\samba\ece3424\public_html\labs\Experiments\Experiment2\CurvefitsExp2.pdf)

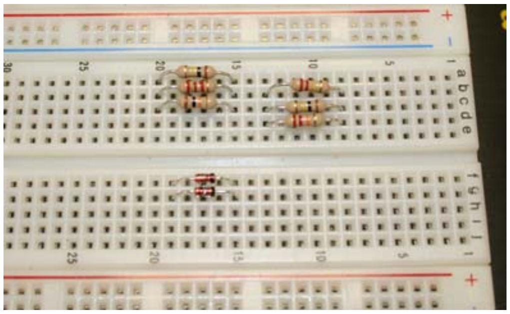
List your results in a results table, along with estimated errors as determined during measurement.

B. Execute test setups in pSPICE using the device model for the 1N4148 diode with the same data points in the data table at the same test levels as your measurements. Show comparisons by means of the X-Y plot function available in Excel.

Look up the parameters for the 1N4148 part via **Edit >Model>Edit Instance Model (Text)** menu of the appropriate SPICE parts library and include these in your results table for comparison and comment.

C. Compare results and comment on the comparisons, accuracies, and error analysis

D. Store used parts on your protoboard for use in later experiments (photo)



APPENDIX A-1: Pinout for 741C opamp

Figure A2-1a: Operational amplifier symbol

Figure A2-1b: 741C Opamp: 8-pin DIP

APPENDIX A-2: Extra diode and capacitance parts. You should have a sufficient number in your parts kit, but if not some extras may be located in the parts box in the parts/wires drawer of your workstation.