



NPTEL ONLINE CERTIFICATION COURSES

Course Name: *Analog Electronic Circuits*

Faculty Name: *Dr. Pradip Mandal*

Department : *Electronics and Electrical Communication Engineering*

Topic:

Analysis of simple non-linear circuit

CONCEPTS COVERED

Concepts Covered:

- ☐ Analysis of non-linear circuit to Find solution
- ☐ Graphical method of finding solution
- ☐ Iterative method of finding solution
- ☐ Practical Method and working model of diode
- ☐ Application of the diode model
- ☐ Notion of Small signal equivalent circuit



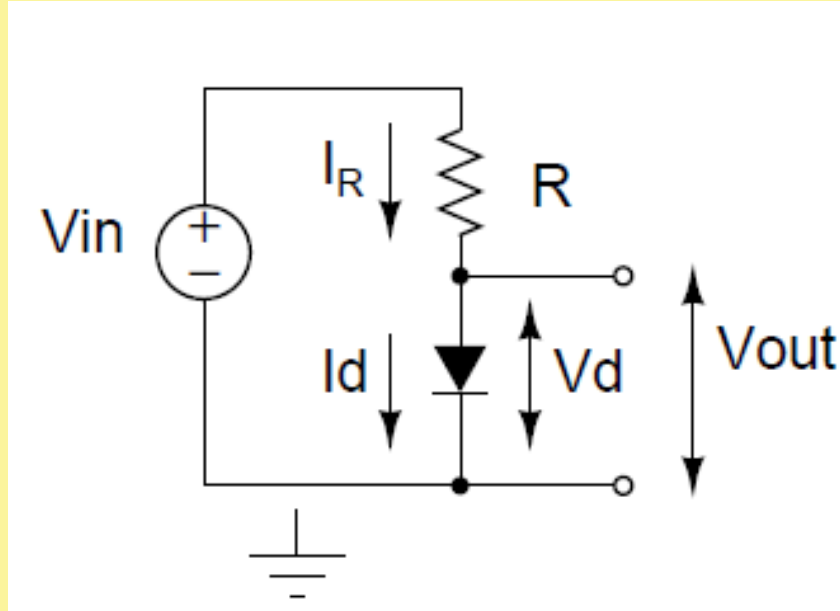
Flow of Discussion (Bottom-up) - *Components*

- **System /Sub-systems**(*for specific application*)
 - **Modules** (*performing specific tasks*)
 - **Building blocks** (*having specific characteristics*)
 - **Components** (*devices/circuit elements*)
- **Week 1:**
 - Introduction and objective of this course;
 - Revisit to pre-requisite topics (Electrical Theory);
 - **Starting with simple diode circuit and its analysis.**
 - Revisiting BJT and MOSFET- operating principles, characteristic equations and equivalent circuits



Analysis of a diode circuit to find solution

- **Diode circuit**

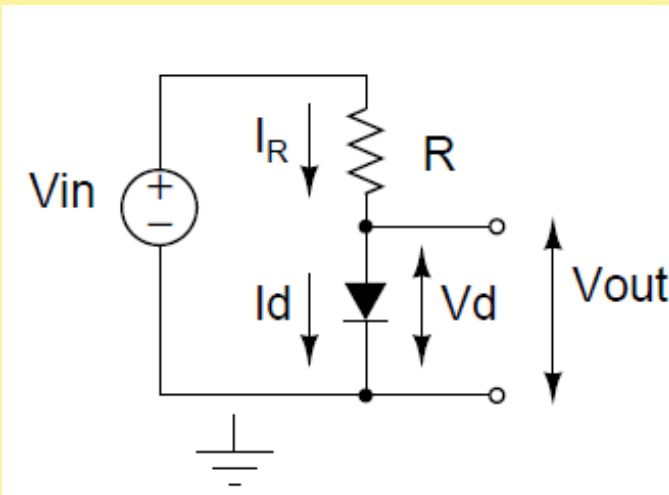


- **I-V characteristic of diode**

$$I_d = I_o \cdot \left(e^{\frac{V_d}{V_T}} - 1 \right)$$

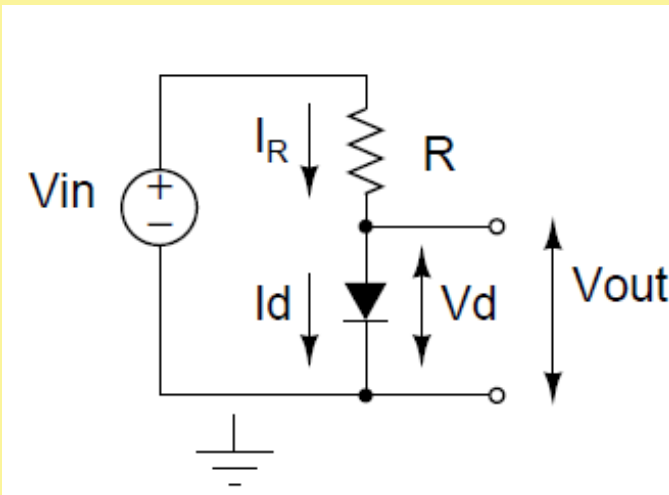
Generalized method of Finding solution point

- **Graphical Method :**
 - **Combining Pull-dn and pull-up chars**



Finding solution point (*contd...*)

- **Graphical Method (*contd...*)**
 - **Rearrangement of pull-up char**



Finding solution point (*contd...*)

- Superposition of Pull-dn and rearranged pull-up chars .

- Iterations using

$$I_d \approx I_o \cdot (e^{\frac{V_d}{V_T}})$$

$$V_d = V_T \cdot \ln \left(\frac{I_d}{I_o} \right)$$

$$I_R = \frac{(V_{in} - V_{out})}{R}$$



Iterative Method of finding the solution point

- Steps of Iterations on Superimposed characteristics using

$$I_R = \frac{(V_{in} - V_{out})}{R}$$

and

$$V_d = V_T \cdot \ln \left(\frac{I_d}{I_o} \right)$$

- Step1:

- Step2:

- Step3:



Iterative Steps to find a solution point (*contd...*)

- **Numerical Exercise of the iterations using equations**

$$I_R = \frac{(V_{in} - V_{out})}{R}$$

and

$$V_d = V_T \cdot \ln \left(\frac{I_d}{I_o} \right)$$

- **Step1:**

- **Step2:**

- **Step3:**

Do it Yourself and verify the answers !!



Convergence of Iterations !

- **Numerical observation:**

- Step1: $I_R(1) = 1 \text{ mA}$, $V_d(1) = 0.59867 \text{ V}$
- Step2: $I_R(2) = 0.940133 \text{ mA}$, $V_d(2) = 0.597067 \text{ V}$
- Step3: $I_R(3) = 0.940293 \text{ mA}$, $V_d(2) = 0.597071 \text{ V}$

- **Condition to converge:**

- (Slope of pull-up char) / (Slope of pull-dn char) $\ll 1$!!



A Practical Method of finding a solution

- **Numerical Solution with a guess and corresponding error**

- $V_d(\text{on}) \approx 0.6\text{V}$:

$$I_R = ?$$

$$\text{Error} = ?$$

- $V_d(\text{on}) \approx 0.7\text{V}$:

$$I_R = ?$$

$$\text{Error} = ?$$



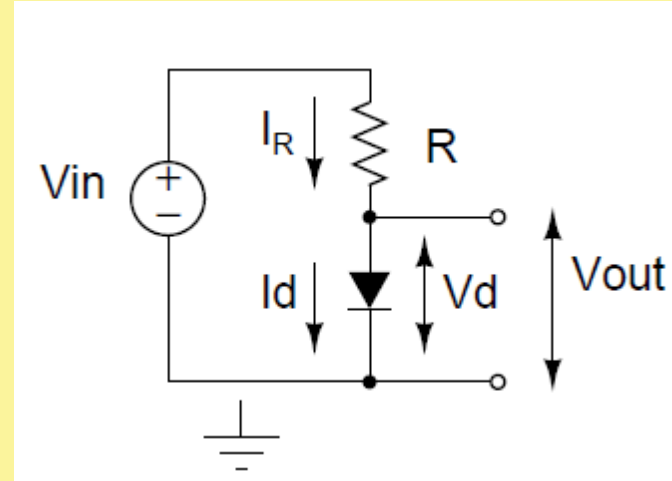
Working Model – *Equivalent Circuit* of a diode

- Diode in “on” state
 - $r_{on} =$
- Diode in “off” state
 - $r_{off} =$
- piece-wise linear model



Application of the Working Model of diode

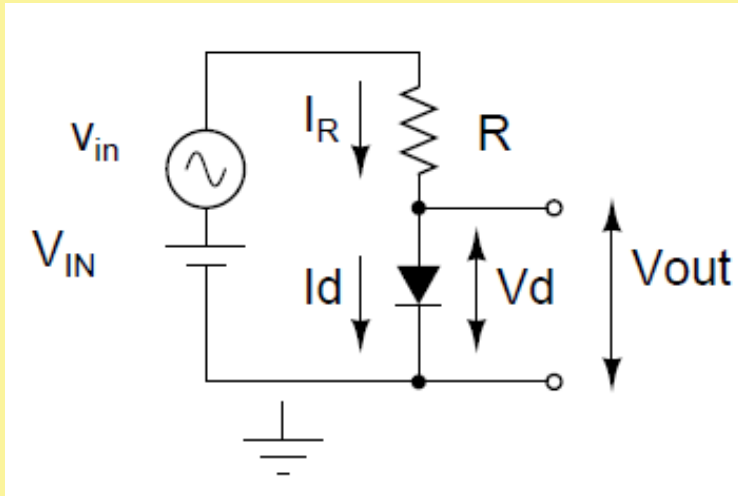
- Use Equivalent circuit
- Find V_{out} when V_{in} is changing (with time):
 - $V_{out} = ?$
 - Pictorial discussion



- Input-Output Transfer Char.

Application of the Working Model (*contd...*)

- **Finding V_{out} when V_{in} has a.c. signal**
 - Using Equivalent circuit and through circuit equations



Application of the Working Model (*contd...*)

- Interpretation of different parts of V_{out} obtained through equation

$V_{out} =$

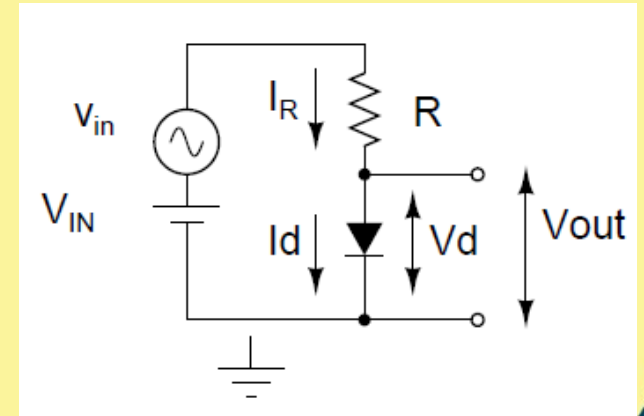
- Interpretation of parts of V_{out} in In-Out Transfer Char.



Notion of Small Signal Equivalent circuit

- **In-Out Transfer Characteristic**

- Large signal and Small signal

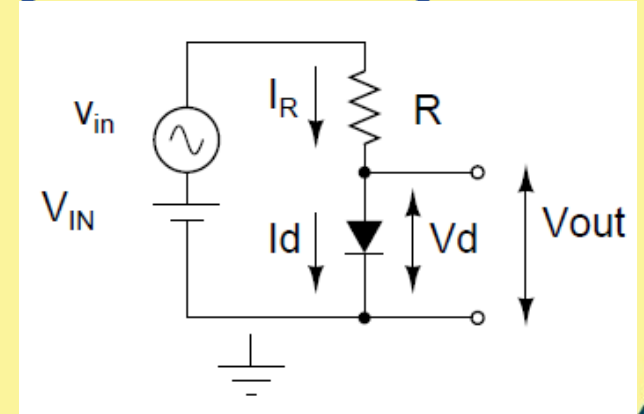


- **Small signal equivalent circuit**

- Rules to get it
- Graphical interpretation

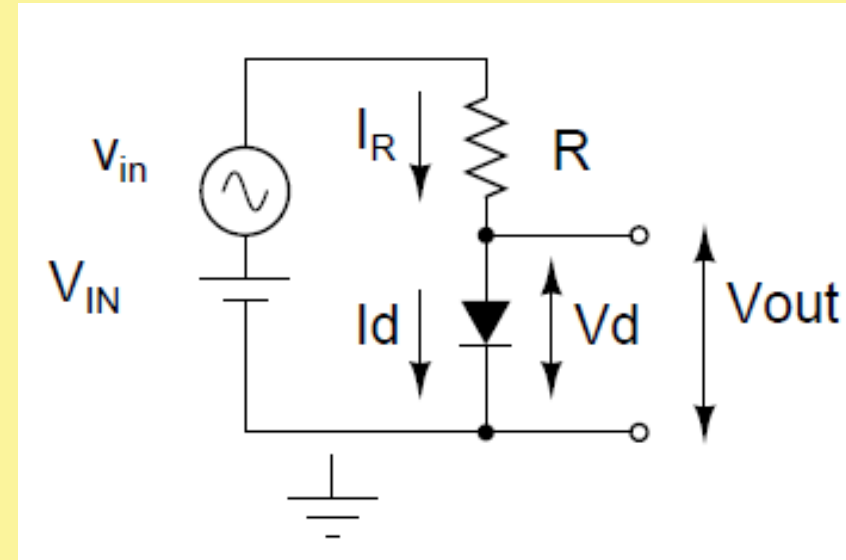
Small signal equivalent circuit (*contd...*)

- **Advantages of small signal equivalent ckt**
 - Linearization of non linear ckt (w.r.t. Q-pt)
 - Simpler circuit
 - Superposition theorem is valid
- **Validity of the linear circuit and signals**



Numerical examples

- **Given:** $V_{IN} = 5\text{ V}$, $R = 10\text{ k}\Omega$, $I_0 = 10^{-13}\text{ A}$, $V_T = 26\text{ mV}$
- **Find I_d and V_{out} ,**
 - Using Two Iterations
 - Using Practical model of diode
($V_Y = 0.6\text{ V}$ and $r_{on} > 0$)
- **Find v_{out} for $v_{in} = 10 \sin(\omega t)\text{ mV}$**
 - Using Large signal model of diode
 - Using small signal equivalent circuit



Conclusion

Conclusion:

- ❑ Analysis of non-linear circuit to find solution
- ❑ Generalized methods of finding solution
- ❑ Practical method of finding solution
- ❑ Simple yet working model of diode
- ❑ Application of the diode model
- ❑ Linearization of non-linear circuit - Notion of Small signal equivalent circuit





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*Thank
you*

