2.3 PRACTICAL LIMITATION FOR DIODES

Figure (2-36) shows diode symbol, term anode and cathode are used to identify the terminals connected to p and n electrodes. When diode is forward, it conduct, current flow as in figure (b), and resistance R = 0, so V = 0, figure (d). When diode is reversed, it not conducts, current flow as in figure (c), and resistance R = ∞, so I = 0 whatever the value of V_R (fig. d). In figure (2-37a), diode is forward; it behaves as closed switch and full voltage E developed across R, resulting current and no voltage drop across the switch

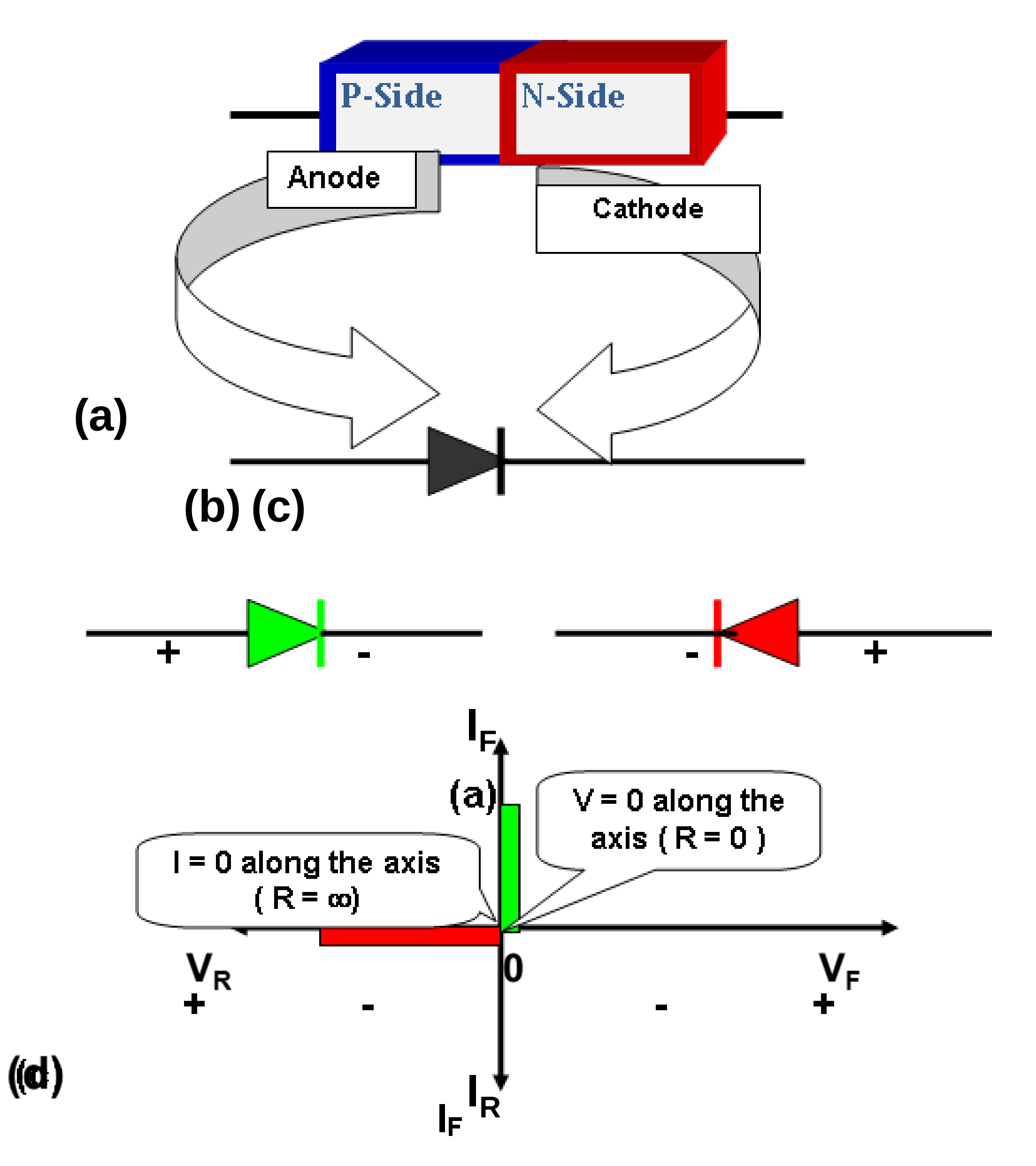

Fig. (2 – 36) Current and Voltage Diode Limitation

In figure (2.37b), the diode is reversed, it behaves as open switch and no voltage across R, result no current flow and the full voltage E is developed across the switch contacts. Since the power is P = V I, so no power appeared if V or I equal zero.

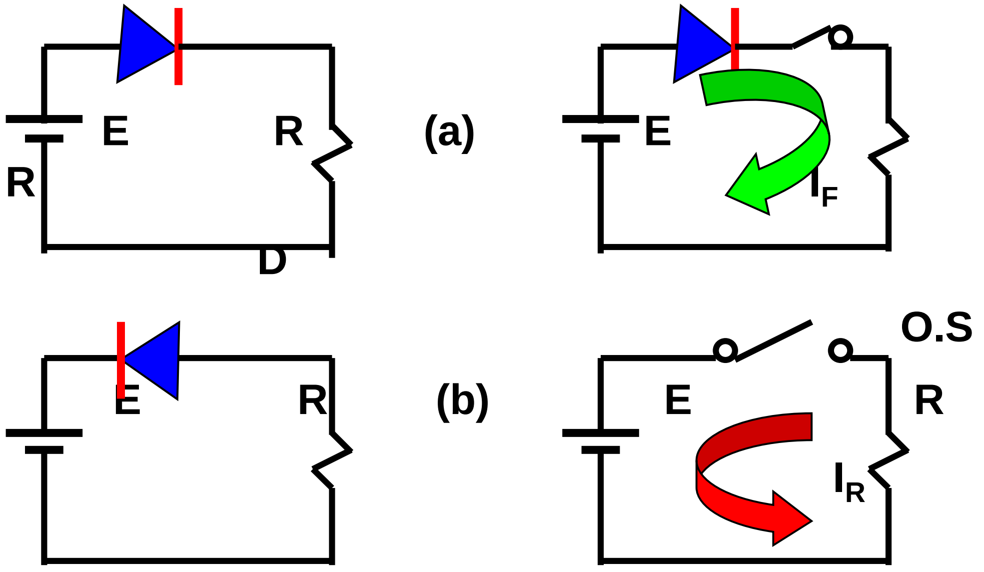

Fig. (2 – 37) Diode Representation in Forward and Reverse Condition

2.3.1 LARGE SIGNAL OPERATION OF THE DIODE

Real diodes are different from ideal, often it is possible to neglect differences and treat all diodes as if they ideal. Forward and reverse characteristics are shown in figure (2.38a). In forward direction, small voltages produce large currents, in reverse direction, current are very small, even with large voltage. In forward bias, V_B must be overcome before conduction takes place, even after V_F exceed V_B, this due to the existence of resistance r_F .

Due to the non-linearity exists, approximation must be considered, fig. 2.38(b) especially when large signals are involved, that is when voltage and currents are greater than V_B or BV. According to this approximation, it is easy to read the operation parameter directly from graph. For example, V_B = 0.8 V and I_J = 100 ma current increments is selected, we get:

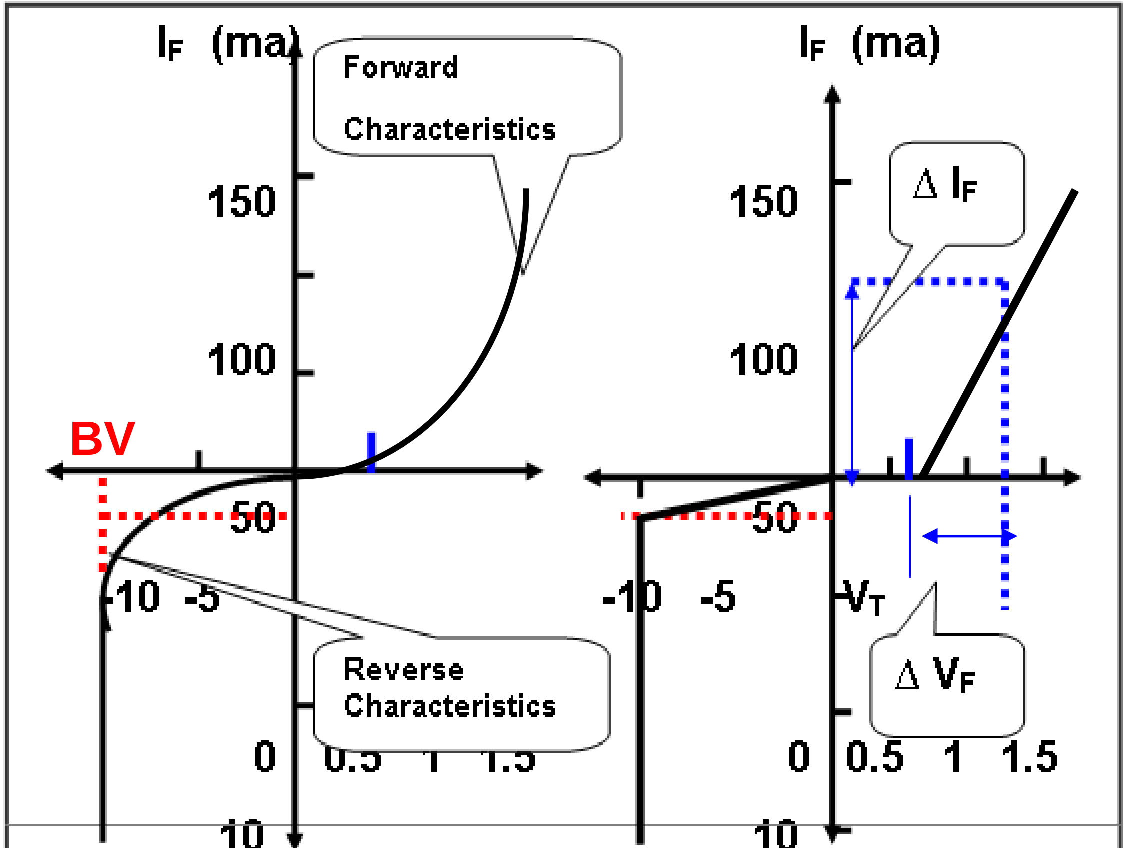

Fig. (2 – 38) General Diode I-V, and Approximated I-V Characteristics

$$r_F = \frac{\partial V_F}{\partial I_F} = \frac{1.3 - 0.8}{(100 - 0)x\,10^3} = 5\Omega$$

Both V_B and r_F can be used to modeling the real diode. To construct a diode model, we begin with ideal diode and then add a various circuit component to be account for actual or real behavior. Figure (2-39) shows the ideal diode, to simulate V_B, we add DC voltage source, and also assume an external voltage

Thus x is positive W.R. y, and the voltage across ideal diode is difference between V_{xy} and V_B. If $V_{xy}<V_B$, anode is positive w.r. cathode, diode conduct. The model in (b) does not include r_F, it is added to (c), the combination of V_B , r_F and ideal diode approximate real diode , fig. (c) is valid

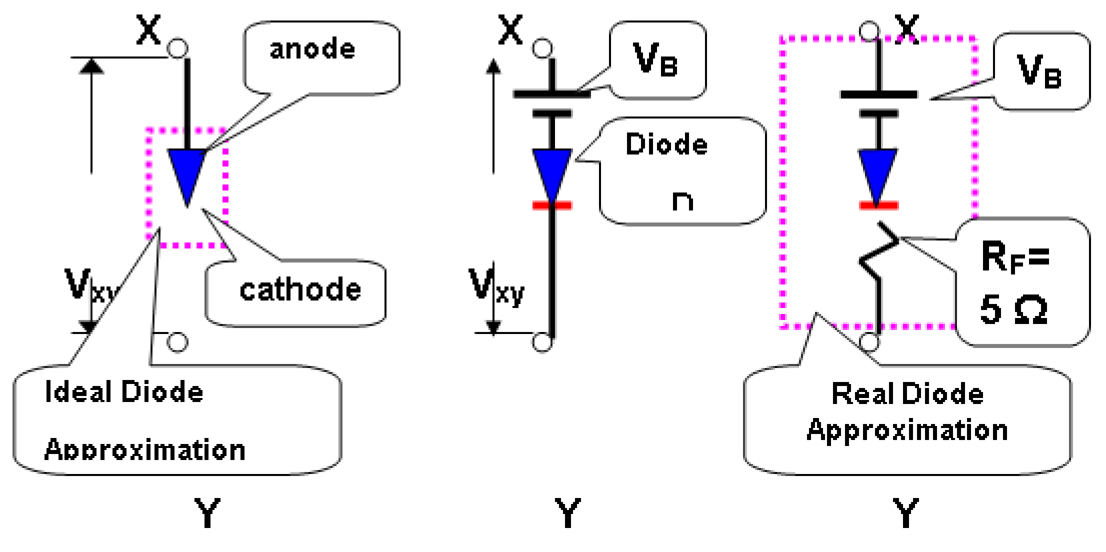

Fig. (2 – 39) Diode modeling for forward bias

only when the diode is forward . When the diode is reverse biased, we are concerned with I_R and BV, we know that I_R is large dependent on temperature and since the diode characteristics is fixed for each fixed temperature, then any models valid for the temperature required. A reverse biased real diode in figure (2.40a), the polarity of V_{xy} indicates that x is negative W.R (y). Approximation in fig. 2.40 indicates that as V_R changes from 0 to -10 V, the change in I_R is from 0 to - 5 μa gives,

$$r_R = \frac{\partial V_R}{\partial I_R} = \frac{10}{5\ x\ 10^{-6}} = 2\ M\Omega$$

Then a model for real; diode reverse biased with V_R< BV as a simple resistance as shown in (b). When V_R> BV, small increase results large current and diode in the breakdown condition, exhibits low resistance. Adding more components as shown in figure(c) can simulate this.

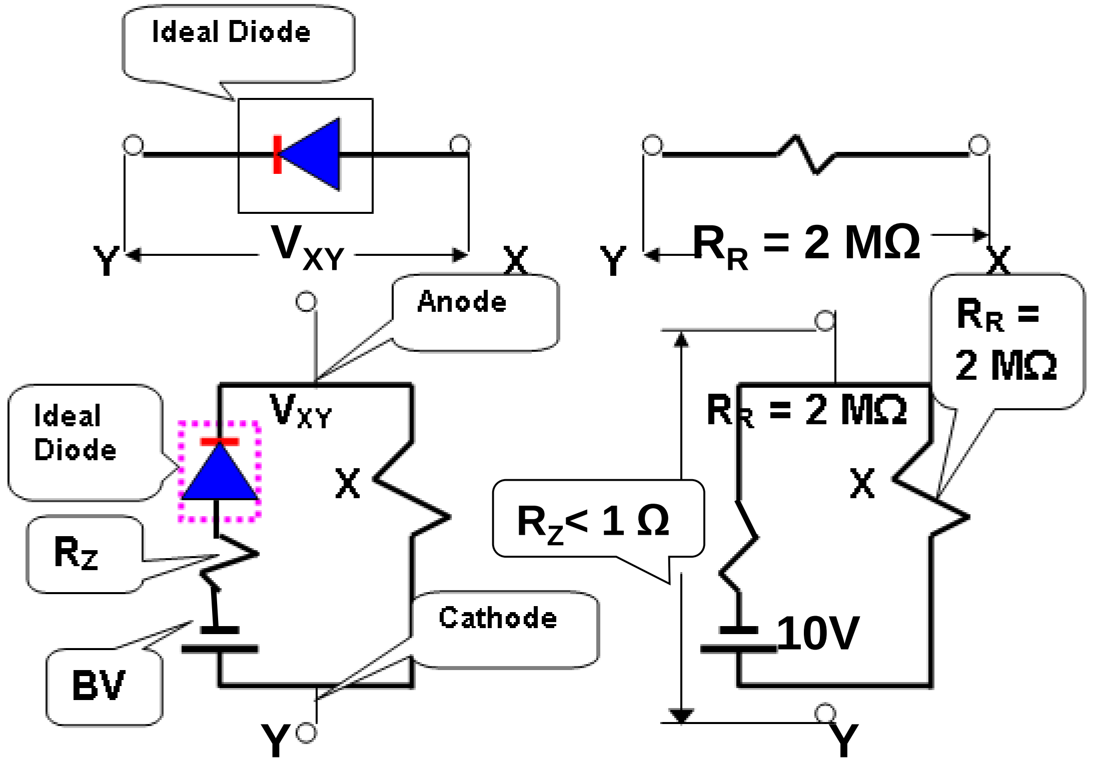

Fig. (2- 40) Diode modeling for reverse bias

Assume V_R< BV, in our example V_R< -10V, this means that the 2 MΩ resistor is the only element in the circuit. Once breakdown voltage is exceeded, V_R> -10 V, the model in figure (c) will be remodeled to as in figure (d) Which is valid only in breakdown condition and zener resistance r_z is the only resistance to limit the diode current and determined by: $r_z = \frac{\partial V_z}{\partial I_z}$

The graphic technique to determine (r_z) is shown in figure (2-41), (r_z) is quite low in the range of few ohms or less. The real diode models for forward and reverse bias can be lumped to a new model valid for all cases as shown in figure (2 - 41). At any given time, the diode can be only in one of its possible three conditions. If it is forward biased, only the branch have V_B, D_1 and (r_F) is considered, although (r_R) is also in the model, it is large compared to r_F, it can be neglected because it is in parallel with it (r_R// r_F).

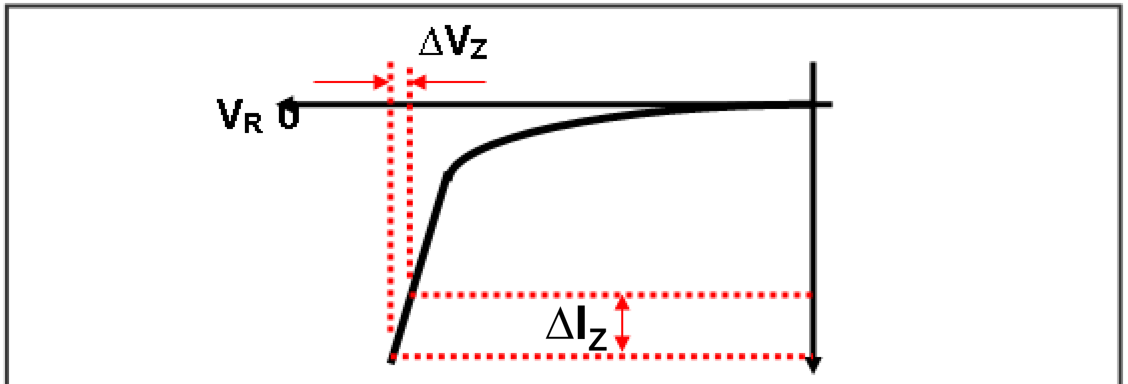

Fig. (2.41) Diode Modeling for Breakdown Condition

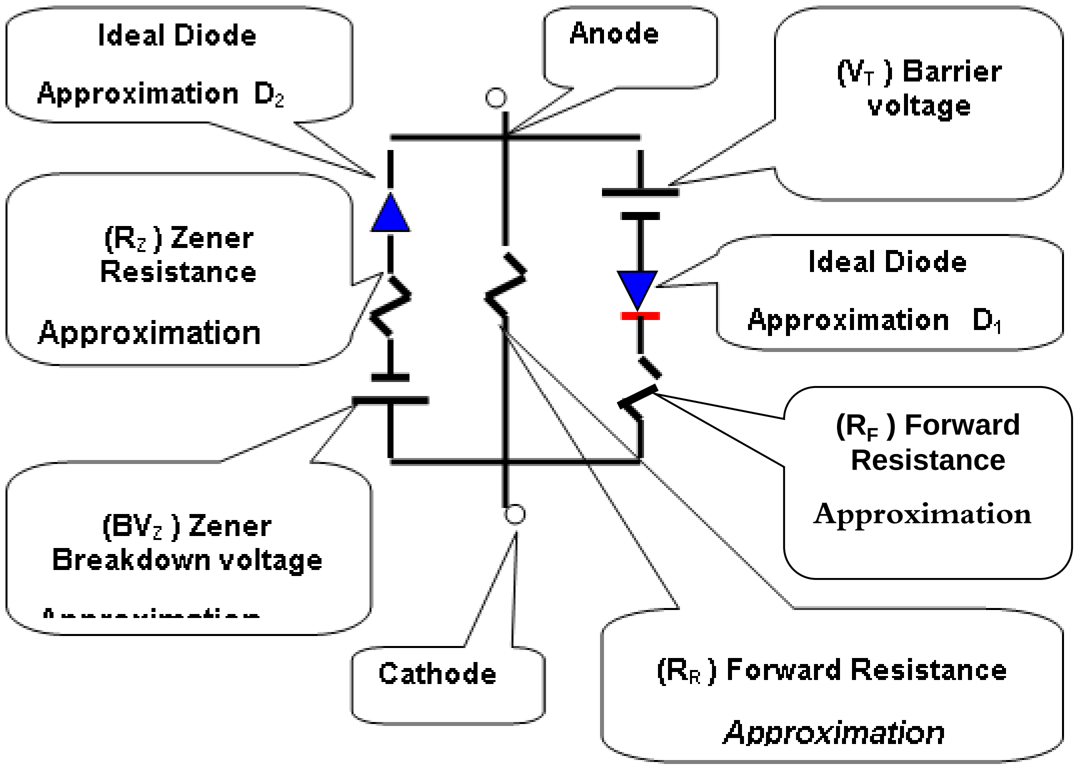

Fig. (2 – 42) Equivalent circuit

If the diode is reverse biased, not in BV condition, D_1 and D_2 are not conduct and hence the branch has (r_R) is considered. If V_R> VB, D_2 conducts, and the branch has D_2, (r_z) and VB is considered. The branch of D_1 is out of circuit while r_R is too large and is considered.

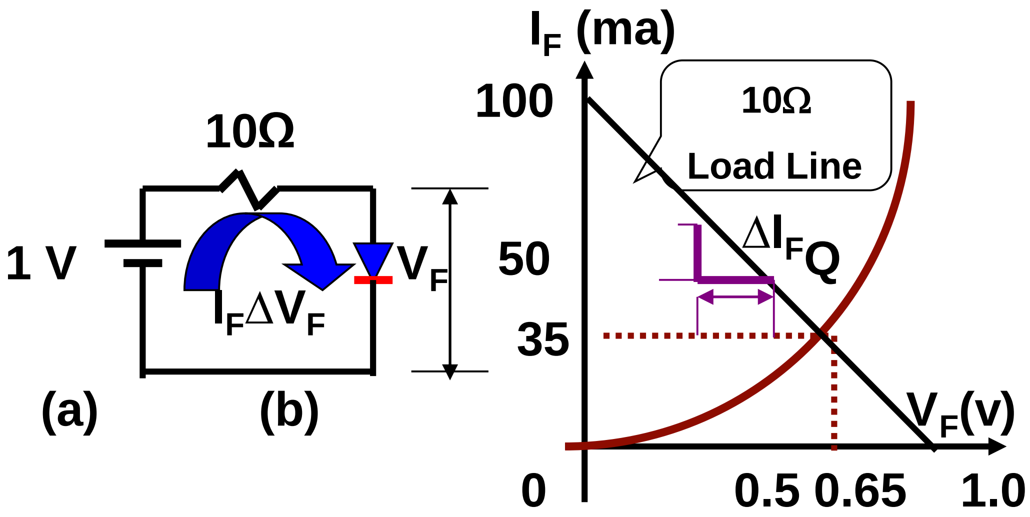

Fig. (2 – 43) Diodes in Small Signal analysis (DC Only

Where small signal is used, between V_B and VB. (around the knees of the I-V characteristics), to analyze small signal operation, SSO, consider the circuit shown in figure (2-42a). The polarity of the battery, 1V DC; forward biases the diode. The current in the circuit results voltage drop across the resistor, 10Ω and therefore diode has less than 1V across its terminal. This means diode operates around the knee of the forward bias. So the graphic technique used to determine actual voltage and current for diode, using Kerchief's Voltage Law for circuit shown, We get: $V_s = I_F R + V_F$, Substitute in values we have in the circuit, then, $1 = 10 I_F + V_F$, the equation describe a straight line and has two unknown parameters, the solution of this equation is the point where the straight line cross the diode characteristics. To locate such line, we substitute each of the two variables V_F and I_F in turn equal to zero.

Set $V_F = 0$ in the above equation, then $1 = 10 I_F + 0$, results, $I_F = 0.1$ A

Set $I_F = 0$ in the above equation, then $1 = 0 + V_F$, results, $V_F = 1$ V.

The straight line obtained by joining these two points ($I_F = 0.1$ A, and $V_F = 1$ V) cross the diode I-V characteristics at point Q which has (I_F=0.35ma, and V_F=35mV).

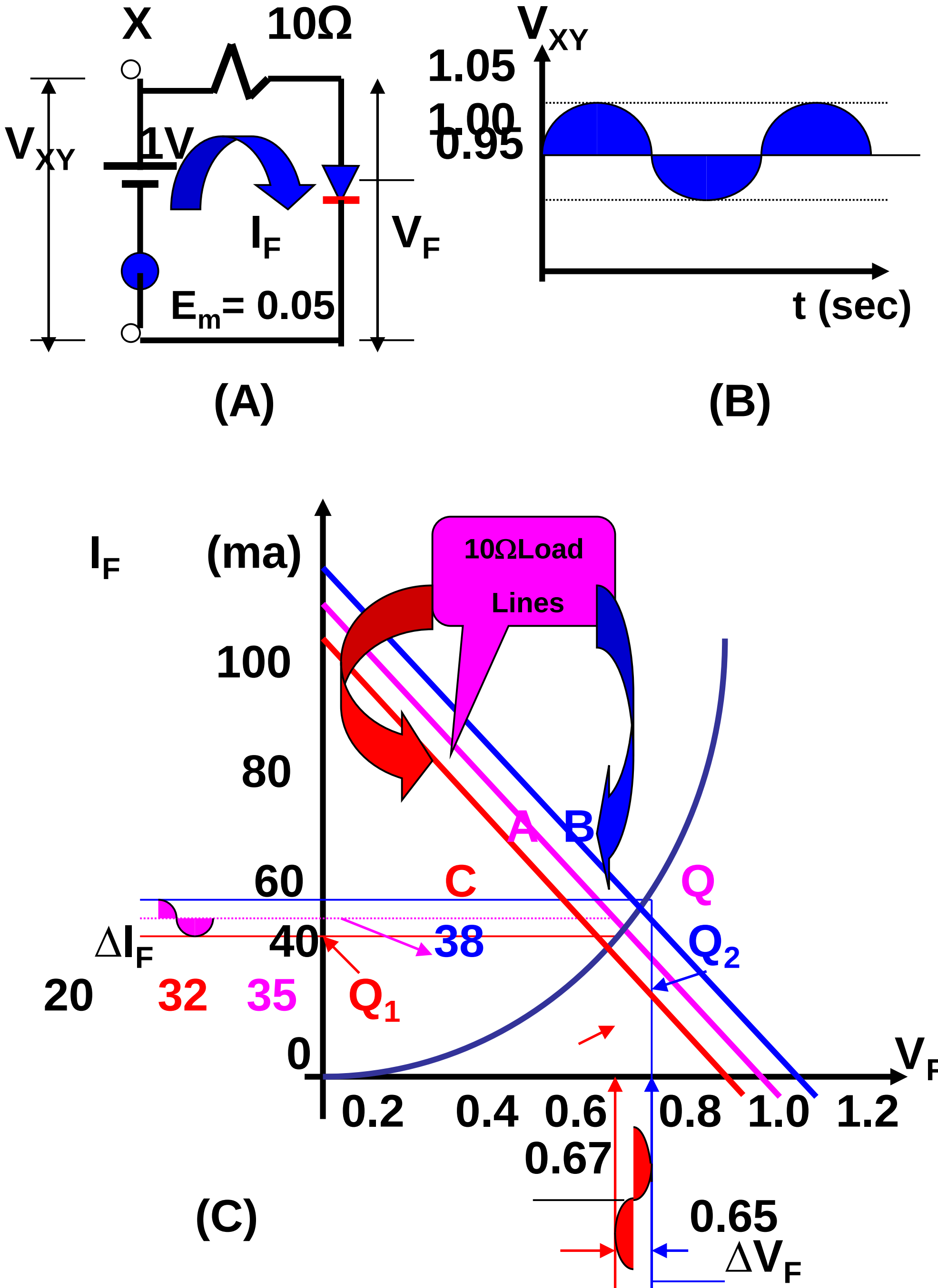

Fig. (2 – 44) Diode in Small Signal analysis (DC and AC

The straight line obtained is called a load line. The circuit of fig.2.43 is similar to that in figure (2-42) except for addition of an AC voltage generator (E_{max} = 0.05 V) in series with DC source, 1 V. So the voltage between x and y is,

- **During the positive half cycle of the ac voltage is equal to, DC voltage + peak of ac voltage =1 + 05 = 1.05V**
- **During the negative half cycle of the ac voltage is equal to, DC voltage-peak of ac voltage = 1 – 05 = 0.95V.**

This two modes are shown in figure (b), it must be noted that, at the instant that the ac generator reverse polarity, the value of ac voltage is zero, and the V_{xy} = 1 volt.

At this point time, load line A is considered (figure c), also it is noted that load line B represent the case of positive peak, and load line C represent the case of negative peak. It means that, the load line moves sinusoidal between the peaks of C and B, also, the diode voltage and current are vary sinusoidal from 0.63 to 0.67 V and from 32 to 38 ma, the peak diode voltage is therefore 0.02 and the peak current is3 ma.

A number of diode applications, only the changing of the ac components V, I required. For example, Dc source required to set the operating point of the diode (Q), in our last example, 1-volt dc is required to put Q at 0.65 V and 35 ma. Once Dc level is established (as reference voltage) it is possible to consider only the ac components. Figure (2.29a), shows the AC equivalent for the circuit shown in figure (2-28), since only the AC response of the circuit being considered, the DC source is not shown. The resistance r_F represents the dynamic or ac resistance of diode,

$$r_F = \frac{\partial V_F}{\partial I_F}\Bigg|$$

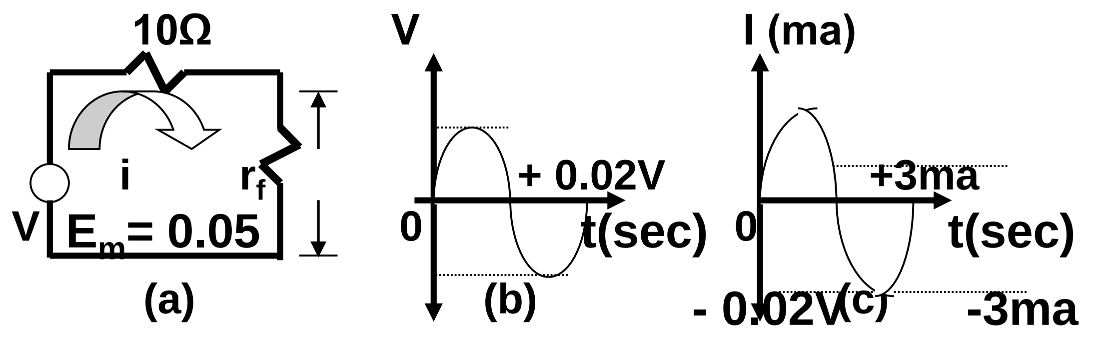

Fig. (2 – 45) AC Analysis Equivalent

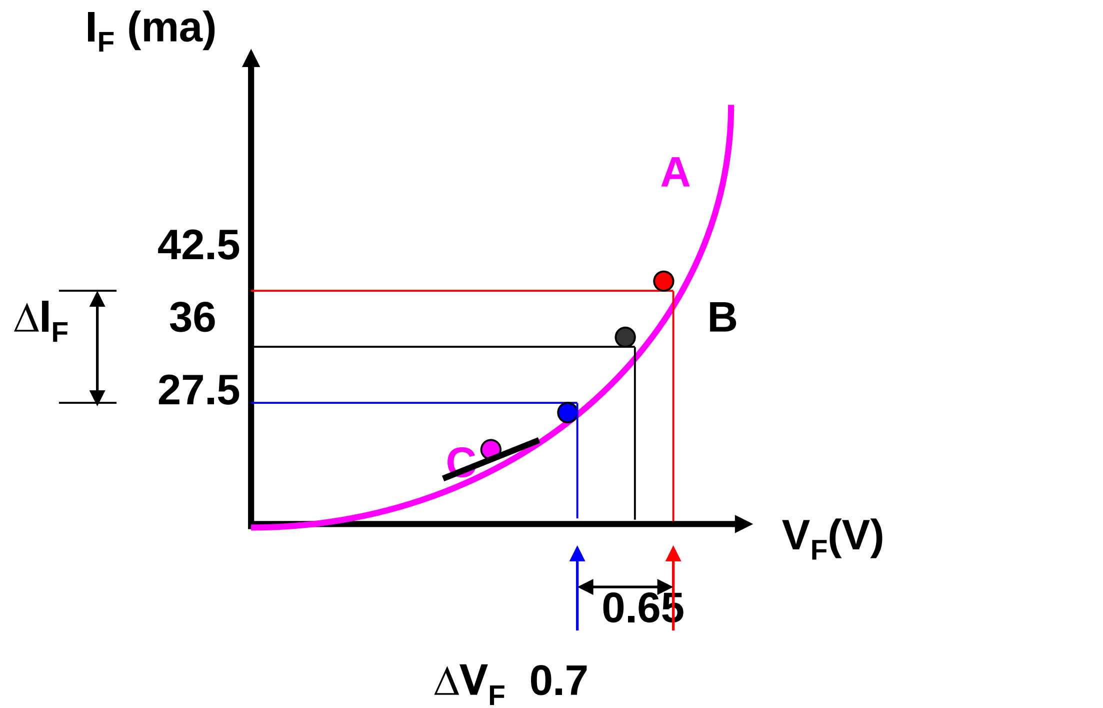

Fig.(2 – 46) Determination of AC Operating Point

Where Q is the operating point with 0.05V change on each side of operating point Q or B in fig.2.44 which results a total current of 15 ma.

$$r_F = \left.\frac{\partial V_F}{\partial I_F}\right|_B = \frac{0.7-0.6}{(42.5-27.5)x\,10^{-3}} = 6.6\,\Omega$$

Note that the difference between (r_f) and (r_F) is the (r_f) is the ac resistance for small changes about the operating point while (r_F) is used for large voltage and currents. The peak diode current and voltage in circuit of figure (2.45a) are,

$$I_m = \frac{E_m}{R+\ r_f} = \frac{0.05}{10+6.6} = 3\ mA \quad \&$$

$$V_m = \ I_m\, r_f = 3\ x\,10^{-3}\ x\,6,6 = 0.02\ V$$

$$r_F = \left.\frac{\partial V_F}{\partial I_F}\right|_B = \frac{0.7-0.6}{(42.5-27.5)x\,10^{-3}} = 6.6\,\Omega$$

2.3.3 SUMMERY

The approximate method for analyzing a diode circuit is summarized in the flow chart of figure (2.47). Study it carefully and review how it was applied in the preceding examples.

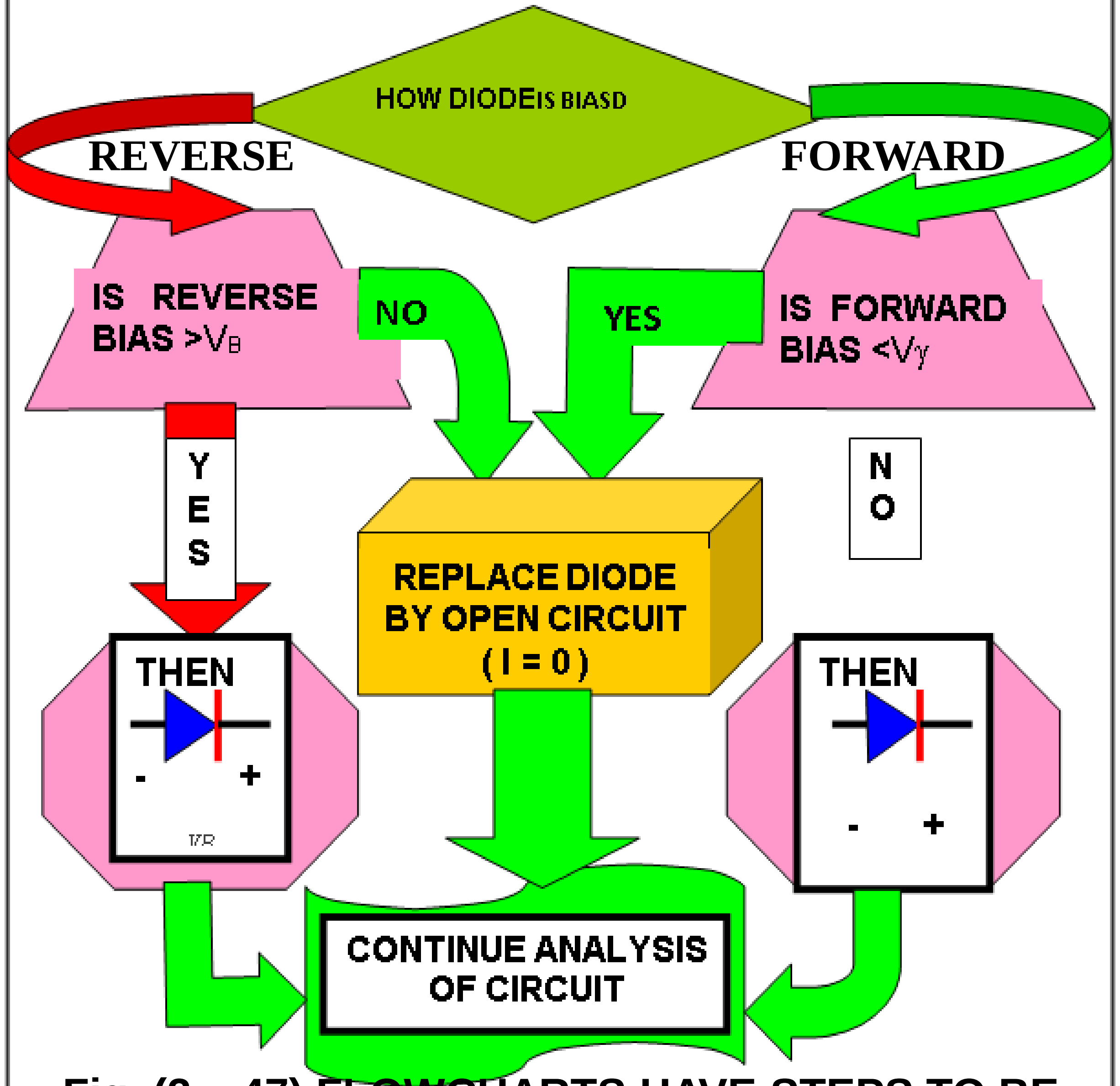

Fig. (2 – 47) FLOWCHARTS HAVE STEPS TO BE FOLLOWED IN APPROXIMATE ANALYSIS OF DIODE CIRCUITS.