Ideal Diodes

ECE 320 Electronics I (Digital Electronics)

Jake Glower - Lecture #6

Diodes

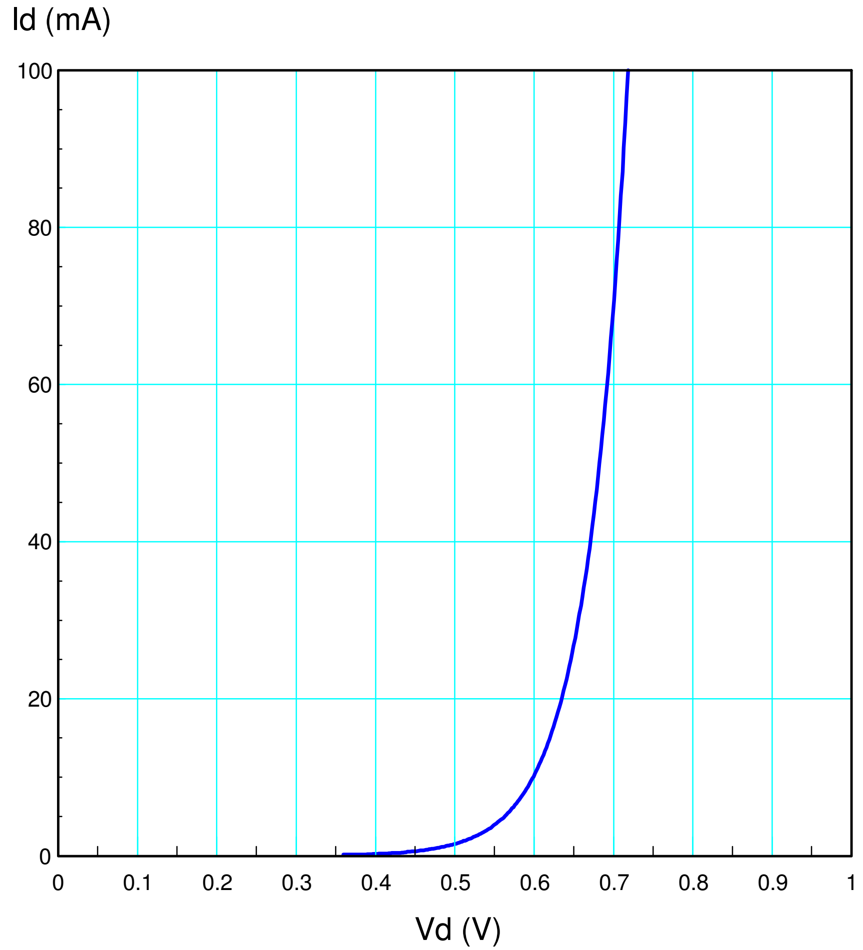
The VI characteristics for a diode are:

$$I_d = I_{dss} \cdot \left(\exp\left(\frac{V_d}{nV_t} \right) - 1 \right)$$

$$V_d = nV_t \cdot \ln\left(\frac{I_d}{I_{dss}} + 1 \right).$$

Problem:

- These are nonlinear equations
- Circuit analysis is difficult
- You have to solve N nonlinear equations for N unknowns



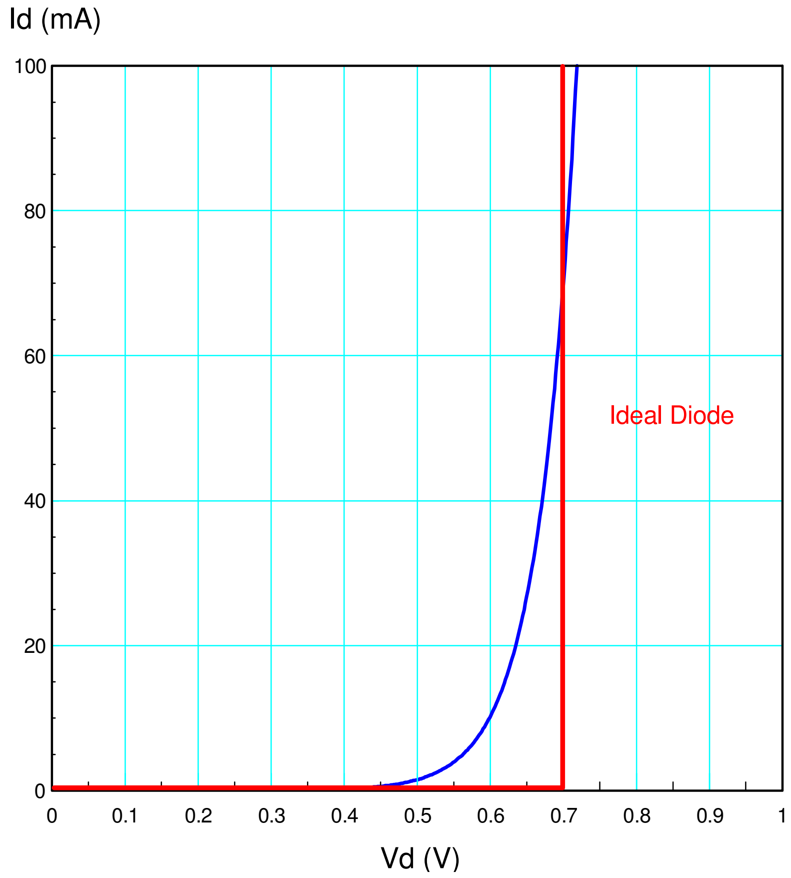
Ideal Diode

Approximate the diode VI characteristics with a model which is

- Simple, and
- Accurate

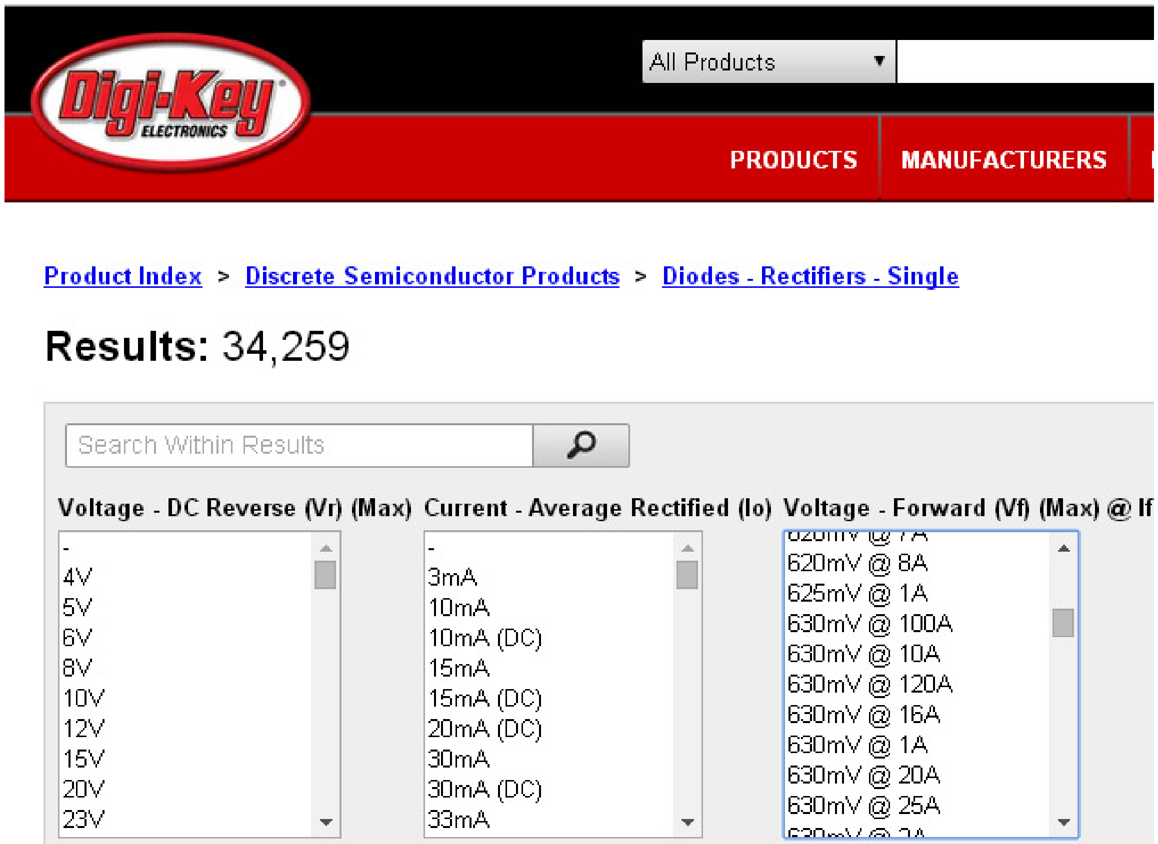
Use a piecewise linear model

State	Model	Condition
On	Vd = 0.7V	Id > 0
Off	Id = 0	Vd < 0.7V



Digikey & Ideal Diodes

- Vf tries to describe a nonlienar curve with a single number
- Ideal Diode: Vd = Vf if Id > 0

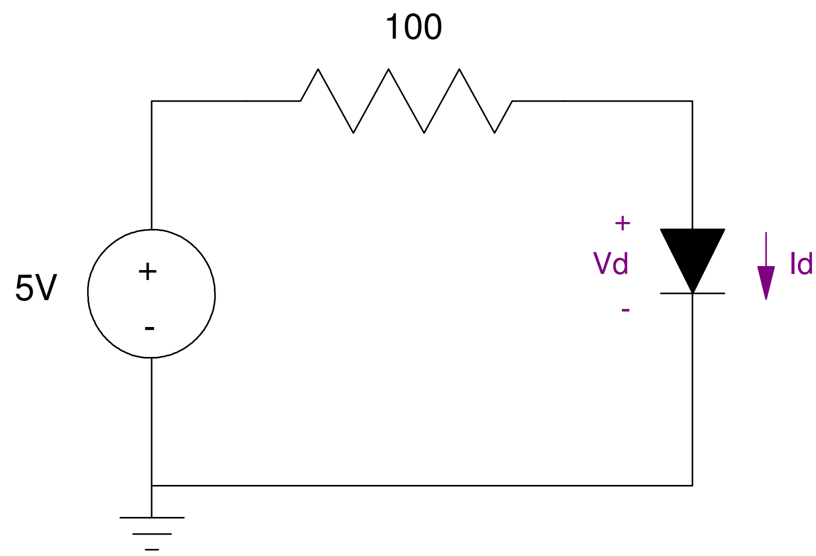


Solving Diode Circuits Using the Ideal Diode Model: Take 1

Nonlinear Solution:

$$I_d = I_{dss} \cdot \left(\exp\left(\frac{V_d}{nV_t} \right) - 1 \right)$$

$$\left(\frac{V_d - 5}{100} \right) + I_d = 0$$



If

- Idss = 7.65e-11
- nVt = 0.0377

then

- Vd = 0.7590V
- Id = 42.41mA

Ideal Diode Model Solution:

Guess the diode is "on"

Vd = 0.7V.

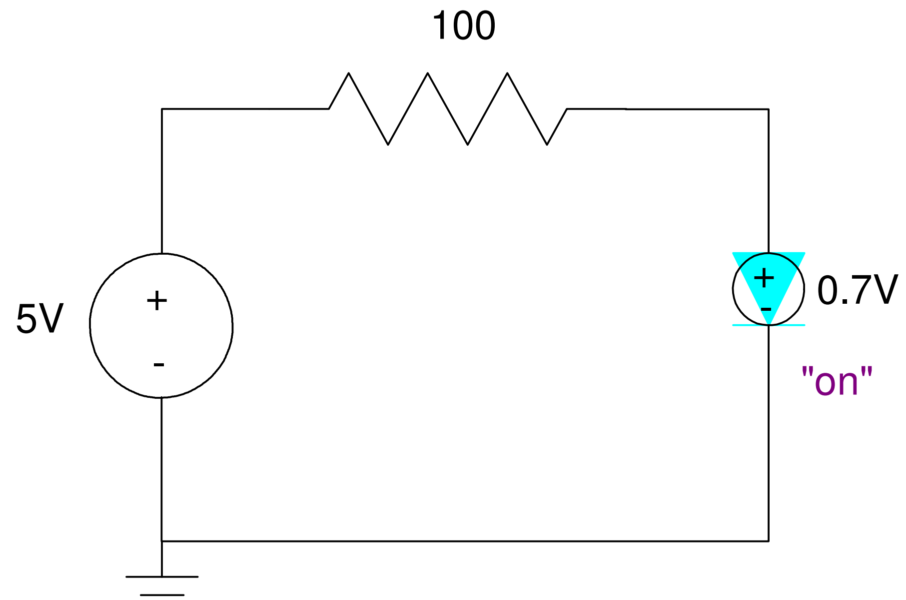
Solve for Id

$$I_d = \left(\frac{5-0.7}{100}\right) = 43mA$$

Check: Id > 0 when on

Note:

- The answer is close
- But slightly different from the nonlienar solution



One Problem, 3 answers

Nonlinear Solution

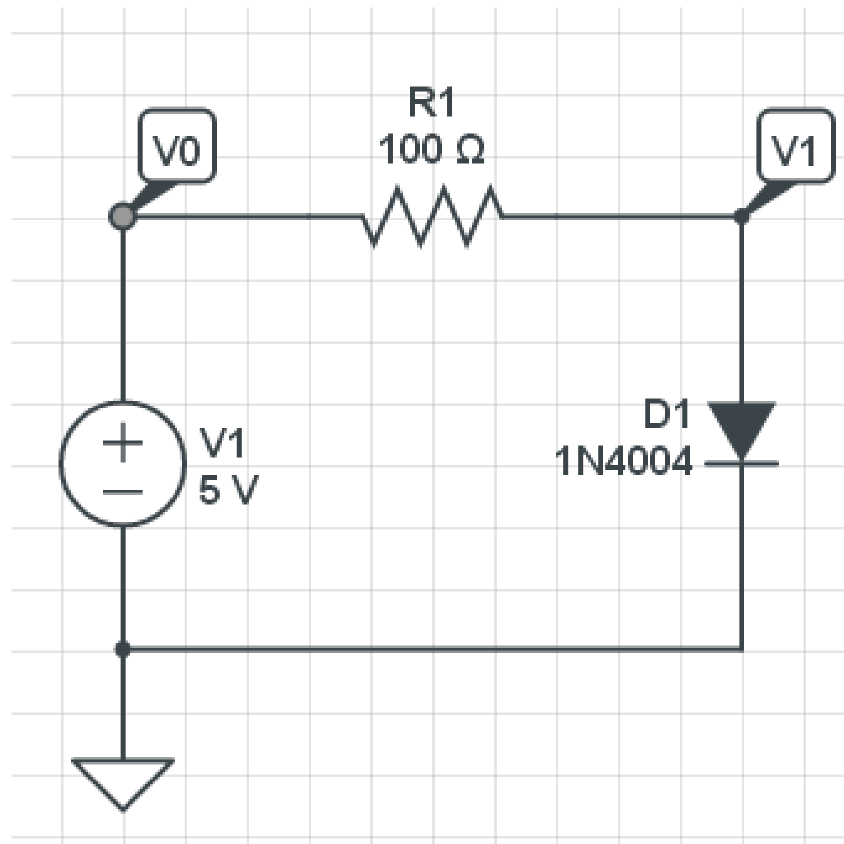
- Vd = 0.7590V
- Id = 42.41mA

Ideal Diode

- Vd = 0.7V
- Id = 43mA

CircuitLab

- Vd = 0.7517V
- Id = 42.48mA



Diode Circuits (take 2)

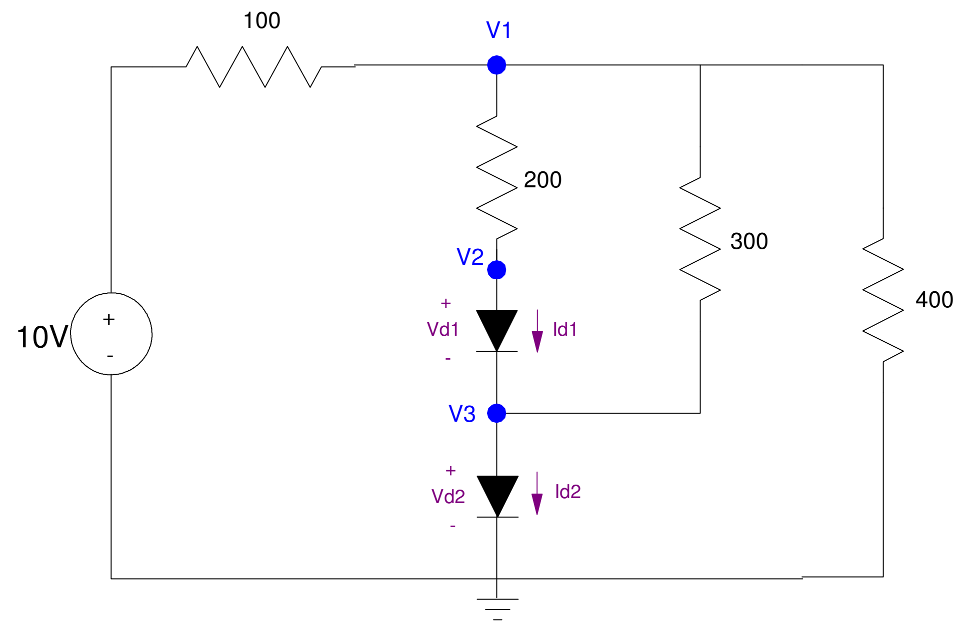
Guess which diodes are on and off

- 2^n permutations
- One is correct
- If you build the circuit, it does *something*

Replace the diodes with their ideal-diode model

Check you results

- On diodes have Id > 0
- Off diodes have Vd < 0.7V



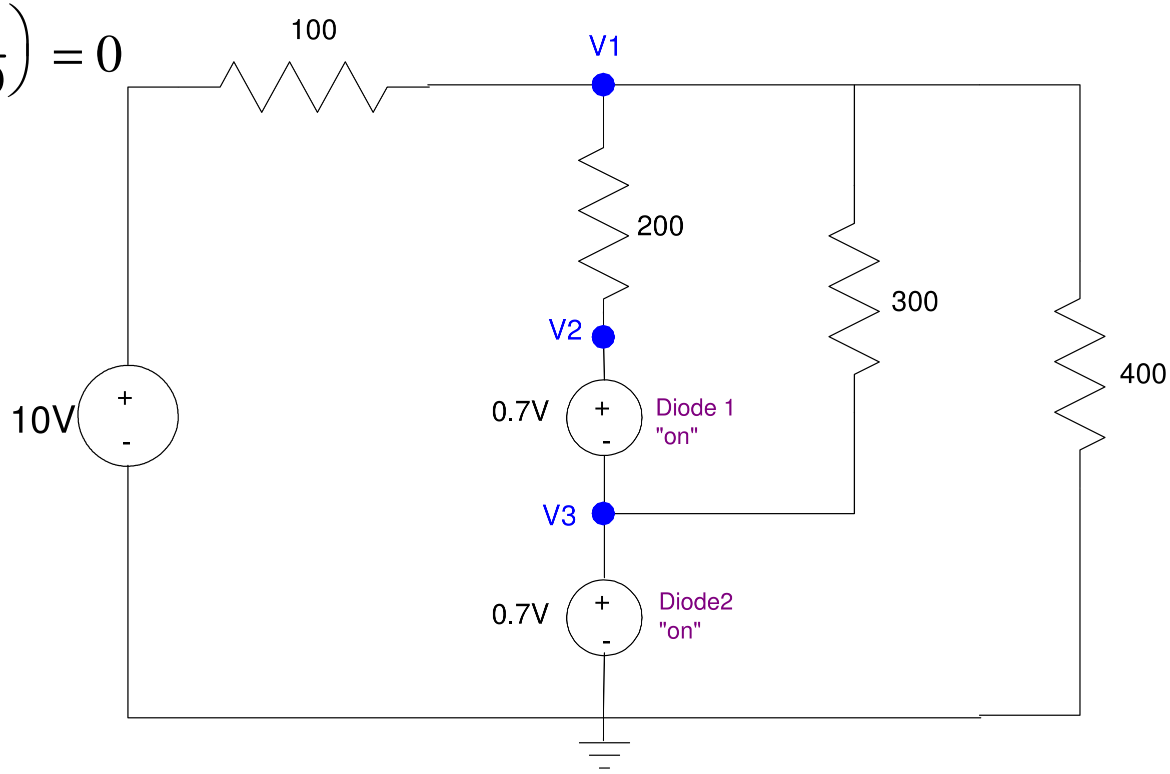
Guess #1: Both diodes are on

- V3 = +0.7V
- V2 = +1.4V

V1 is solved using voltage nodes:

$$\left(\frac{V_1-10}{100}\right)+\left(\frac{V_1-1.4}{200}\right)+\left(\frac{V_1-0.7}{300}\right)+\left(\frac{V_1}{400}\right)=0$$

- V1 = 5.248V



Check:

$$I_{d1}=\left(\frac{V_1-1.4}{200}\right)=19.2mA>0$$

$$I_{d2}=I_{d1}+\left(\frac{V_1-0.7}{300}\right)=32.1mA>0$$

One Circuit, 3 Answers (take 2)

Nonlinear Model:

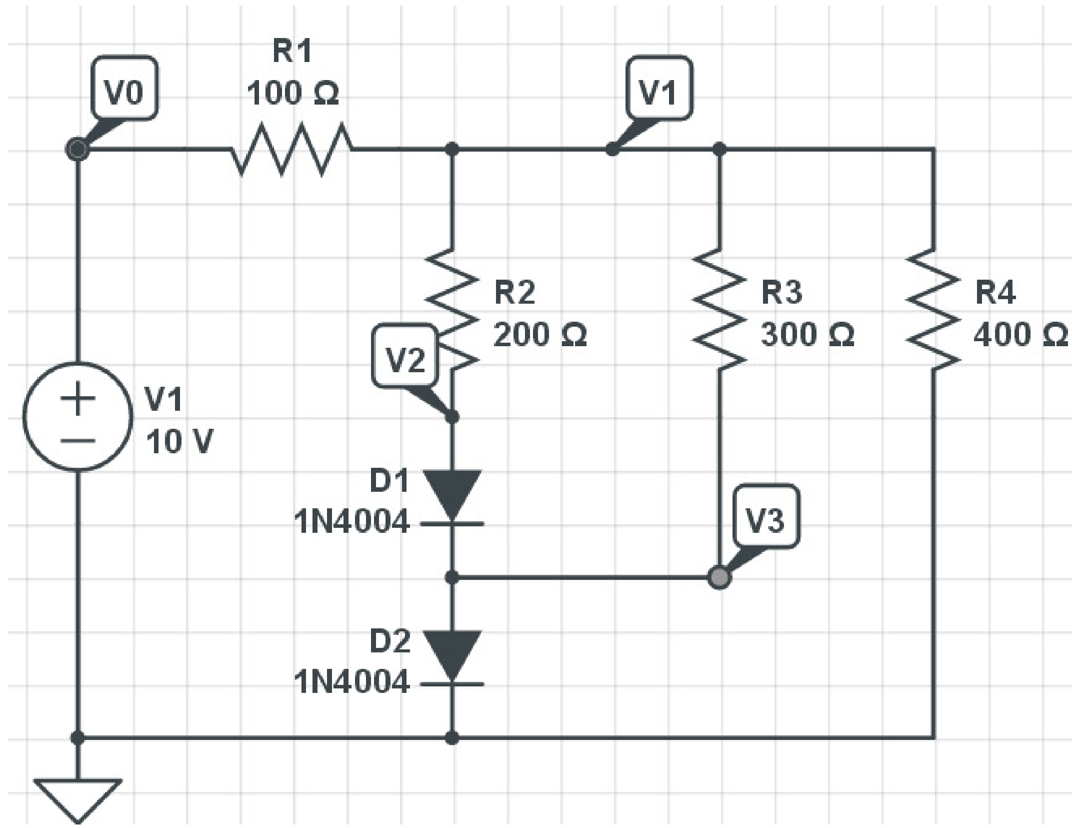
- V1 = 5.2528V
- V2 = 1.4006V
- V3 = 0.7291V

Ideal Diode

- V1 = 5.248 V
- V2 =1.4 V
- V3 = 0.7 V

CircuitLab

- V1 = 5.270V
- V2 = 1.464V
- V3 = 0.7432V



Diode Circuit (take 3)

Repeat if the input voltage drops to 0.2V

Guess both diodes are off

- Id1 = 0
- Id2 = 0

Solve:

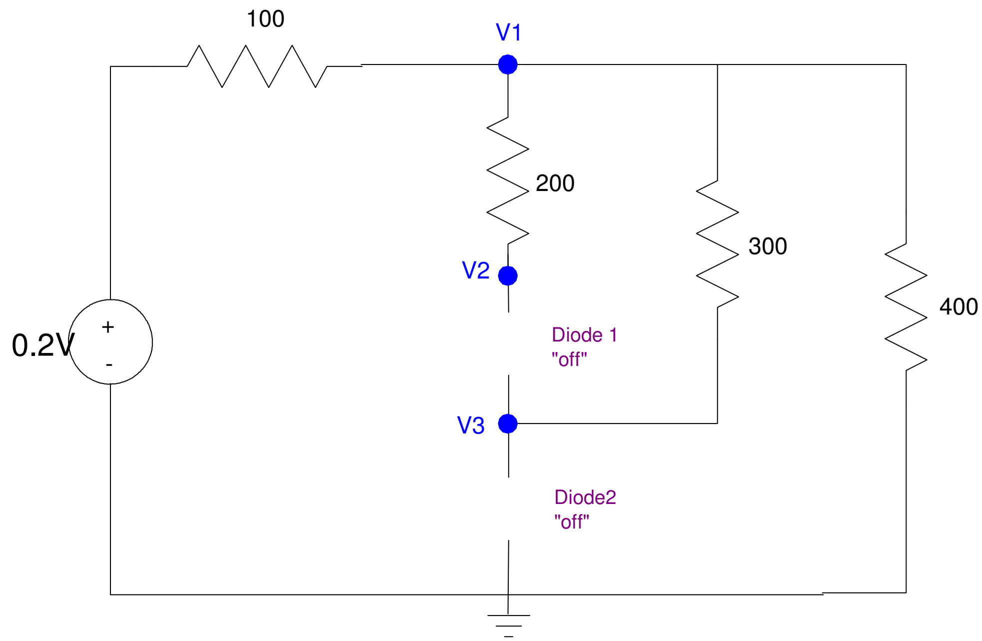
$$\left(\frac{V_1 - 0.2}{100}\right) + 0 + 0 + \left(\frac{V_1}{400}\right) = 0$$

$$V_1 = 0.16V$$

$$V_2 = 0.16V$$

$$V_3 = 0.16V$$

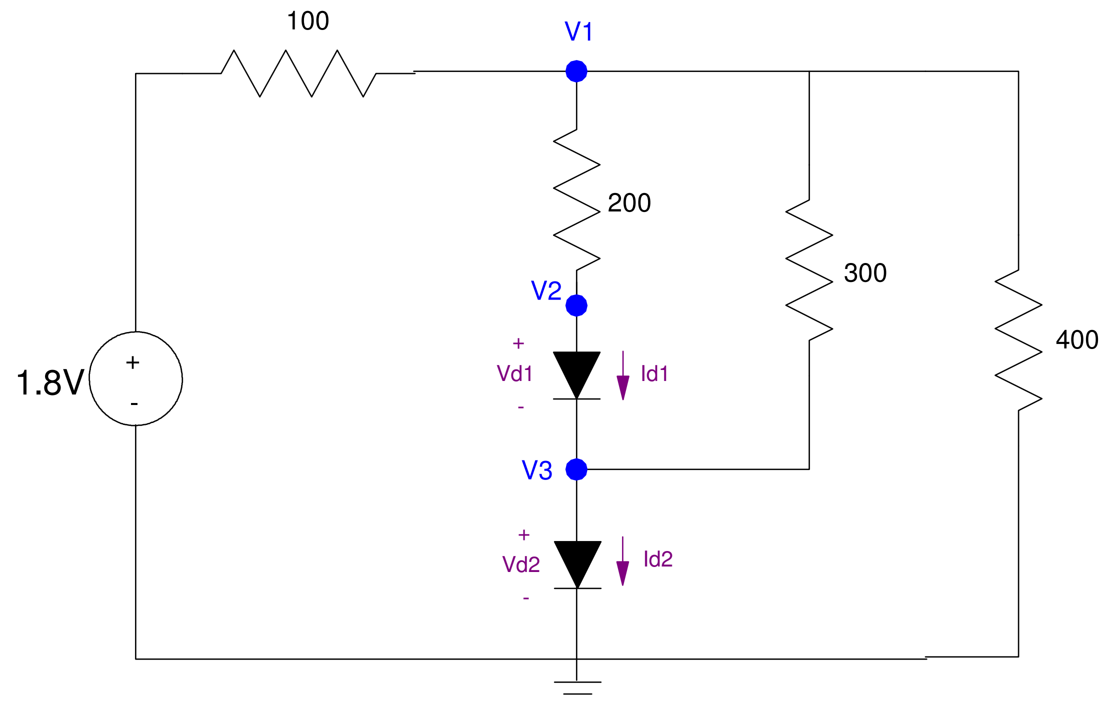
Check: Vd < 0.7



Diode Circuits (take 4)

Repeat when the input becomes 1.8V

- 4 permutations for diode 1 & 2
- One is correct
- *if you build the circuit, it does something*



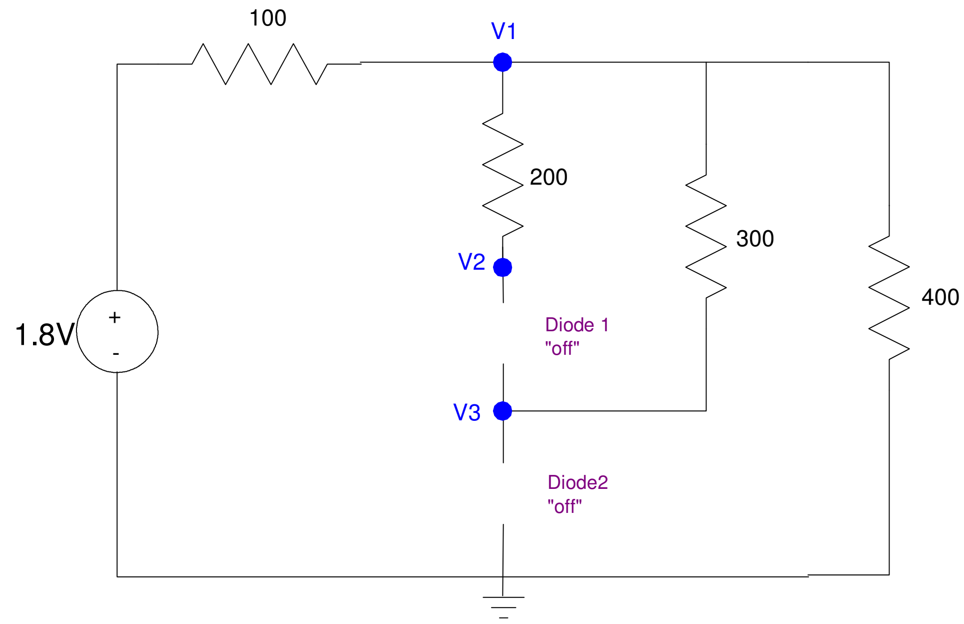
Guess 1: Assume Both Diodes Off:

By voltage division

$$V_1 = \left(\frac{400}{400+100}\right)1.8V = 1.44V$$

$$V_{d2} = 1.44V$$

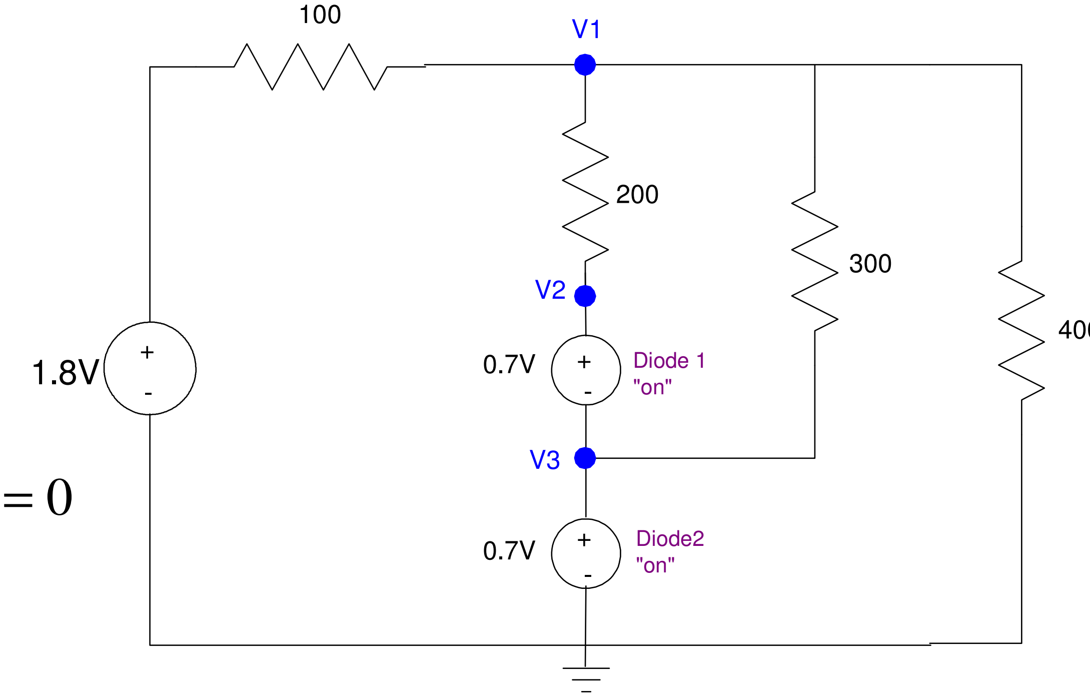
This is too much: 1.44V will turn on diode 2. So, both diodes are not off.



Guess 2: Assume Both Diodes On:

This results in

- V3 = 0.7V
- V2 = 1.4V



By voltage nodes:

$$\left(\frac{V_1 - 1.8}{100}\right) + \left(\frac{V_1 - 1.4}{200}\right) + \left(\frac{V_1 - 0.7}{300}\right) + \left(\frac{V_1}{400}\right) = 0$$

$$V_1 = 1.312V$$

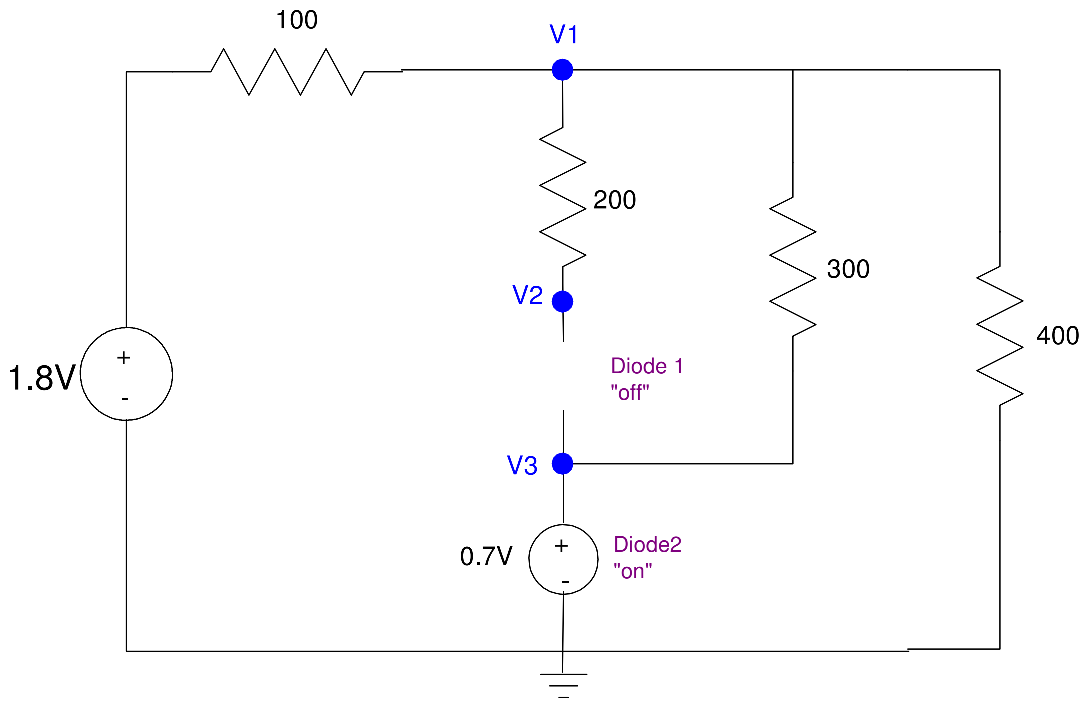
Check:

$$I_{d1} = \left(\frac{V_1 - V_2}{200}\right) = -0.44mA$$

Guess 3: Assume Diode2 is on, Diode1 is off:

Solve using voltage nodes:

$$\left(\frac{V_1-1.8}{100}\right)+0+\left(\frac{V_1-0.7}{300}\right)+\left(\frac{V_1}{400}\right)=0$$



This gives

- V1 = 1.2842 V
- V2 = 1.2842 V
- V3 = 0.7 V

Check: Diode 1 is off:

Vd1 = V2 - V3 = 0.5842V < 0.7V

Diode2 is on

$$I_{d2}=\left(\frac{V_1-0.7}{300}\right)=0.263mA>0$$

One Circuit, Three Solutions

Ideal Diode:

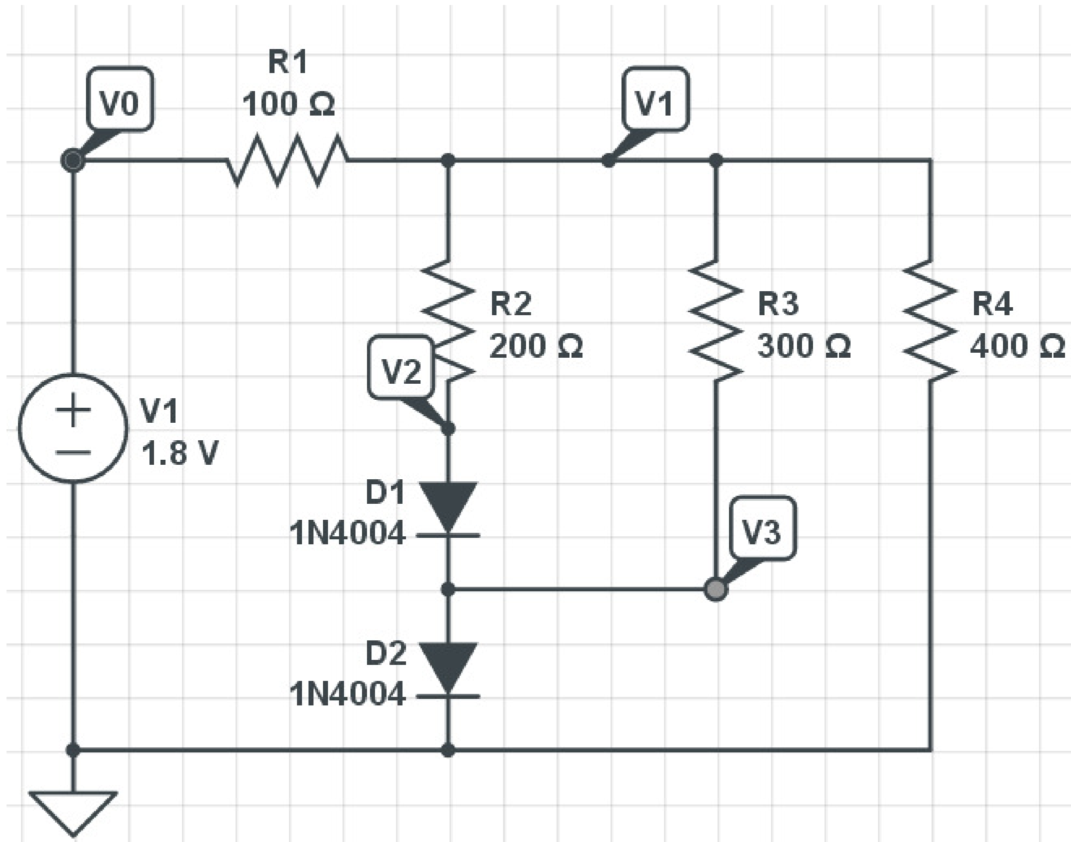
- V1 = 1.2842V
- V2 = 1.2842V
- V3 = 0.7V

Nonlinear

- V1 = 1.2585
- V2 = 1.2115
- V3 = 0.6484

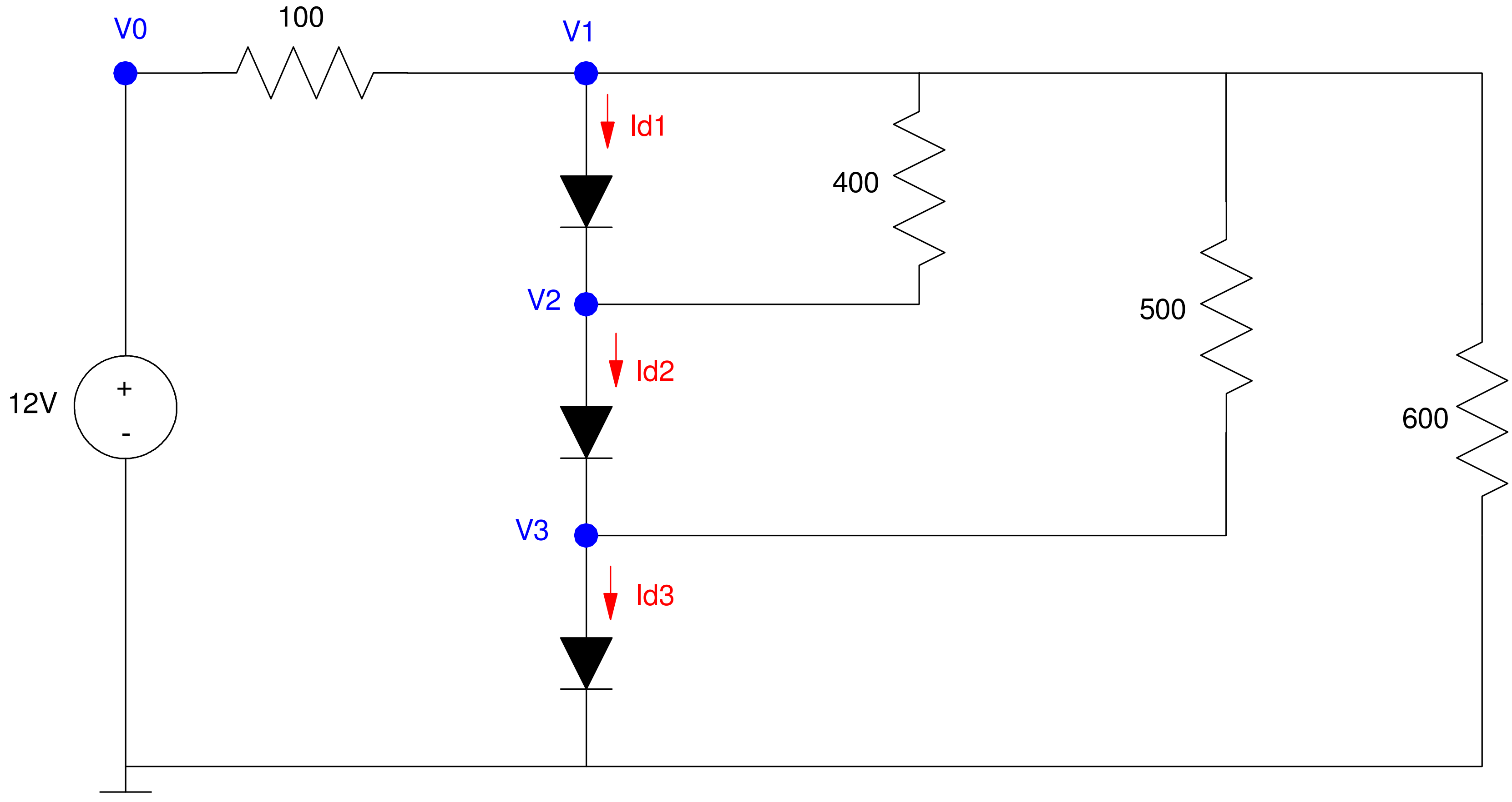
CircuitLab

- V1 = 1.255V
- V2 = 1.202V
- V3 = 0.6415V



Handout:

Determine the voltags and currents assuming ideal silicon diodes



Summary

Ideal diodes simplify circuit analysis

- Result is a linear circuit
- Results will be slightly off

Ideal diodes give better intuition for how diode circuits work

- The diode is a valve that's either on or off

They are a little annoying

- There are 2n possible circuits to analyze
- One is correct (the diode will do something)