SEMICONDUCTORS

Diodes

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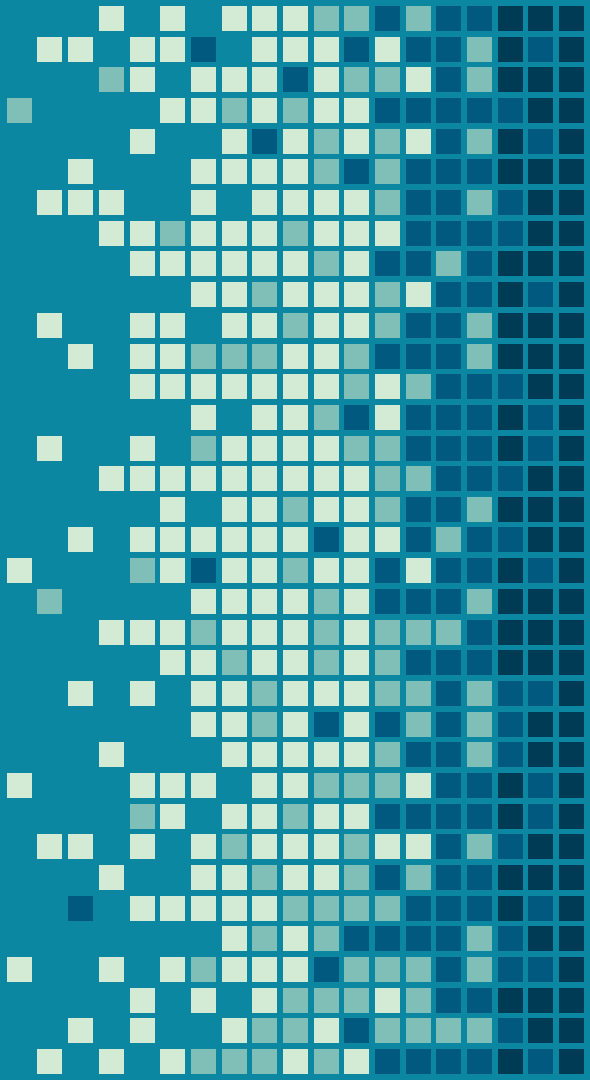
Electrical Engineering – SS 2019 – Duke TIP



INTRO TO SEMICONDUCTORS

What is a semiconductor?

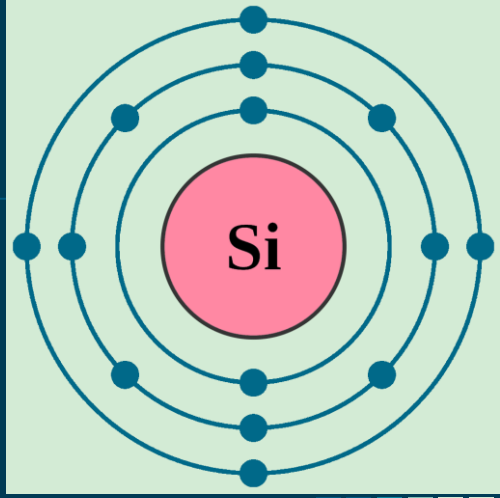
- Conductor – material with number of free electrons.
- Insulator – material with few or no free electrons.

- So is a semiconductor something in between?

Semiconductor

- Semiconductor – a material whose conductivity falls between that of a conductor and an insulator.
- Have several properties that we will exploit:
  - Passes current in one direction more easily than the other direction.
  - Has a variable resistance.
  - Sensitivity to light or heat.
- Common semiconductors: silicon, germanium
- Fun Fact: Silicon Valley was named after the semiconductor silicon. Why?

Silicon



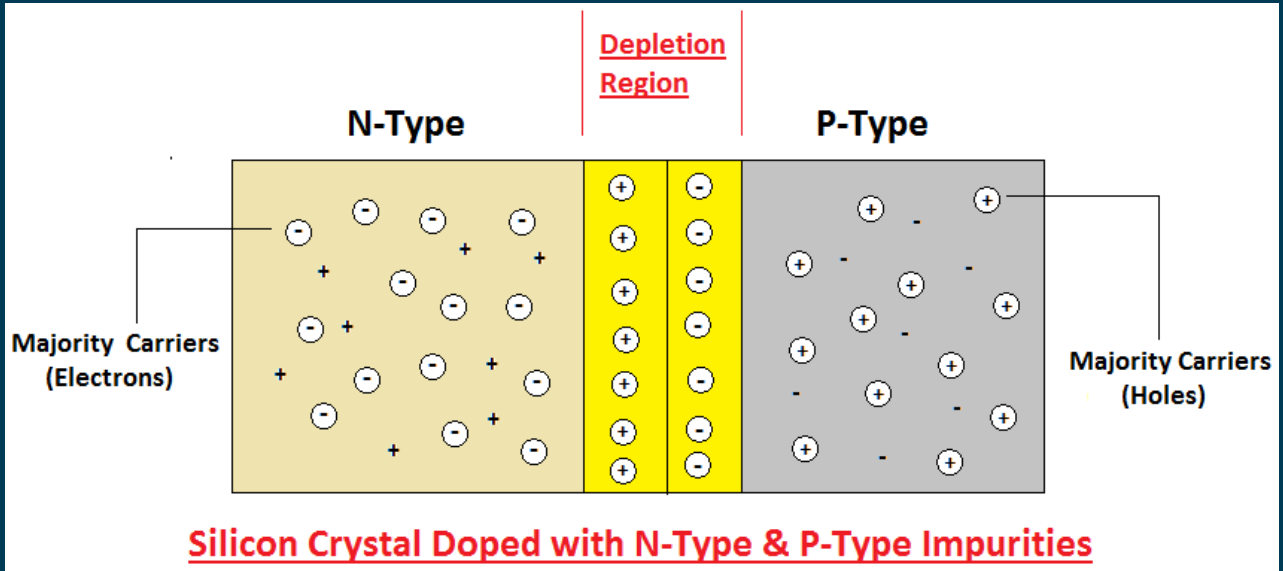
- A great, plentiful semiconductor.
- Has 4 valence electrons, but wants 8.
- It shares electrons with neighboring atoms.
- Holes – opposite of electrons, space in shell where an atom wants an electron.
  - Holes flow in the opposite direction of electrons
  - Holes flow + to - (same as current convention)
- Silicon has 4 electrons and 4 “holes”.

Doping

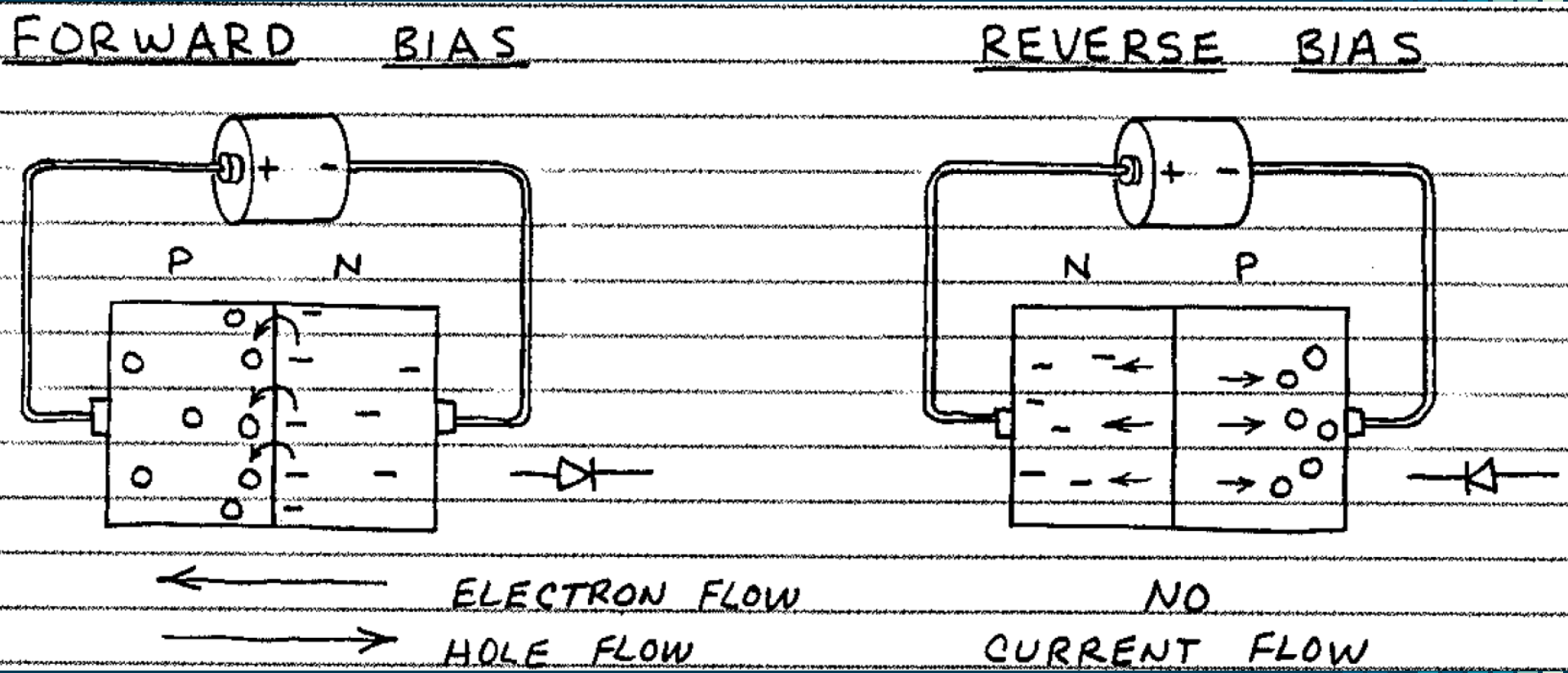
- Silicon on its own isn't very useful.
- We mix it with other atoms like boron or phosphorus to make it have very useful electrical properties.
  - Boron – has 3 valence electrons. When clustered with a silicon atom, it has 1 hole.
    - P-Type - electron deficient (P=positive)
  - Phosphorous – has 5 valence electrons. When clustered with a silicon atom, it as 1 additional e^-.
    - N-Type – extra electron (N=negative)

P-N Junction

- Both P-type and N-type will conduct electricity. Not very useful.
- By adding a P-type material with an N-type material, we can create a much more interesting and useful component leveraging this P-N Junction.

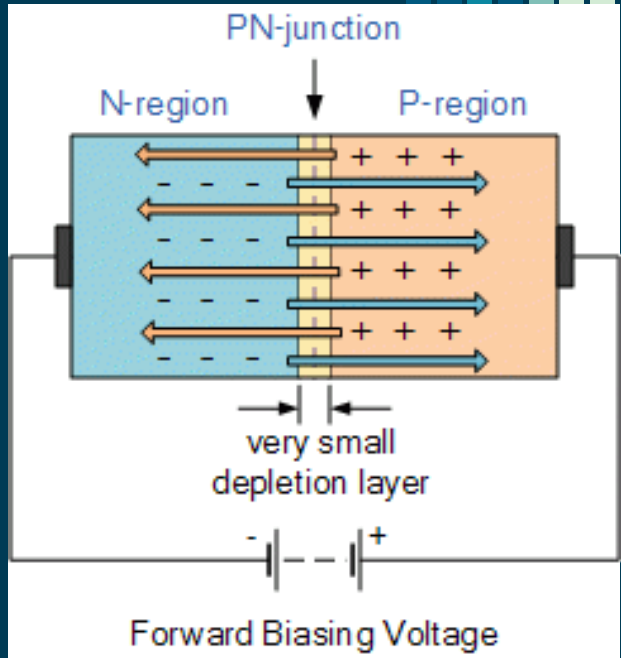


Forward & Reverse Bias



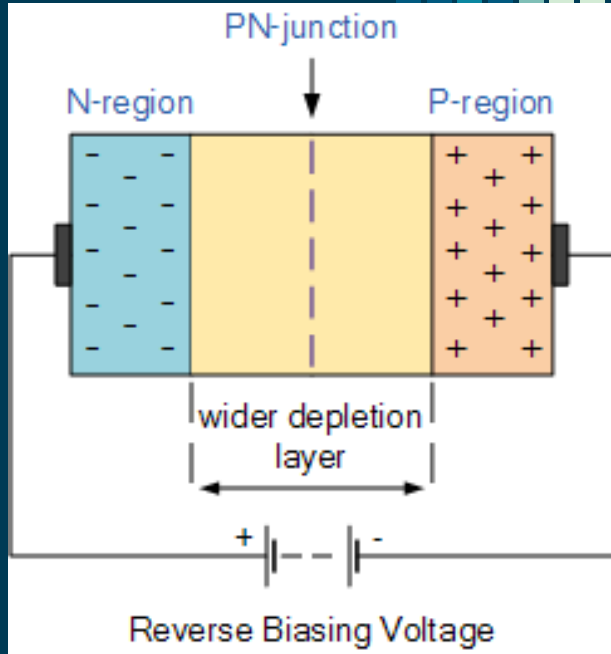
Forward Bias

- P-type region connected to the positive terminal.
- N-type region connected to the negative terminal.
- The charge from the battery repels holes and electrons towards the junction.
- If the voltage exceeds the forward voltage (~0.7 V for silicon), then the electrons will cross the junction to combine with the holes and current will flow.

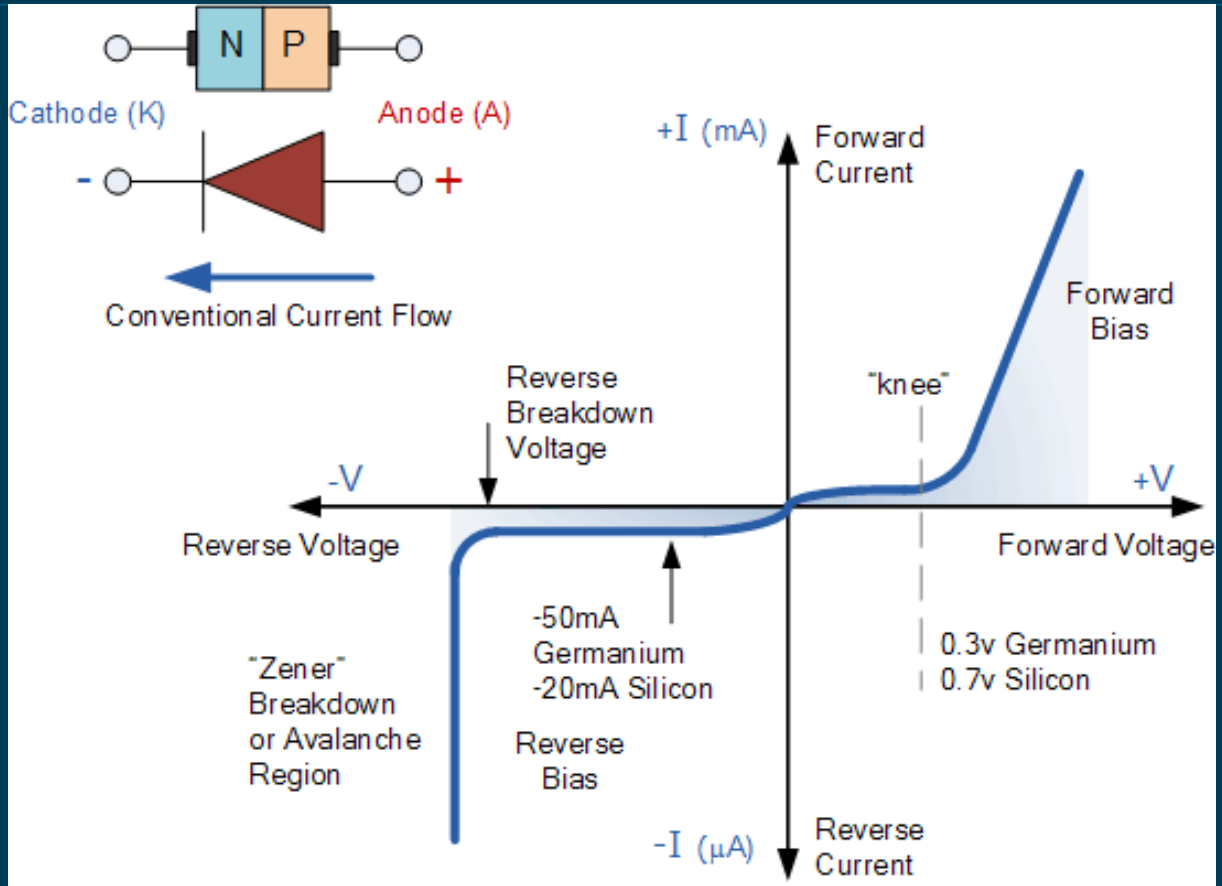


Reverse Bias

- P-type region connected to the negative terminal.
- N-type region connected to the positive terminal.
- The charge from the battery attracts holes and electrons away from the junction.
- Therefore, no current can flow.



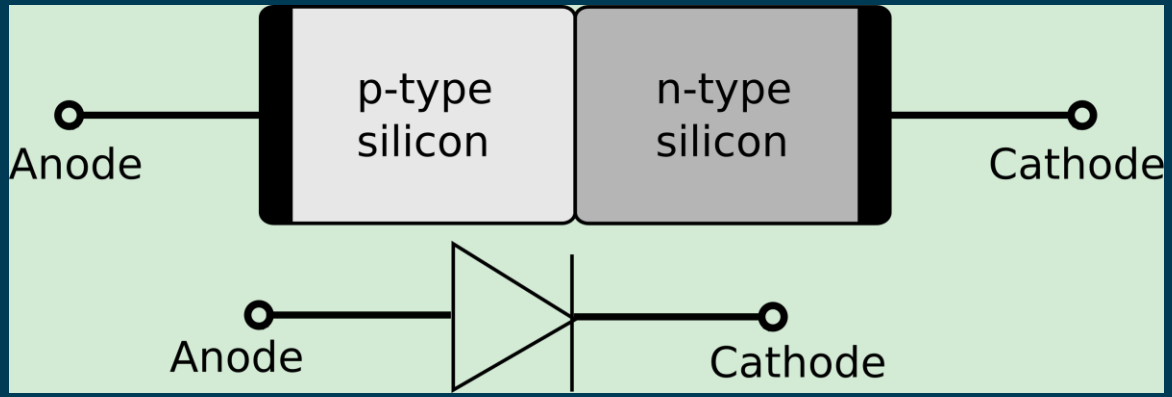
I-V Curve


N
P
Cathode (K)
Anode (A)
-
+
Conventional Current Flow
+I (mA)
Forward
Current
Forward
Bias
"knee"
Reverse
Breakdown
Voltage
-V
+V
Reverse Voltage
Forward Voltage
-50mA
Germanium
-20mA Silicon
0.3v Germanium
0.7v Silicon
"Zener"
Breakdown
or Avalanche
Region
Reverse
Bias
-I (µA)
Reverse
Current

DIODES

Diode

- A diode is just a P-N junction!
- Diode - a two-terminal electronic component that conducts current primarily in one direction
- It has low (ideally zero) resistance in one direction, and high (ideally infinite) resistance in the other.

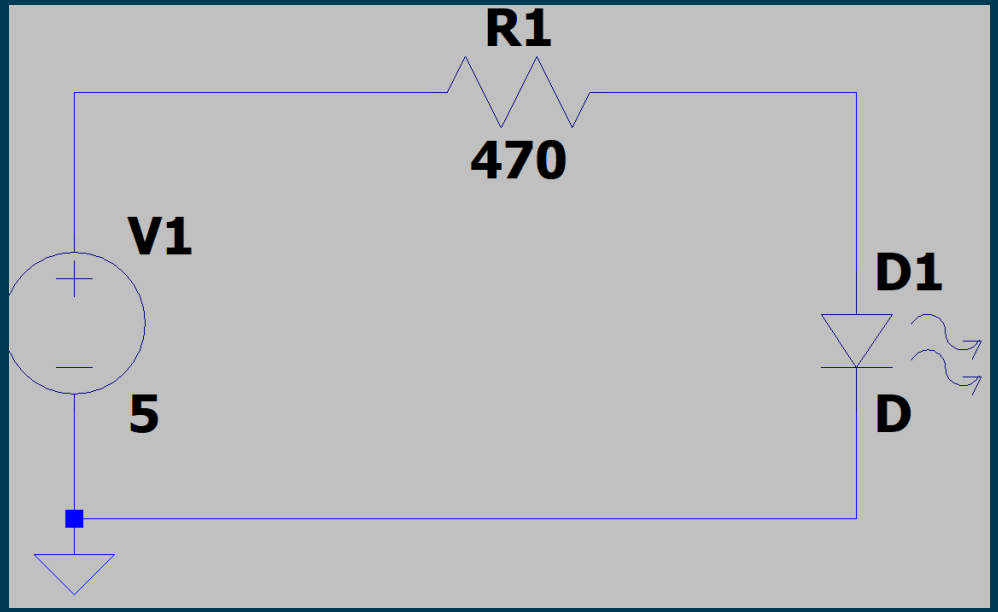


An LED is a diode!

- LED – Light Emitting Diode
- LED - a semiconductor light source that emits light when current flows through it.
- Electrons in the semiconductor recombine with holes, releasing energy in the form of photons.

Activity: LED Circuit Activity

- What happens if you flip the polarity?
- Why do we need the resistor? What happens if you remove it?



Diode Uses

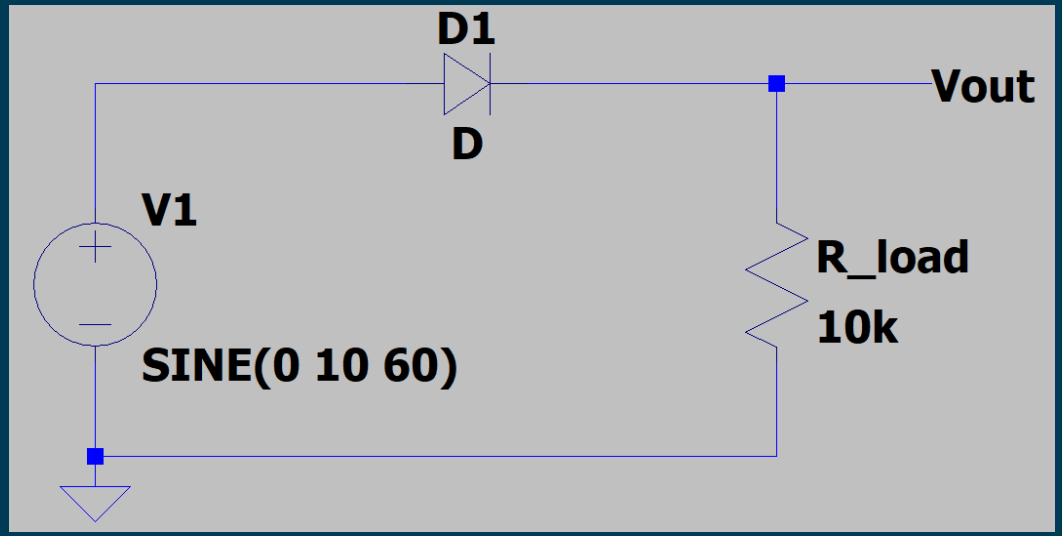
- Voltage regulation
- Voltage rectification
- Surge protection
- Voltage blocking or reverse voltage protection
- Producing light
- Oscillation generators

PROBLEMS

ACTIVITIES

Activity: Diode Rectifier

- What does the output voltage Vout look like if the input voltage is an AC sinusoidal signal?
- What does it look like if the diode is reversed?

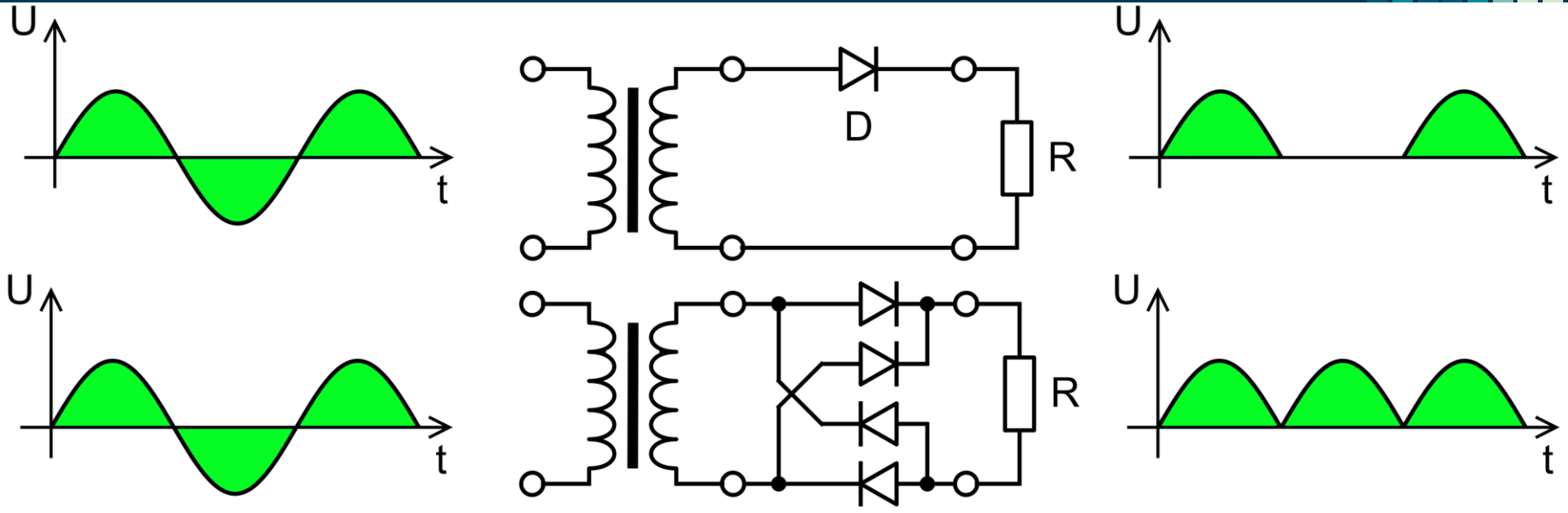


Activity: Rectifying AC to DC

- How could we make a DC voltage out of an AC sinusoidal signal using diodes and a capacitor?

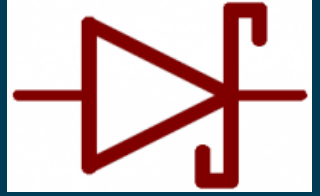
Rectifiers

- Ltspice simulations
- Why do we use a transformer?



ZENER DIODES

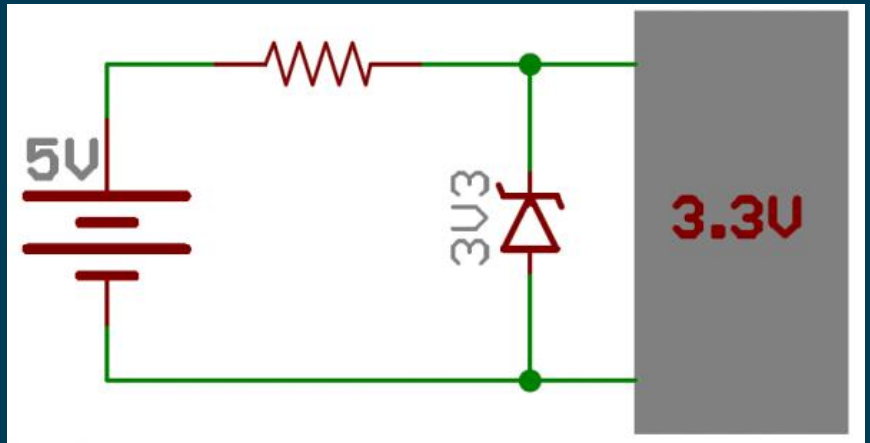
Zener Diodes



- They're usually used to intentionally conduct reverse current.
- We reverse bias them instead of forward biasing.
- Zener's are designed to have a very precise breakdown voltage, called the zener breakdown or zener voltage.
- When enough current runs in reverse through the zener, the voltage drop across it will hold steady at the breakdown voltage.

Zener Circuit Applications

- Taking advantage of their breakdown property, Zener diodes are often used to create a known reference voltage at exactly their Zener voltage.
- They can be used as a voltage regulator for small loads, but they're not really made to regulate voltage to circuits that will pull significant amounts of current.



MORE ACTIVITIES

Activity: Flyback Diode

- We discussed flyback diodes.
- Supply 3V to DC motor and measure voltage across.
- Switch off the DC supply.
- How high does the reverse voltage get?