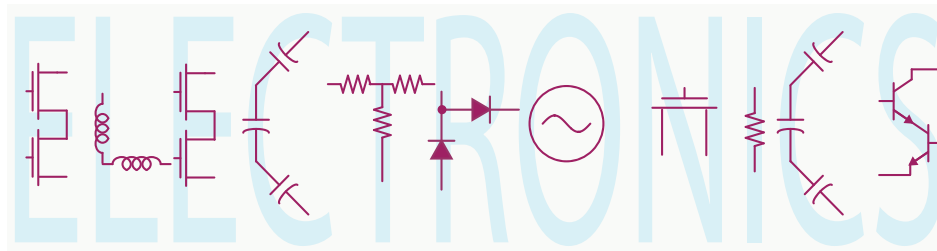


*EE 42/100*  
*Lecture 20: Diodes and Applications*



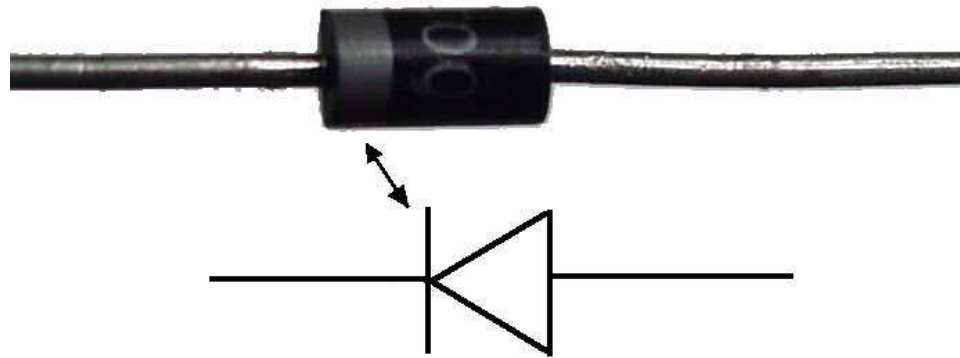
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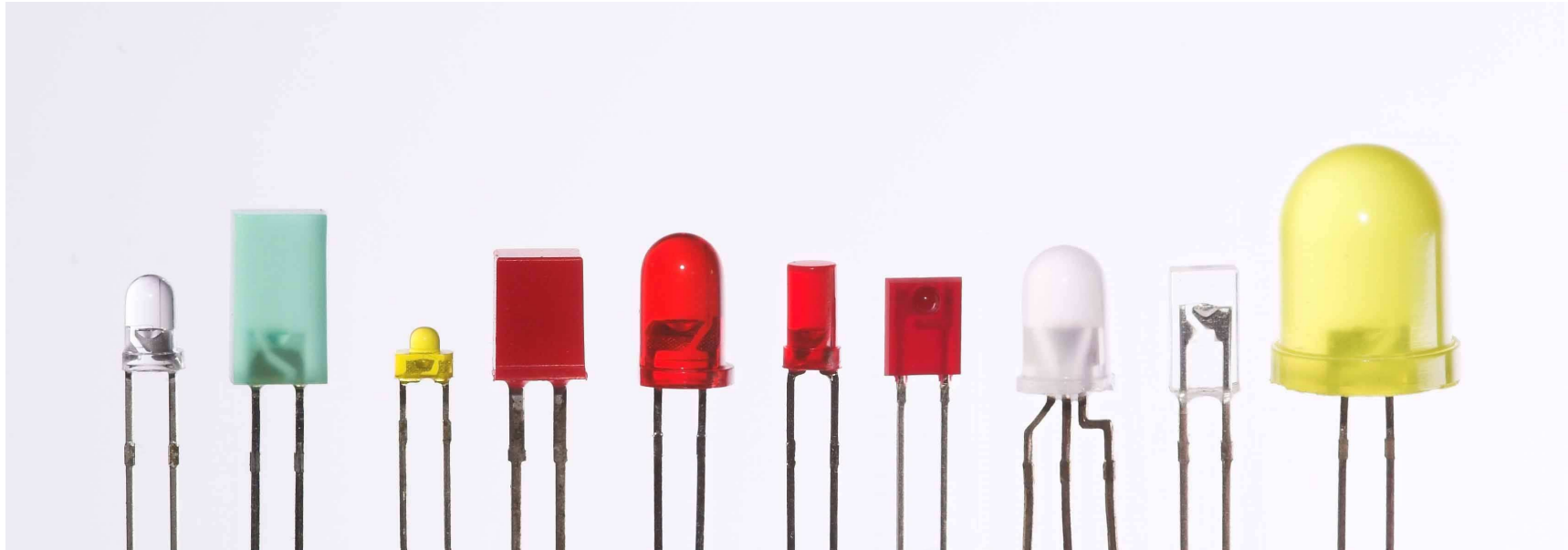
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# Diode Introduction



- A diode is our first example of a non-linear element. To a very good approximation, the current through the diode is exponentially related to the voltage across the diode.
- Diodes are manufactured primarily using a semiconducting process. The junction between two semiconducting materials creates a diode.

# Light Emitting Diode (LED)



- A light emitting diode emits light (of a particular color) when current flows through the diode. The conversion efficiency is much better than light bulbs.
- In incandescent light sources, a lot of heat is produced, which lowers the efficiency (it's just a thin wire in vacuum!)
- Compact Fluorescent (CF) lights bulbs are more efficient, but need high frequency AC signals
- LEDs as a light source run on DC and lower voltages (although light bulbs with built-in AC->DC are available for direct replacements) and are very reliable (much longer lifetime inherently, but also by construction if many tiny bulbs are used in parallel).

## *Diode Operation*

- A “p-type” semiconducting material has an excess of mobile “holes” (vacancies that move around and act as positive charges). These holes act like positive charges.
- An “n-type” semiconductor has an excess of mobile electrons. Note that in isolation both materials are neutral.
- When placed into contact, the mobile electrons and holes flow across the junction and the initially uncharged materials obtain charge. This creates a potential barrier between the junctions.
- This potential barrier prevents (balances out) the flow of current across the barrier in steady state.

## *Diode I-V Curve*

- When a “forward-bias” is applied across the diode, lowering the built-in potential, a rush of current flows across the junction. It can be shown that this current is an exponential function of the barrier height.
- When a “reverse-bias” is applied, the barrier height increases, and so no current flows.

## *Diode Leakage and Reverse Breakdown*

- Even with a reverse bias voltage, some small leakage current flows through the diode. This is because there are always a very small number of electrons (holes) in the p-type (n-type) material that are moving around. If they reach the potential barrier, they “float up” (remember they are electrons) or “fall” off the barrier. There are so few electrons (holes) in the p-type (n-type) material that this is a rare occurrence.
- Note that by this argument, the leakage current is independent of the reverse bias. Electrons will ‘float’ up the barrier no matter the height! Holes will ‘fall’ down the barrier no matter the height.
- If a sufficiently negative voltage is applied, the internal barrier height gets so large that breakdown occurs. Then a seemingly unlimited current can flow.

## *Zener Reference*

- When breakdown occurs, the diode behaves like a “battery”. No matter what current is drawn, the voltage is nearly constant. This is often used as a voltage reference.
- The breakdown mechanism can be due to quantum mechanical tunneling or due to avalanche breakdown.
- Note that even though it’s acting like a battery, it’s actually passive and so it does not source current.

## *Ideal Diode Model*

- An ideal diode only allows current to flow in one direction. That's because the current is zero when a negative voltage is applied. When a positive voltage is applied, any current can flow and so the diode looks nearly like a short circuit.
- The “on” voltage is related to the barrier height, and for Si it's about 0.7V. For LEDs it's larger, between 2V - 4V.
- Always use a series resistor with an LED to limit the current.



## *Half-Wave Rectifier*

- The simple circuit shown above will only conduct during the positive cycle of the sinusoidal voltage.
- This is called “rectification” because it fixes the AC voltage if you’re trying to get rid of it’s negative polarity. As we’ll see soon, this way we can easily convert AC to DC.

## *Full-Wave Rectifier*

- This bridge circuit will conduct current during both cycles. Due to the polarity of the diodes, current is always flowing in the same direction through the load, even for a negative voltage.
- This means that the circuit performs an absolute value function.

## *Filtered Rectified Voltage*

- The capacitor is used to filter out the variations in the voltage.
- During the positive cycle, the capacitor is charged and it holds its output steady. The charging time is very fast because the diode “on” resistance is very small.
- During the negative cycle, the diode turns off and the output voltage is provided by the capacitor. If the load is sufficiently large, then the discharge time constant is relatively long, and so the voltage droops only a bit.

## *Full-Wave Filtered Output*

- The same idea works for the full-wave rectifier, and now the output variation is even less.
- Bridge rectifiers are ubiquitous in equipment used to convert AC line voltages to DC voltages used by most electronic equipment. A transformer is need to bring down the line voltage. Increasingly, transformers are replaced by switching power supplies, something we'll learn about later.

# Clippers

- Diodes are often used to limit the voltage excursion, especially to protect a circuit.
- When DC sources are used in series with the diodes, the clip point can be set to any desired value. Zener references are handy for this application.

## *Level Restorers*

- In this circuit the diode turns on initially and charges the capacitor to the AC voltage. Note that once the voltage starts to drop, the diode turns off.
- The output voltage is therefore level shifted by the DC voltage held on the capacitor.
- In this case the voltage excursions are now negative and never rise above zero!
- If a load is connected, then the capacitor should be large enough to minimize the droop.

## *Another Level Restorer*

- If we now flip the direction of the diode, the current will only flow during the negative half cycle, charging the capacitor now in the opposite direction.
- Then output is now lifted by the DC voltage stored on the capacitor. The voltage will now always remain positive and never go below zero!

## *Voltage Doubler*

- If we rectify the above voltages, we can generate positive or negative DC voltages of twice the magnitude. This is a voltage doubler!