Analysis of diode

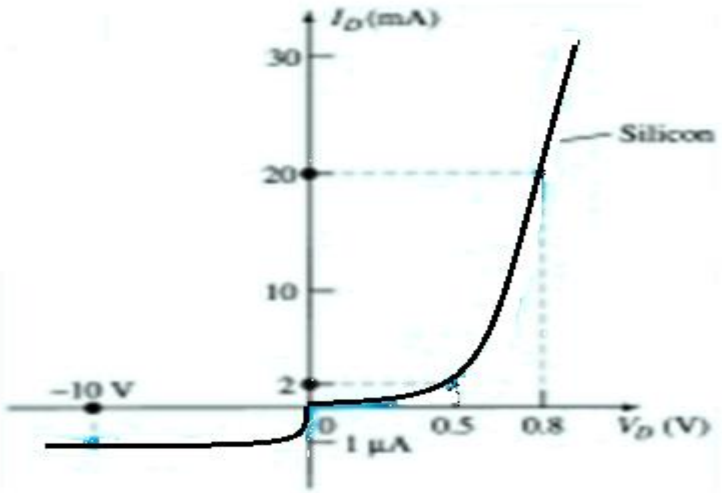
Analysis of diode means study of response of diode for different applied voltages. We can analyse diode in three ways.

1) Analysis of diode in laboratory
2) Analysis of diode on paper
3) Analysis of diode using software

1-Analysis of diode in laboratory- We can study behaviour of diode in laboratory by using variable voltage source, resistors and multi-meter.

2-Analysis of diode on paper- We can study behaviour of diode on paper in two ways.

a) Graphical analysis- We study response of diode for different voltages by diode characteristic. For any particular voltage we find out point on characteristics, this point represents current for that particular voltage.
   Suppose we want to find current through a diode for 0.5V and 0.8V by given characteristics.



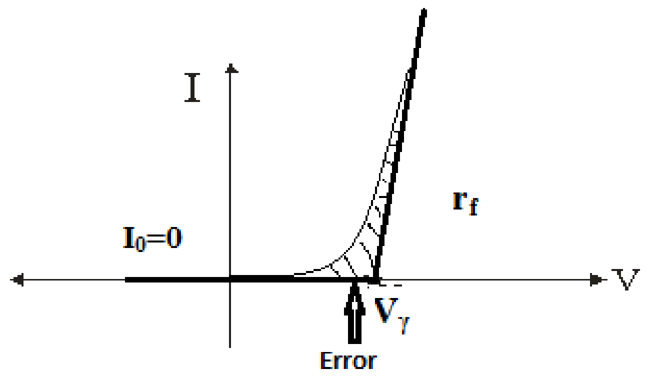
   From diode characteristics we can see current for diode at 0.5V and 0.8V is 2mA and 20mA respectively.

b) Mathematical analysis- We study response of diode by diode equation.
   Suppose we want to find current of a Germanium diode at 0.3V and temperature around diode is 27^0C. Reverse saturation current I_0 for this diode at this temperature is 2μA.
   So from diode equation $I = I_0 \left(e^{V/\eta V_T} - 1\right)$

$$I = 2\times10^{-6}\left(e^{0.3/1\times26\times10^{-3}} - 1\right) = 2\times10^{-6}\times2.71 = 5.42\mu A$$

   In above calculation we can see we have to use complex exponential function to find current through for a diode for a particular applied voltage.

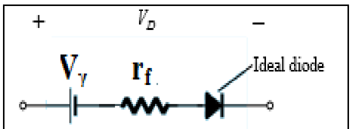
Piece-wise linear characteristics or First approximation of characteristics-



Piece-wise linear characteristics

From above discussion it is clear that for actual on paper analysis of diode we have to use nonlinear graph in graphical analysis and exponential function for mathematical analysis. Nonlinear exponential functions are tough to analyse. To simplify our analysis we compromise with some error and use approximate characteristics of diode. In this approximate characteristic we assume that diode shows zero current for all voltages less than cut-in voltage. Because for this voltage range diode shows very small current, we compromise with some error and consider this current to zero. For voltages greater than cut-in voltage diode shows fast rise in current. We consider linear graph for this voltage range, just like a resister. For this linear approximation again we compromise with some small error. It is now clear that we represent nonlinear characteristics of diode by pieces of linear functions (see figure above). In this approximation in reverse bias condition of diode we consider constant reverse current sometimes we consider zero current in reverse bias condition. This approximate characteristic of diode generally called **piece-wise linear characteristics or first approximation characteristics.**

For circuit analysis we use equivalent circuit of diode by using piece-wise linear characteristic.

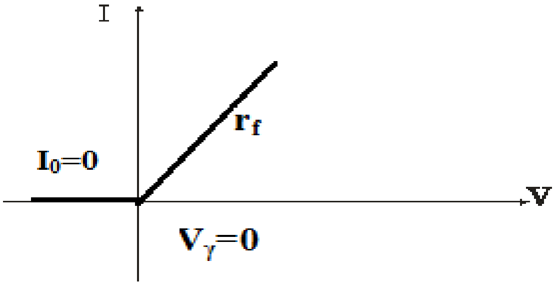


Equivalent Circuit

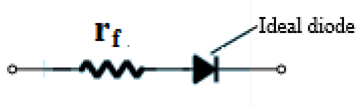
Equivalent circuit- Equivalent circuit is a representation of unknown device in the form of known circuit elements like resistor, voltage source etc. This representation presents approximate behaviour of diode on the basis of piece-wise linear characteristics. From piece-wise linear characteristics we can see that for voltage range less than cut-in voltage diode shows zero current and for voltage greater than cut-in voltage diode shows resistive behaviour. So in equivalent circuit of diode there should be a voltage source to represent cut-in voltage and a resistor for resistive behaviour of diode. In figure cut-in voltage is shown by voltage V_γ and resistive behaviour of diode is shown by forward bias resistance, r_f. Ideal diode in equivalent circuit shows that this equivalent circuit of diode will be useful in forward bias condition only. For reverse bias it will be open circuited. This equivalent circuit is called **piece-wise linear model.** To analyse circuit including diode, diode can be replaced by its equivalent circuit.

Diode characteristics with second approximation-To make analysis of diode easier, we can simply diode equivalent circuit with more approximation. In this approximation we can assume cut-in voltage of diode is zero or forward resistance of diode is zero. Diode characteristics with this approximation is called diode characteristics with second approximation

i) **If we consider cut-in voltage of diode is zero-** The piece-wise linear characteristics will be simplified and analysis of diode will be easier. But error in result will be increased. The simplified characteristics and its respective equivalent circuit will be as follows.

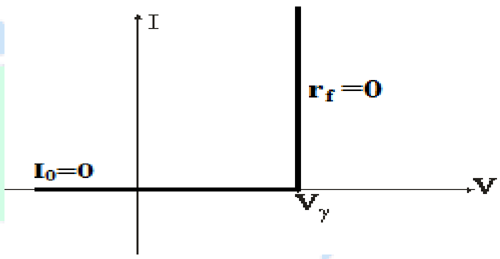


Characteristics with 2nd approximation

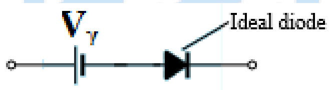


Equivalent circuit

ii) If we consider forward resistance of diode is zero- The piece-wise linier will be more simplified and analysis of diode using this will easier. But there will be some more error. Graph of characteristic with this approximation and its equivalent circuit will be as follows.

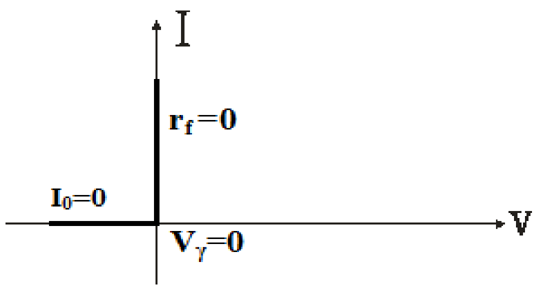


Characteristics with 2nd approximation

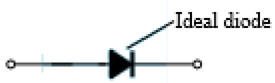


Equivalent circuit

Diode characteristics with third approximation (Ideal diode) - If we assume that cut-in voltage and forward resistance both of a diode are zero then diode will be considered as an ideal diode. Characteristic of diode with this approximation will be called characteristic with third approximation. While using this characteristic analysis will easier, but error in result will be increased. Characteristics and its respective equivalent circuit will be as follows.



Characteristics with 2nd approximation

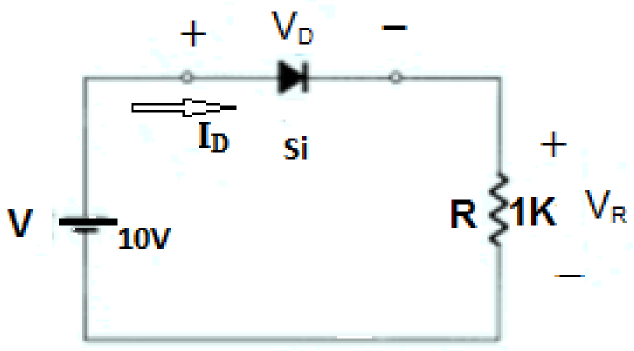


Equivalent circuit

So, ideal diode is a diode which shows zero cut-in voltage and zero resistance in forward bias condition. In reverse bias condition ideal diode shows zero current so infinite resistance. In forward bias it will short circuited in the circuit. In reverse bias it will be open circuited.

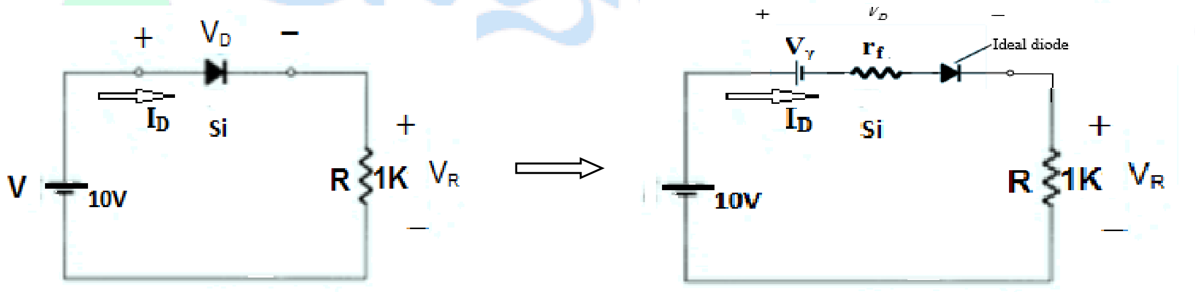
To understand approximation we can take example of a circuit including voltage source, diode and resistor.

Example



Find I_D, V_D and V_R in above circuit using equivalent circuit of diode with approximations.

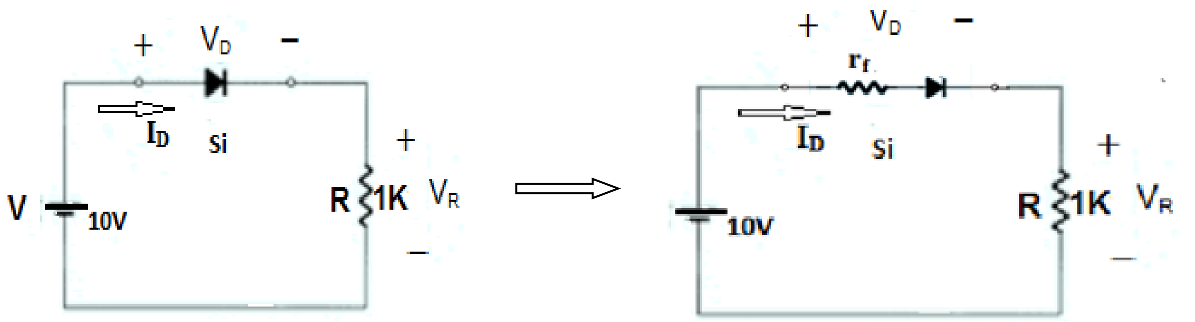
i) On using piece-wise equivalent circuit (equivalent circuit with first approximation) diode will be replaced by its equivalent circuit. V_γ=0.7V and r_f=10Ω



Circuit **Diode replaced by equivalent circuit with 1st approximation**

I_D = (10-0.7)/(1000+10)=9.2mA, V_D=0.7+0.0092*10=0.792V, V_R= 1000*0.0092=9.2V

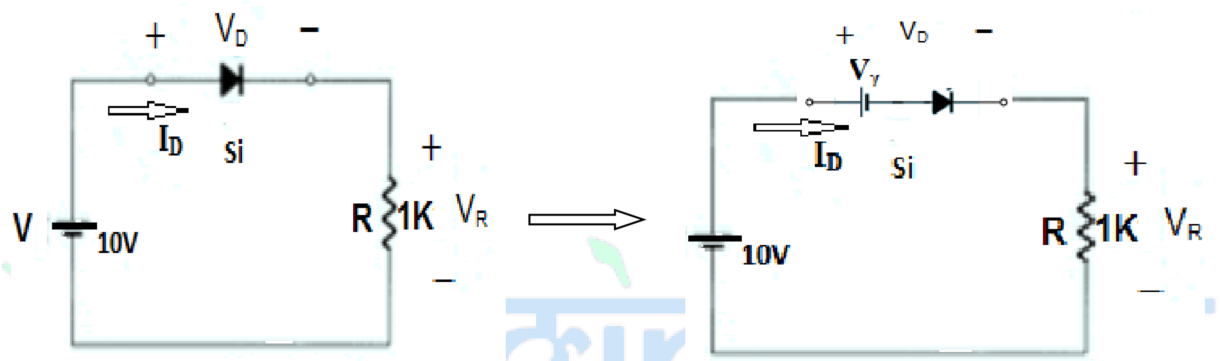
ii) a) If we use diode equivalent circuit with second approximation then diode in circuit will be replaced by its second approximated equivalent circuit (V_γ=0).



Circuit **Diode replaced by equivalent circuit with 2nd approximation**

I_D = (10)/ (1000+10)=9.9mA, V_D=0.0099*10=0.099V, V_R= 1000*0.0099=9.9V

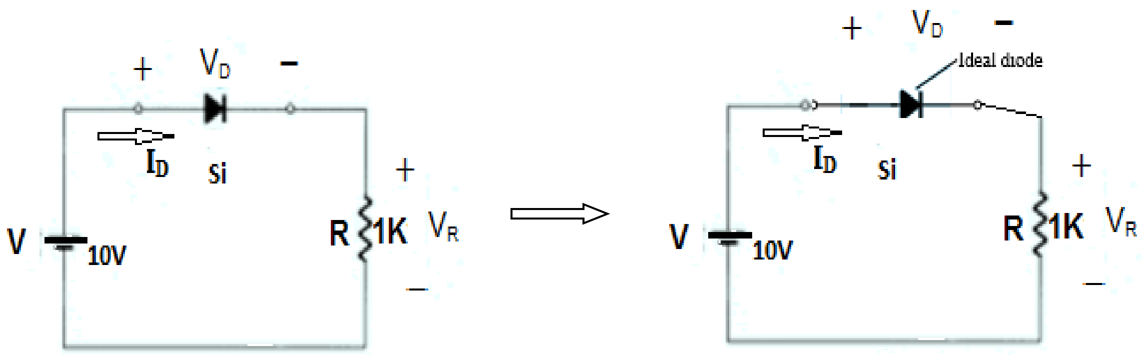
b) If we consider r_f=0 then circuit will be as follows.



Circuit **Diode replaced by equivalent circuit with 2nd approximation**

I_D = (10-0.7)/(1000)=9.3mA, V_D=0.7V , V_R= 1000*0.0093=9.3V

iii) If we consider third approximation of diode means ideal diode, so V_γ=0V and r_f=0Ω, diode in circuit will be replaced by ideal diode.



Circuit **Diode replaced by equivalent circuit with 3rd approximation**

I_D = (10)/(1000)=10mA, V_D=0V, V_R= 1000*0.01=10V

From above example it is clear that for piece-wise equivalent circuit current in circuit is 9.2mA which is near to actual value but on using approximations analysis becomes easier and error in current value is increased. For second approximation current is 9.3mA (When r_f=0) and it is 9.9mA (when V_γ=0). On using third approximation calculation is much easier than piece-wise model but error is increased. Current for this third approximation is 10mA.

So if we are ready to compromise with error of 0.8mA (10mA - 9.2mA) in current, then we can replace diode in circuit by an ideal diode. So we can say **more easy more error, less easy less error.**