ECE 3410 – Microelectronics I
SPICE Handout IV

Diodes

Diodes are declared much like resistors or capacitors.   A diode is identified by a leading 'D':

```
D1 annode cathode model_name
```

Where a resistor or capacitor would be assigned a value, a diode is specified by a more sophisticated *model*. A model contains several parameters which control the non-linear behavior of diodes and other complex devices. A diode model is declared by the following statement:

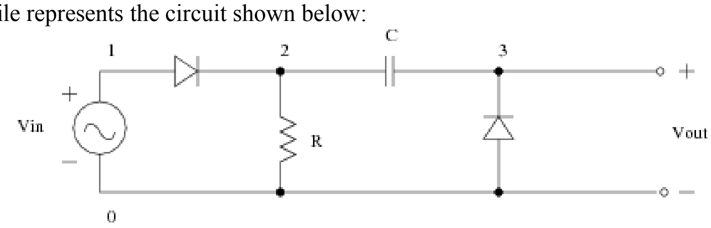
```
.model model_name D( parameters )
```

The `model_name` can be anything of your choosing; "diode" or "diode1" are suitable choices. The parameters are a comma-separated list of values. The minimal values are `Is` and `n`, which are typically on the order of 10fA and 1, respectively.

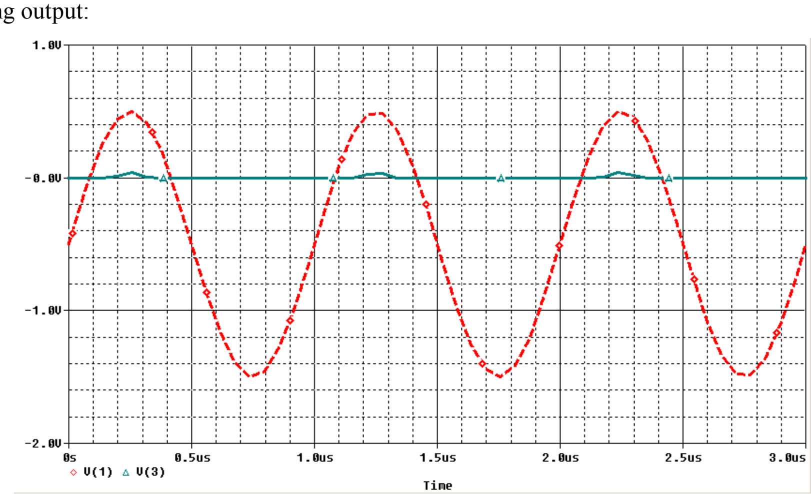
<u>Example 1:</u>

```
* rectifier plus dc restoration circuit

.probe

.model diode d(Is=1e-14, n=0.8)
vin 1 0 sin(-0.5 1 1Meg)
d1 1 2 diode
r1 2 0 1k
c1 2 3 100pF
d2 0 3 diode

.tran 0.05us 3us
.end
```

The above SPICE file represents the circuit shown below:



The resulting output:

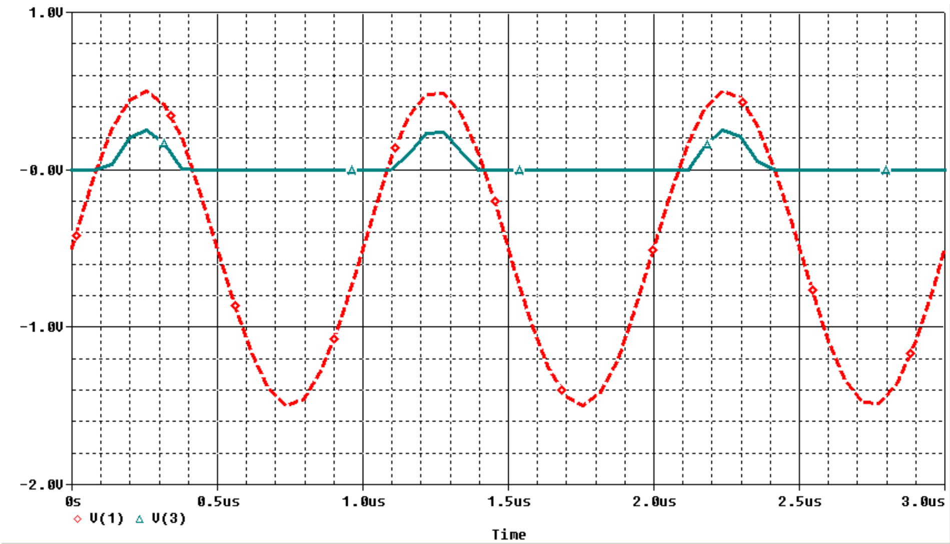


Very little happens at the output of this circuit, because the diode's forward voltage is barely exceeded by the input. It is possible to create a diode model with approximately ideal behavior. Recall the diode exponential characteristic:

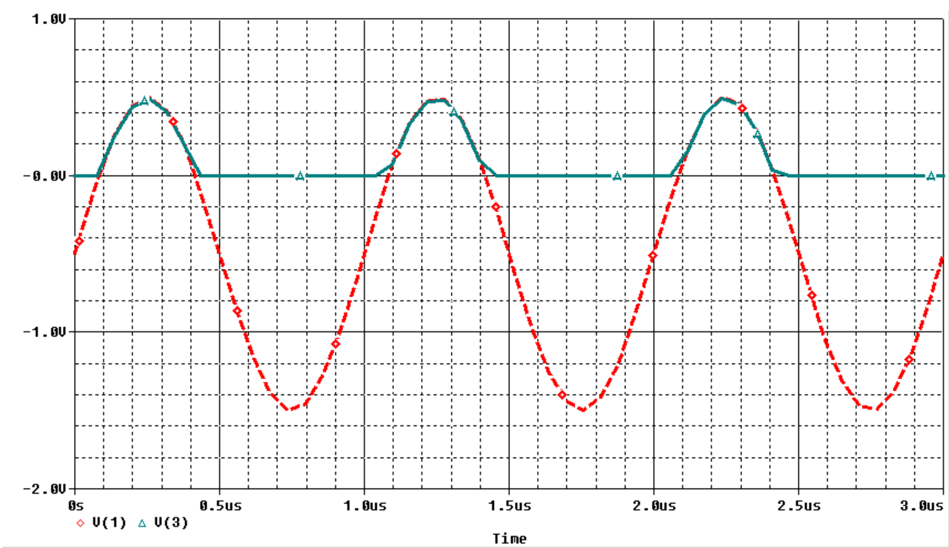
$$I_d = I_S e^{v_d / n V_T}$$

If n is very small, then a very small v_d is required to create a large device current. Therefore we can approximate an ideal diode by creating a model with a very small n.

Here are the results of the rectifier simulation with n=0.4:



And with n=0.2:

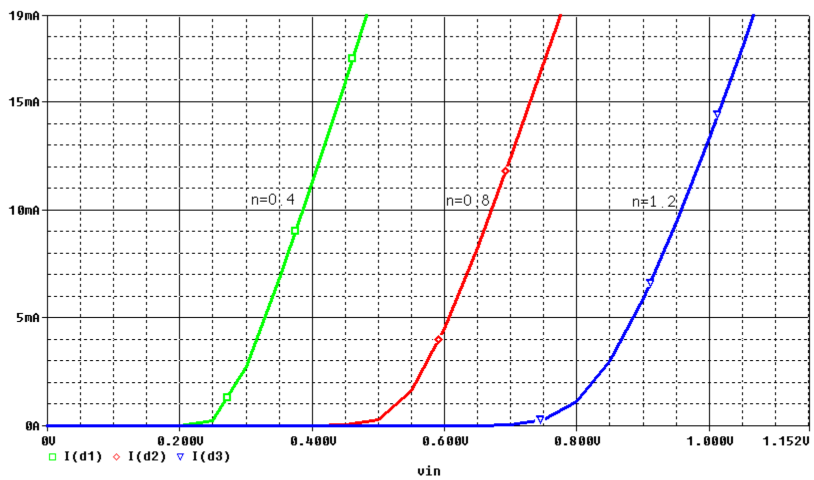


Example 2:

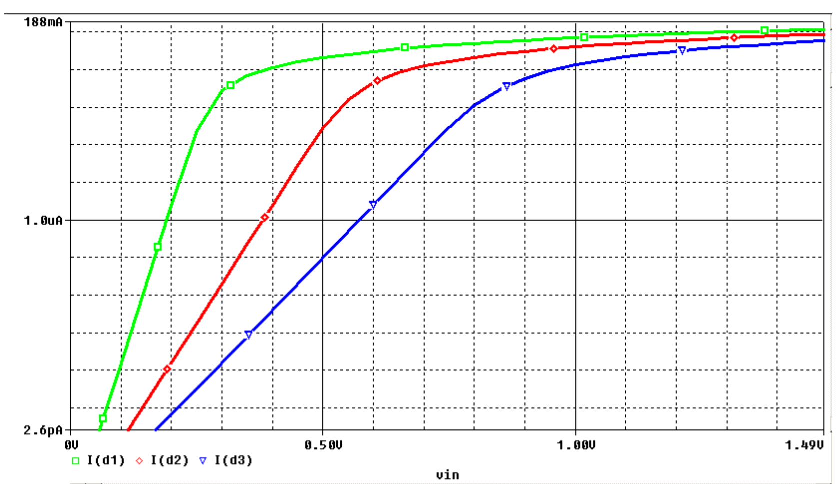
You can also define multiple diode models within the same file, as in the following example.

```
* Diode I-V behavior

.probe

.model diode1 d(Is=1e-14, n=0.4)
.model diode2 d(Is=1e-14, n=0.8)
.model diode3 d(Is=1e-14, n=1.2)

vin 1 0 dc 1V
r1 1 2 10
d1 2 0 diode1

r2 1 3 10
d2 3 0 diode2

r3 1 4 10
d3 4 0 diode3

.dc vin 0 1.5 0.05
.end
```

The results of this simulation are shown below using a linear scale.



This simulation illustrates that the diode's forward voltage is significantly dependent on n. We also see that the diode does not switch on instantaneously. This fact may be better illustrated using a log scale on the vertical axis:

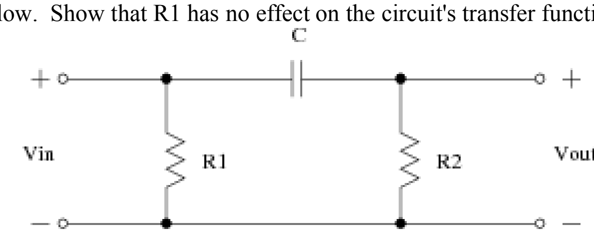


The log-scale results show that the diode current behaves exponentially at small forward voltages. This is indicated by straight lines on a log scale. As the voltage grows, it becomes limited by the 10Ω resistor. When this happens, we see a straight line on the linear scale, and the curve becomes nearly horizontal on the log scale. In this case the diode is said to be "on" because the current depends mostly on other elements in the circuit; the diode can therefore be treated as an effective short circuit. Notice that there is a gradual transition between these regions.

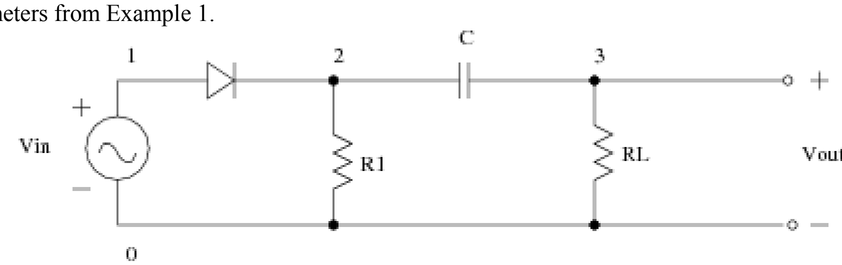
Exercises

1. Simulate the examples given in this handout. Turn in printouts of your output plots.

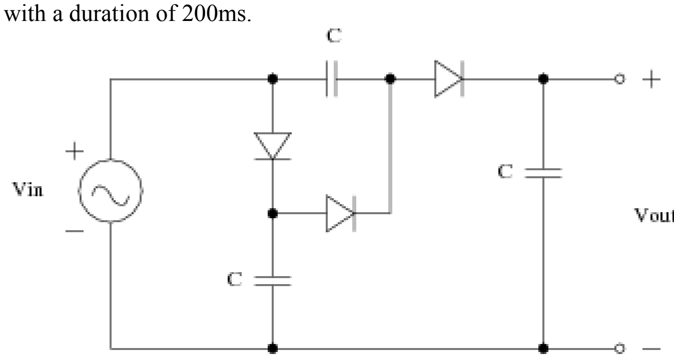
2. Examine the circuit below. Show that R1 has no effect on the circuit's transfer function.



3. Design a SPICE file for the schematic below, using R1=1kΩ, C=1pF and RL=10kΩ. For D1, use a model with parameters IS=1fA and n=0.1. For Vin, use the stimulus from Example 1. Simulate using the transient simulation parameters from Example 1.



4. Create a SPICE file representing the circuit below, using C=1pF, and for each diode Is=1fA and n=0.01. For Vin, use a sinusoidal voltage source with zero offset, 2-V amplitude (4V p-to-p), and a frequency of 100Hz. Perform a transient simulation with a duration of 200ms.



Turn in a plot showing the input and output waveforms. Repeat the simulation using n=1 in the diode model, and turn in a plot showing the input and output waveforms (be sure to label the two plots so that they can be distinguished from each other).

Extra Credit (20 pts): Can you explain the results obtained in exercise 4?