Analog Electronics

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1st **semester**

Chapter 3
Special-Purpose Diodes

Lec. 7

Zener Regulation with variable load

Figure 1 shows a zener voltage regulator with a **variable load resistor across** the terminals.

The zener diode **maintains a nearly constant voltage across R_L as long as** the **zener current is greater than I_{ZK}** and **less than I_{ZM}**.

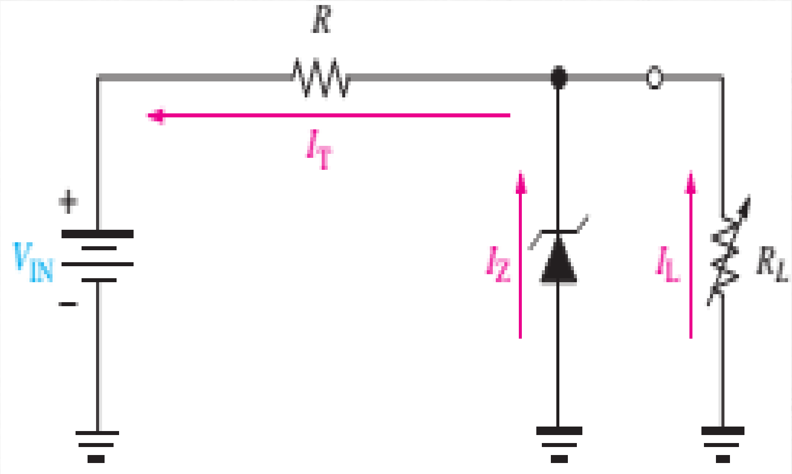
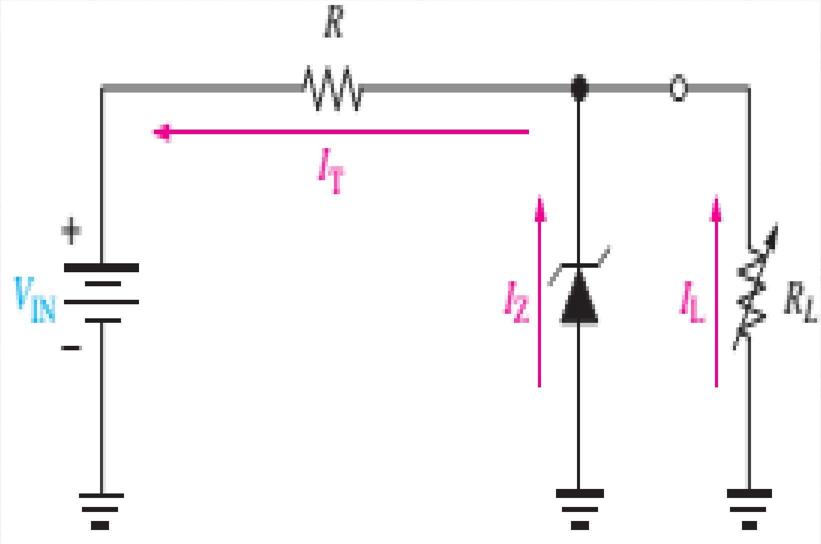


Figure 1: Zener regulation with a variable load.



When **R_L=∞** (open-cut), the **load current is zero,** and **all the current passes through the Zener diode.**

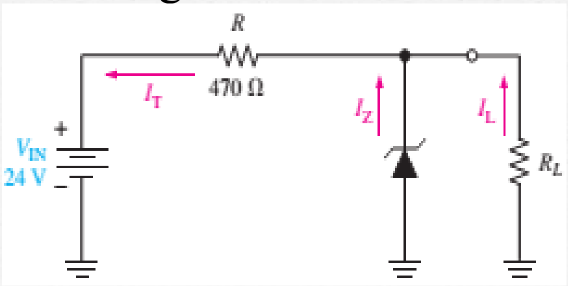
The **current** is **divided** between the **Zener diode and R_L,** when RL is connected. The total current through R remains constant **as long as** the **Zener is regulated**.

As **R_L decreases**, **I_L increases,** and **I_Z decreases**. The Zener **continues to regulate the voltage until I_Z reaches its minimum value**.

Now, the **load current is maximum**, and a **full-load condition exists**.

Example:

Determine the **minimum** and the **maximum load currents** for the Zener diode in Figure 3 will maintain regulation. **What** is the **minimum value of R_L** that can be used? V_Z= 12 V, I_{ZK}= 1 mA and I_{ZM}= 50 mA. Assume an ideal Zener diode where Z_Z= 0 Ω and V_Z remains a constant 12 V over the range of current values.



Solution

When I_L=0, (R_L=∞), I_Z=I_{Zmax}= I_T

$I_{(Z(max))}$= I_T= (V_{IN} -V_Z)/R= (24-12)/470= 25.5 mA

R_L can be removed without disturbing regulation if this value is less than 50 mA.

$I_{L(min)}$ = 0 A

$I_{L(max)}$ occurs when I_Z is minimum (I_Z = I_{ZK})

$I_{L(max)}$ = I_T−$Iz_{(min)}$ = 25.5 mA −1 mA = 24.5 mA

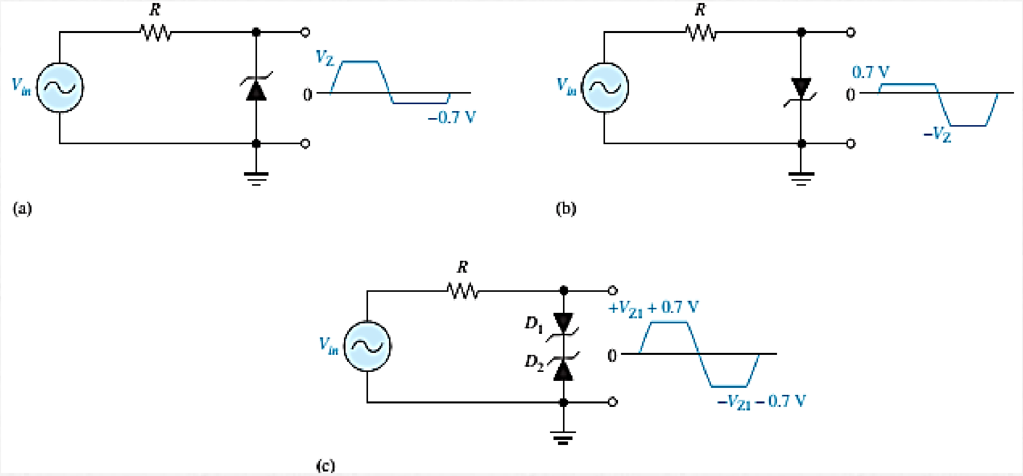
The minimum value of R_L is

$R_{(L(min))}$ =V_Z/$I_{(L(max))}$ = 12 V/ 24.5 mA= 490 Ω

Regulation is **maintained** for any value of R_L between 490 Ω and infinity.

Zener Limiter

- Zener diodes can be **used** as **limiters**. Figure 4 shows **three basic ways** the limiting action of a Zener diode can be used.
- During the negative alternation, the Zener acts as a **forward-biased diode and limits the negative voltage to 0.7V, as in part (A).**
- When the Zener is **turned around**, as in part (**B**), the **negative peak** is limited by Zener action, and the **positive voltage is limited to +0.7V**. **Two back-to-back Zeners limit** both peaks to the Zener voltage **± 0.7V,** as shown in part (**C**).



- Figure 4: Basic Zener limiting action with a sinusoidal input voltage.

Varactor Diode

A varactor diode is a special-purpose diode **operated** in reverse bias to form a **voltage-controlled capacitor** rather than traditional diodes.

The **applied voltage** controls the **capacitance** and hence the resonant **frequency**. The **width of the depletion region** increases with **reverse bias**.

These devices are commonly **used** in communication systems.

Varactor diodes are also referred to as tuning diodes.

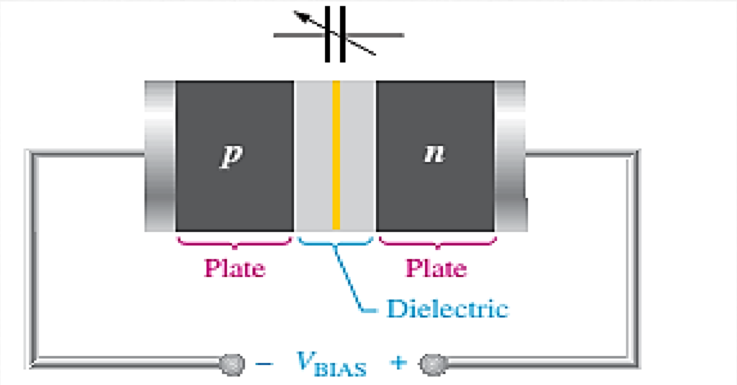


Figure 5: The reverse-biased varactor diode acts as a variable capacitor.

Optical Diodes

This section introduces three types of optoelectronic devices: the light-emitting diode, quantum dots, and the photodiode.

The Light-Emitting Diode (LED)

Light Emitting Diodes (LEDs), diodes can be **made** to emit light electroluminescence or sense light.

When the **device** is forward-biased, **electrons cross the pn junction from** the n-type material **and** recombine with holes in the **p-type material**.

The **free electrons** are in the conduction band and at a higher energy than the **holes** in the valence band.

The **difference in energy between** the electrons and the holes **corresponds** to the energy of visible light.

When **recombination** takes place, the **recombining electrons** release **energy in the form of photons**.

Conduction Electrons and Holes

The emitted light tends to be monochromatic (one color) depending on the band gap (and other factors). A large exposed surface area on one layer of the semiconductive material permits the photons to be emitted as visible light. This process, called **electroluminescence**, is illustrated in Figure 6. LEDs vary widely in size and brightness–from small indicating lights and displays to high-intensity LEDs used in traffic signals, outdoor signs, and general illumination.

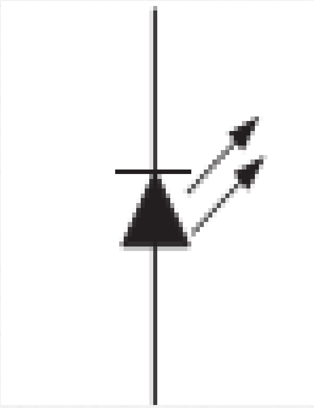


Figure 6 A: Symbol for an LED. When forward-biased, it emits light.

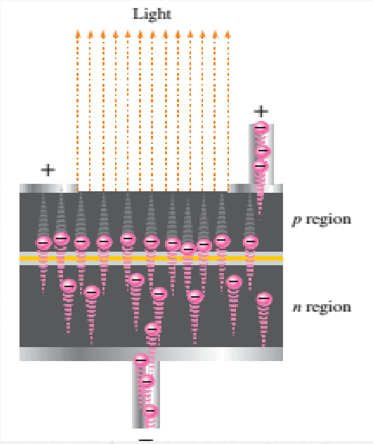


Figure 6 B: Electroluminescence in a forward-biased LED.

The Photodiode

The **photodiode** is a device that operates in **reverse bias**, as shown in Figure 13,

where is $\mathbf{I_\lambda}$ the reverse light current.

The **photodiode has** a small transparent window that allows light to strike the pn junction.

A **photodiode** differs from a rectifier diode in that the reverse current increases with the light intensity when its pn junction is exposed to light. When **there is no incident light**, the reverse current, I_λ, is almost negligible and is called the dark current.

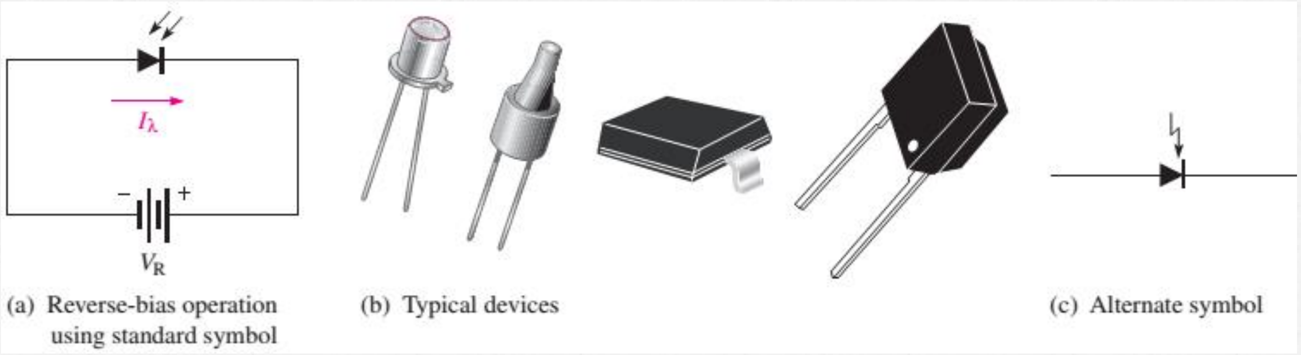


Figure 13:Photodiode.

You are less likely to encounter several types of diodes as a technician. Among these are the **laser diode**, the **Schottky diode**, the **pin diode**, the **step-recovery diode**, the **tunnel diode**, and **the current regulator diode.**

The Laser Diode

Laser light is **monochromatic**, meaning it **consists of a single color, not** a mixture of colors, compared to incoherent light, which consists of a wide band of wavelengths.

The laser diode normally **emits** coherent light,

whereas the **LED emits** incoherent light.

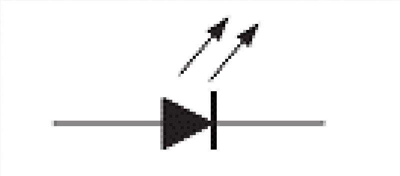


Figure 14: Symbol for a Laser Diode.