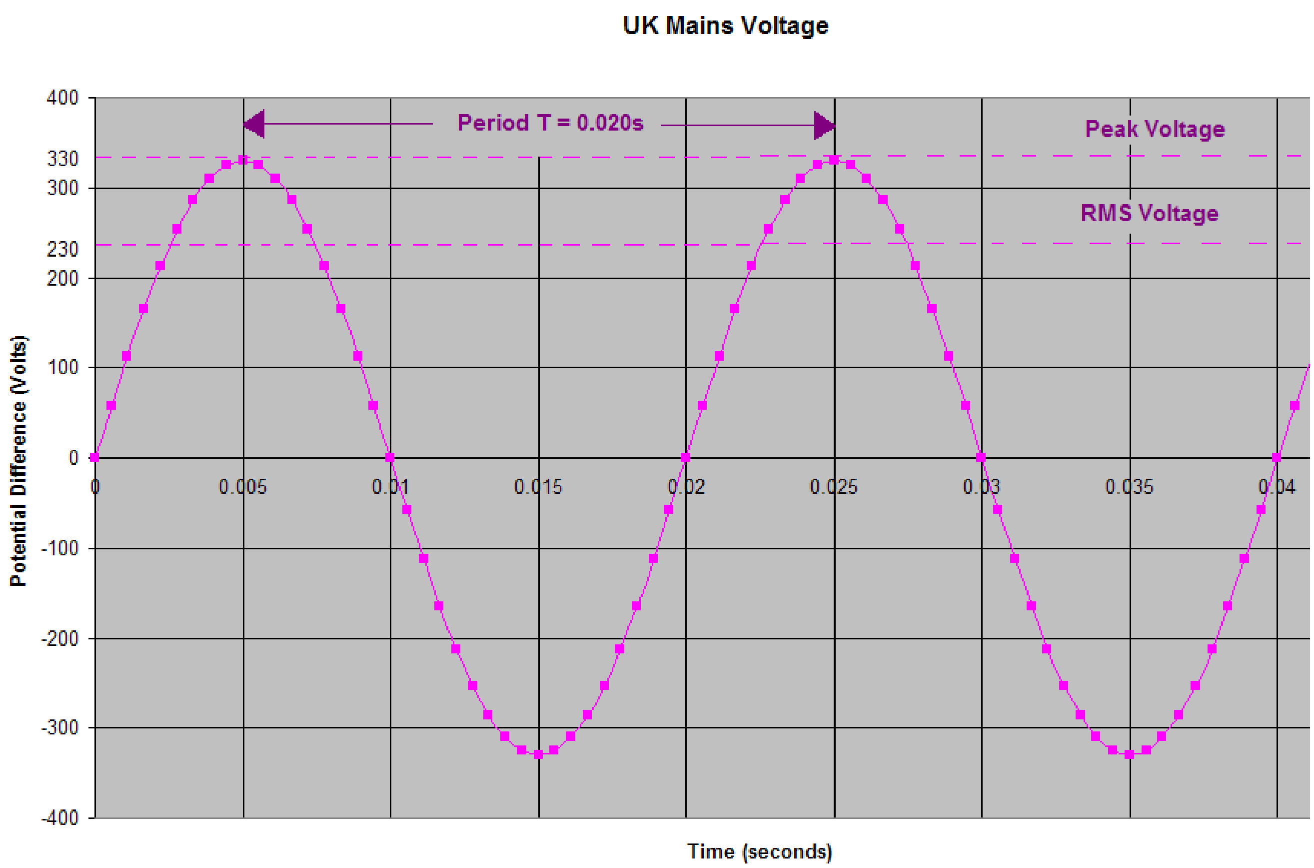
Applications of Diodes – DC Power Supply

- One of the most common uses of a diode in **large-signal** operation is as a rectifier.
- Large-signal means changes in V and I are large.
- A DC power supply is a device that gives a constant DC voltage output for a sinusoidal voltage input.
- The sinusoidal input is normally taken from the mains supply of 230 V, 50 Hz.

  * The 230 V designated here is the rms value of voltage.

230V 50 Hz mains supply

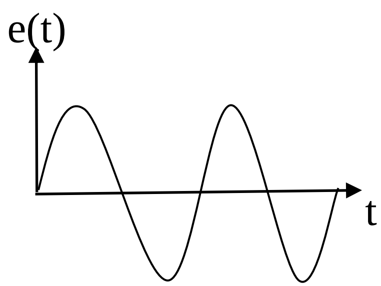


Designing a DC Power Supply

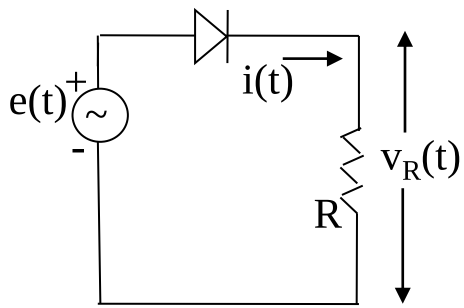
Rectifier

- A rectifier is the first stage in designing a constant DC power supply.
- A rectifier is a device that allow current to flow through in one direction only.

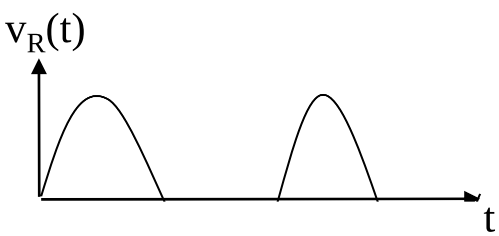
A simple rectifier circuit that contains an ac source e(t) and load R



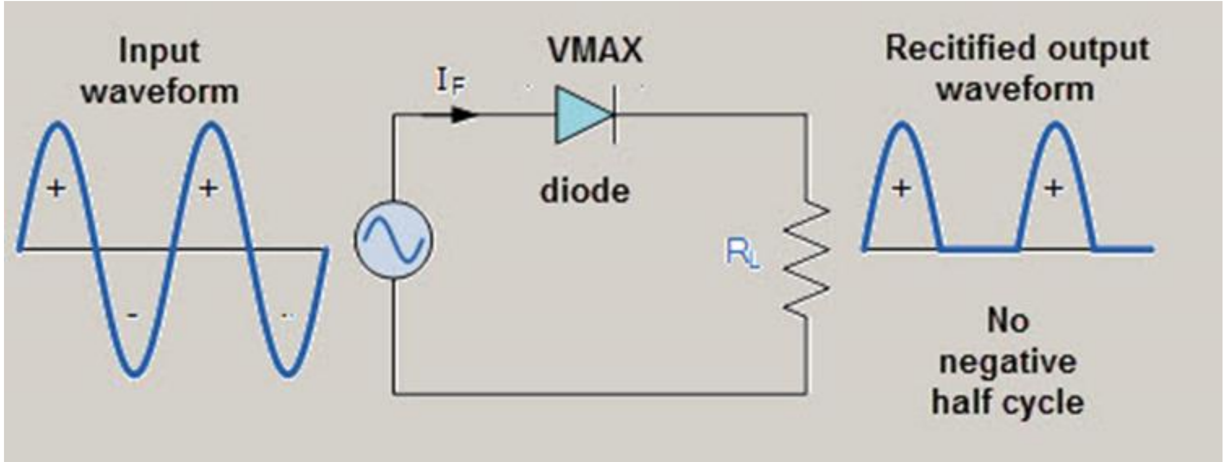
Input



Rectifier



Output



- During the +ve half cycle the diode is forward biased and current will flow.
- During each –ve half cycle the diode is reverse biased and no current flows (except for I_s).
- Net effect is the conversion of an ac voltage into a pulsating DC voltage, the fundamental step in the construction of a DC power supply.
- **The single diode is called a half wave rectifier**.

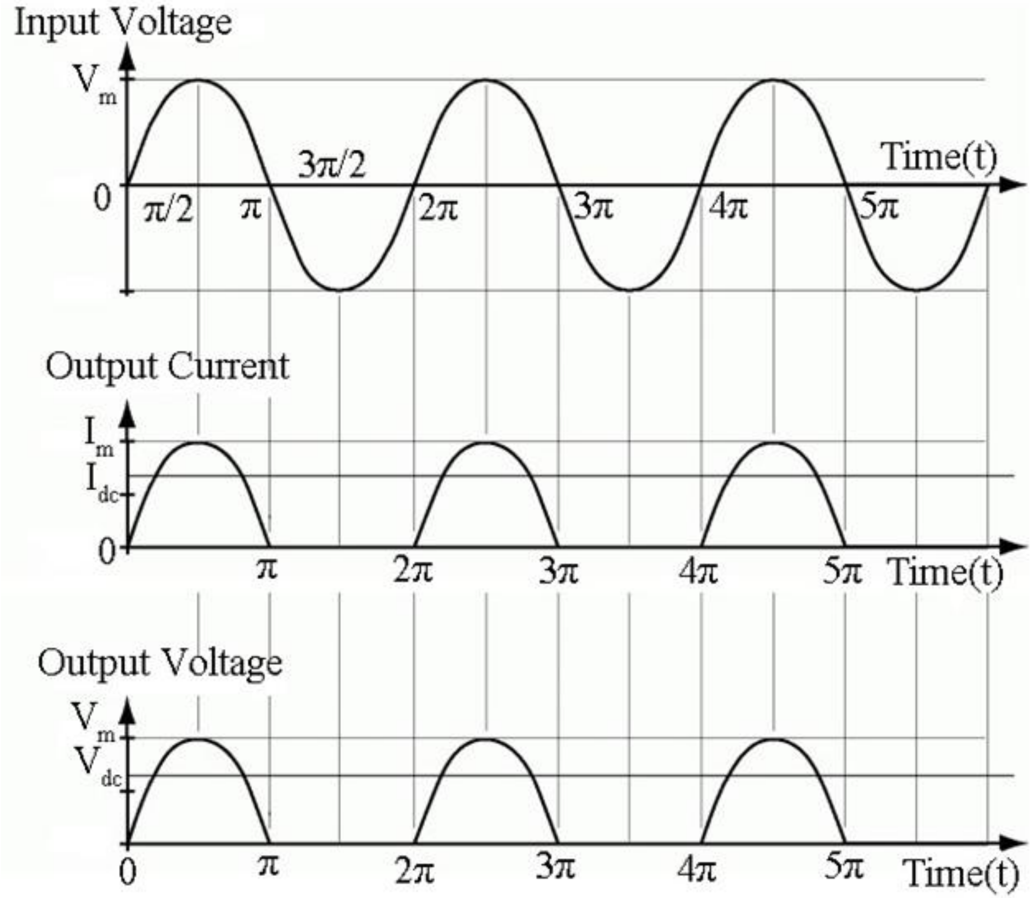


Figure 2: Waveform of Half Wave Rectifier

Elementary DC Power Supplies

- Most practical circuits require a DC voltage source that produces and maintains a constant voltage.
- This is done by converting the pulsating half sine waves obtained with a rectifier to a steady DC level.
- This is achieved by filtering.
- The pulsating half sine waves (like all periodic waveforms) can be regarded as waveforms that have both a DC component and ac components.
- The purpose of filtering these waveforms for a DC power supply is to reject all the ac components.

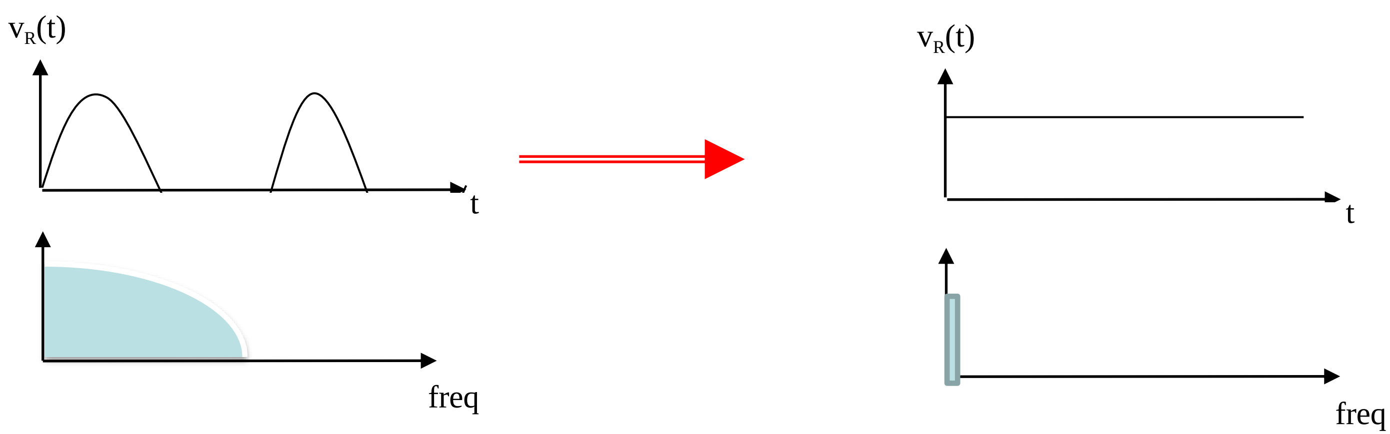
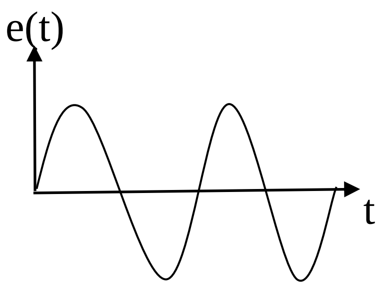
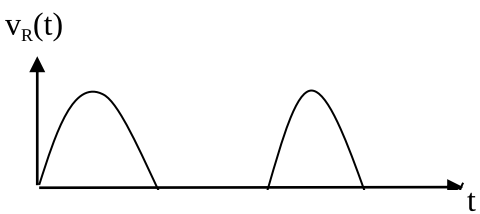


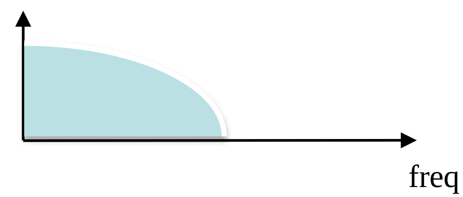
Illustration of frequency spectra

Sinusoidal (single frequency)

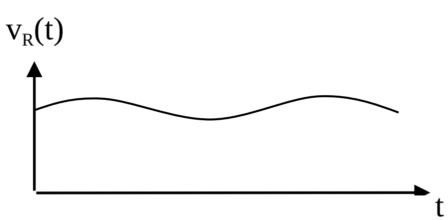


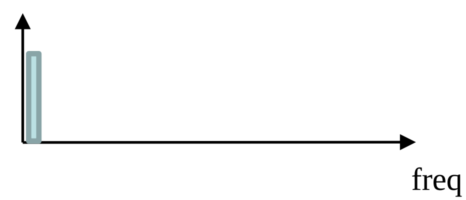
Rectified sinusoidal (many frequencies)





Filtered (Low frequencies)

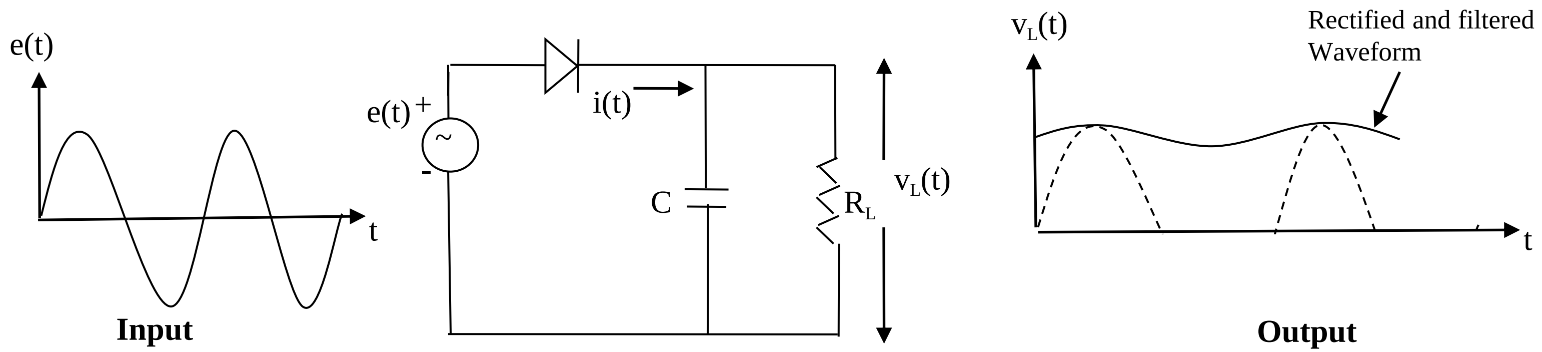




- The simplest kind of filter that will do this is a capacitor.
- Capacitor has reactance Xc= 1/(2πfC)

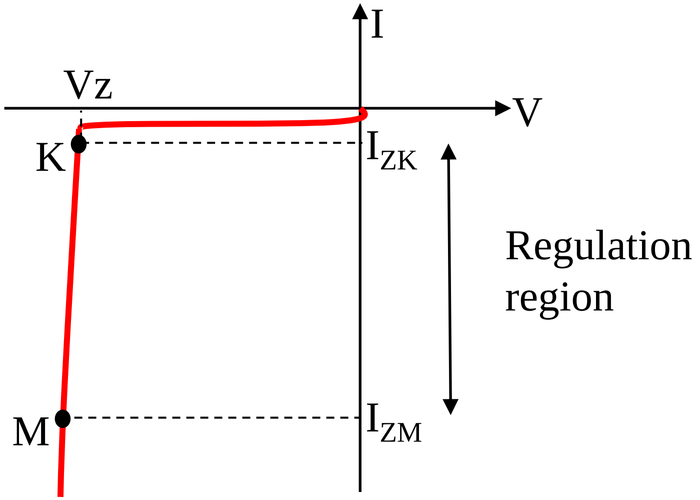
where f is frequency in Hz and C the capacitance in F

- Thus Xc α 1/f.
- If we connect a capacitor in parallel to the diode then at high frequencies the rectified signal will see a low impedance path to ground and will not appear in the output.
- In practice a power supply will supply a DC current to a load.
- Then the circuit for the elementary DC power supply is



Zener Diode

- The Zener diode is a PN junction device and **operates in the reverse-breakdown region only**
- The breakdown voltage V_Z of a Zener diode is set by carefully controlling the doping level during manufacture.

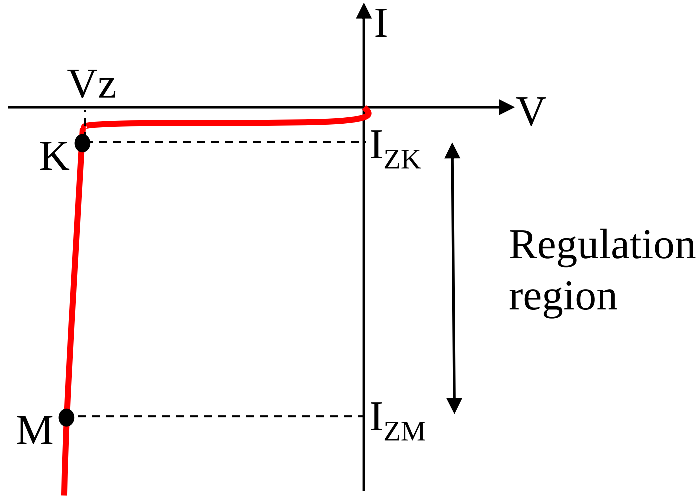


• When reverse voltage V_R is increased the reverse current (called Zener current I_z) remain very small up to the 'knee' point K.

•At K the breakdown process begins.

•From K, the breakdown voltage V_z remains essentially constant with increasing I_z.

•This ability of a diode is called the regulating ability.



- Two important points must be noted

1) There is a minimum value of I_z called breakdown current I_{ZK} which must be maintained in order to keep the diode in the breakdown (or regulation region). When current is reduced below I_{ZK} the voltage changes rapidly and the regulation is lost.

2) there is a maximum value of zener current I_{ZM} above which the diode may be damaged. The value I_{ZM} is given by the maximum power dissipation of the zener diode and will be supplied by the manufacturer.

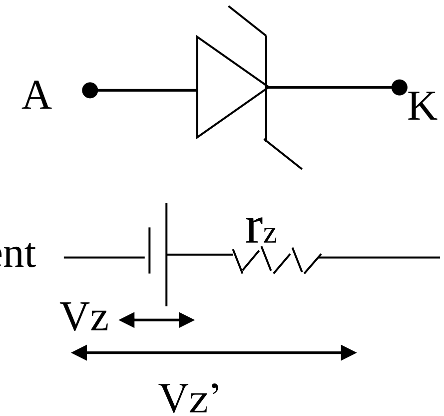
$$I_{ZM} = P_{ZM} / V_z, \text{ where}$$

P_{ZM} = power rating for zener, V_z = breakdown voltage.

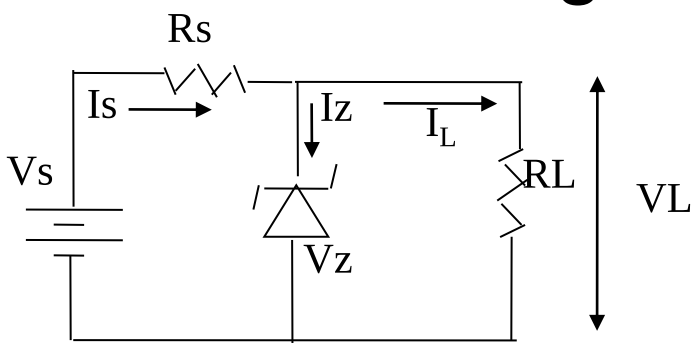
- The circuit symbol and a practical equivalent circuit for a Zener diode are

Circuit symbol

Practical equivalent Circuit



Zener diode Voltage Regulator

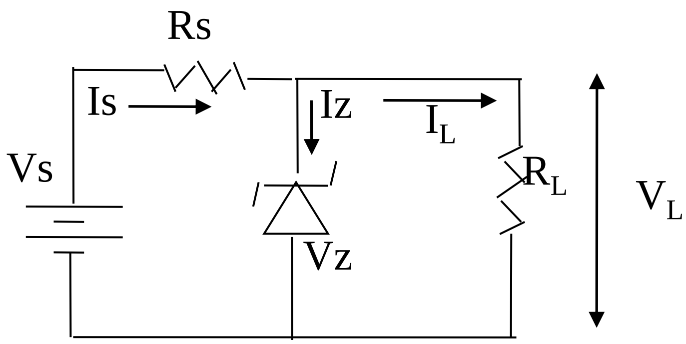


- For operation $V_s > V_z$ and this ensures operation is in the breakdown region of the Zener.
- The input current $I_s = (V_s - V_z) / R_s$

where V_s is DC input voltage and V_z is Zener Voltage.

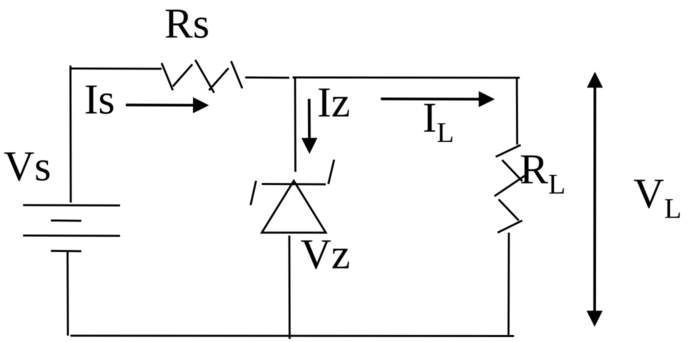
- Zener acts as a constant voltage source of Vz

Zener diode Voltage Regulator



- A practical Zener has a finite value of r_z (Zener resistance).
- Therefore there is a voltage drop across r_z
- Voltage across terminals of load $V_L = V_z + I_z r_z$
- If r_z is small $V_L = V_z$
- Applying Kirchoff's Law the current through the load resistor is
  $I_L = I_s - I_z$ where $I_L = V_L / R_L$
- Rs is connected in series with Zener to limit the current in the circuit.

Operation of Zener Regulator

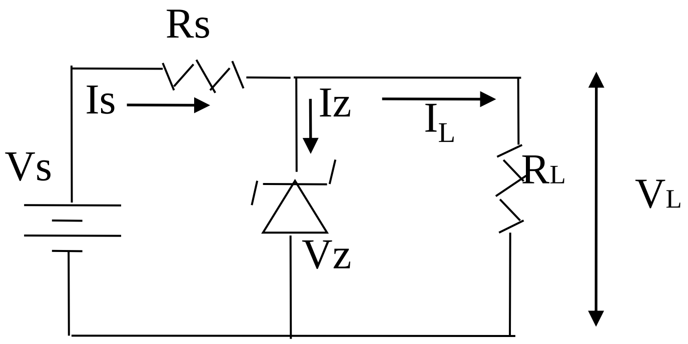


1) Regulation with varying input voltage

(a) when Vs increase, Is increases.
This increases the current through Zener without affecting I_L.
Increase in Is will increase the voltage drop across Rs thereby keeping the load voltage V_L constant.

(b) If Vs is decreased Is is also decreased.
Current through Zener is decreased and voltage drop across Rs is reduced.
Therefore V_L and I_L remains constant.

Operation of Zener Regulator

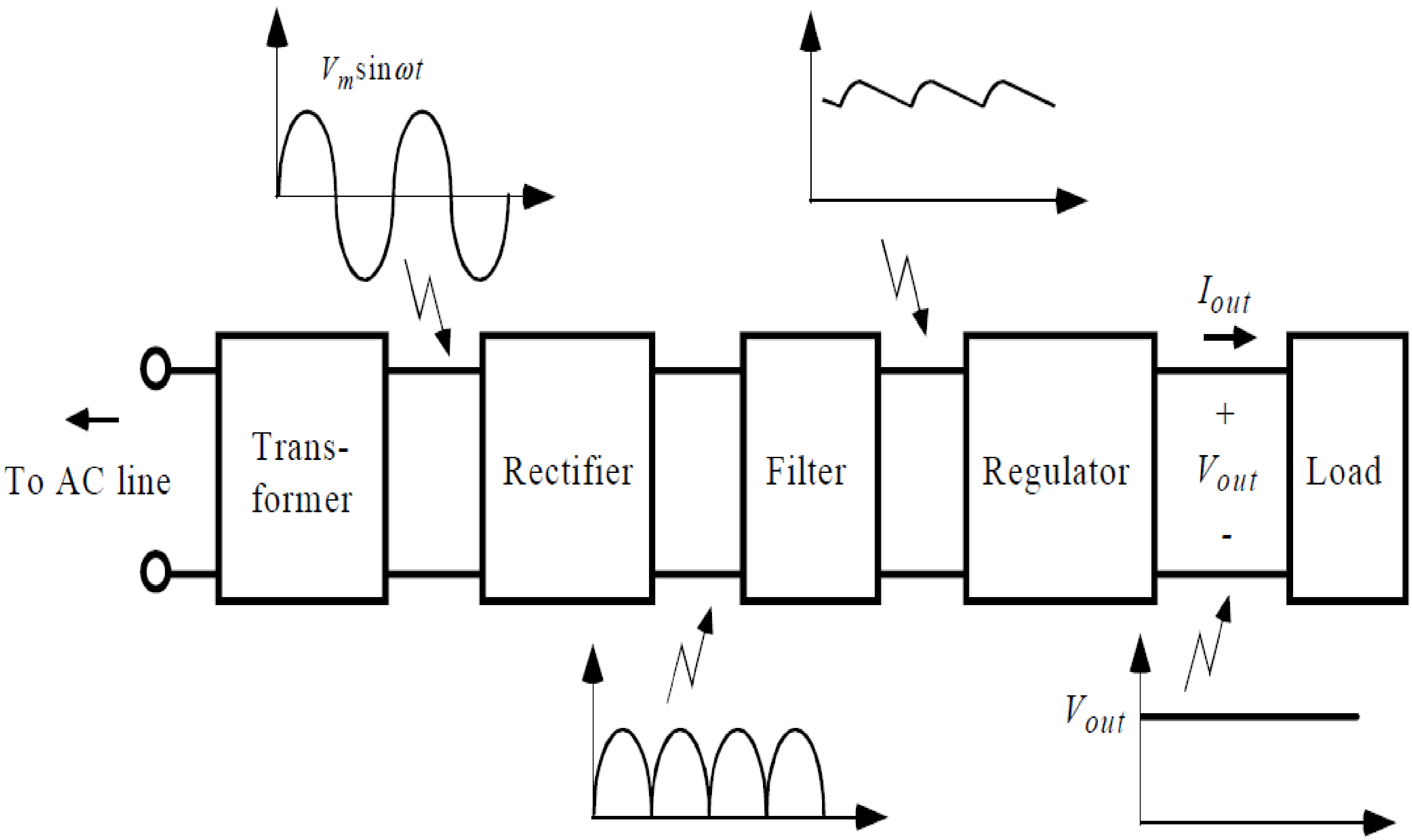


2) Regulation with varying load resistance –

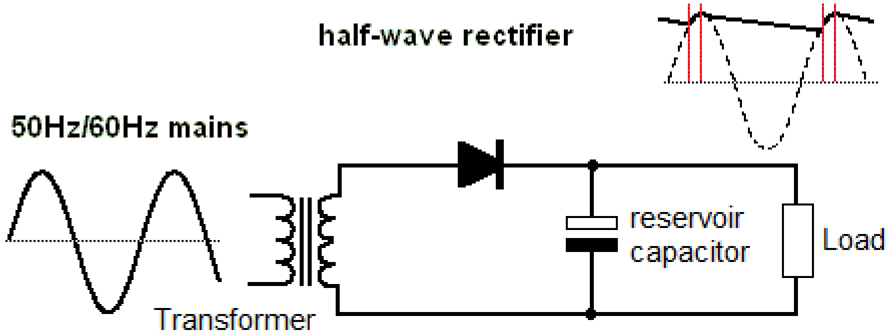
variation of R_L changes I_L so changing V_L.

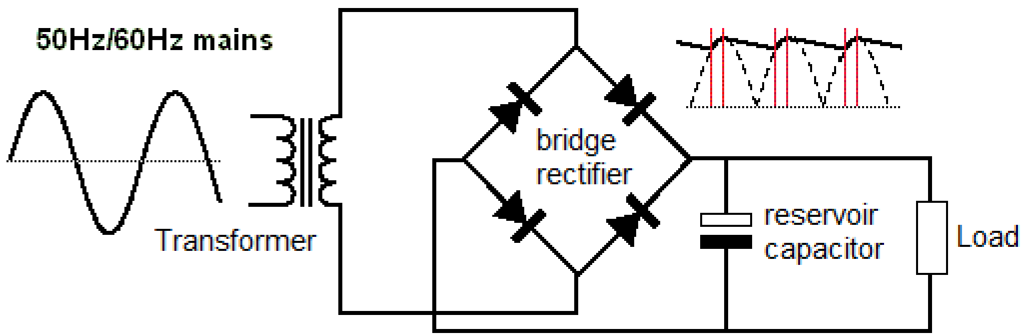
(a) when R_L decreases, I_L increases.
This causes Zener current I_z to decrease.
As a result, I_s and voltage drop across R_s remain constant.
Therefore V_L is also kept constant.

(b) If R_L increase, I_L decrease and I_z increase.
This keeps I_s and voltage drop across R_s constant.
Therefore V_L remains constant



Components of a typical linear power supply





full-wave (bridge) rectifier