Analog Circuit -I

Dr. Chandrima Mondal

Assistant Professor

Jadavpur University

Relation to Other Courses

- **Prerequisite:**
  - **Basic Electronics**
  - **Circuit Theory**
- **Relation to other courses:**
  - **Analog Circuit 2**
  - **Digital Circuit**
  - **Analog Communication**

Syllabus

Introduction to Electronic Circuits: (1L)

Diode & wave shaping circuits:(6L + 2T)

Different rectifier circuits, ripple factor, efficiency, TUF, PIV, power supply filters, clipper and clamper circuits, peak detector, voltage multiplier. RC filter response for non-sinusoidal signals, compensated attenuator.

BJT circuits:(8L + 3T)

Biasing and stability analysis: fixed bias, collector to base feedback bias, emitter bias, voltage divider bias, transistor as a switch AC analysis: modeling (re, hybrid equivalent, and hybrid π models), expressions for input impedance, output impedance, voltage gain, current gain for different configurations including emitter follower with different biasing circuits, DC bias with voltage negative feedback, effects of source and load resistance, two-port system approach- combination networks: Darlington pair, cascade and cascode configurations, current mirror circuits. Frequency response: Low frequency and high frequency response, Miller effect, brief overview on multistage amplifier, frequency effects and square wave testing. *Design application and SPICE Simulation*.

FET circuits:(7L +2T)

Biasing: fixed bias, self-bias, voltage divider bias, common drain, common gate configurations AC analysis: Modeling (small signal model), expressions for input impedance, output impedance, voltage gain for different configurations like fixed bias, self-bias, voltage divider bias, common drain, common gate configurations Frequency response: low frequency and high frequency response, Miller effect . *Design application and SPICE Simulation*.

OPAMP circuits: (8L + 3T)

Basics, differential amplifier circuit, concept of open loop and closed loop gain, DC offset and frequency parameters, slew rate, differential and common mode operation , applications: inverting and non-inverting amplifier, transresistance amplifier, transconductance amplifier, log and antilog amplifier, adder, subtractor, multiplier, divider, buffer, differentiator and integrator, active filters, Equation solver, Schmitt trigger and multivibrators, rectifier clipper and clamper circuits, peak detector.

Regulated Power Supply:(6L + 2T)

Voltage regulation, Zener diode & IC regulator, regulation factor, filter circuit’s discrete transistor voltage regulation (series and shunt), switching regulators, switch mode power supply.

- Total 36 L and 12 T

- classify diode models and apply those in different diode circuits (K_2, K_3)
- Understand RC filter response for non-sinusoidal signals (K_2)
- understand and analyze different DC and AC equivalent circuits to realize BJT and FET amplifiers. (K_2, $K_{4,}$ A_1)
- Explain characteristics of op-amp and apply them in various analog electronic circuits. (K_2)
- analyze and design filters, amplifiers and voltage regulators. (K_4, K_5)

Books

- **Text books:**
  - J. Millman, C. Halkias and S. Jit, “Electronic Devices and Cicuits”, Tata McGraw-Hill, 4th edition, 2015.
  - Adel S. Sedra and Kenneth C. Smith, "Microelectronic Circuits-Theory and applications", seventh Edition , 2017
  - Ramakant A. Gayakwad, “Op-amps and Linear Integrated Circuits”, Prentice Hall, 4th Edn
- **Reference books:**
  - D. A. Neaman, "Electronic Circuits: Analysis And Design", 3rd Edition", Tata McGraw-Hill, 2010
  - Donald Schilling and Charles Belove, "Electronic Circuits: Discrete & Integrated", Tata McGraw-Hill Education 2002
  - Robert L. Boylestad, Louis Nashelsky, "Electronic Devices and Circuit Theory " Pearson; 10 edition 2009

Grading

- Attendance
- Homework
- Assignments
- 2 class tests

  60 minutes each

30%

Final exam

- *bring calculator*

70%

Miscellany

- **Classroom etiquette:**
  - Arrive in class on time!
  - Bring your own copy of the lecture notes.
  - Turn off cell phones.
  - No distracting conversations

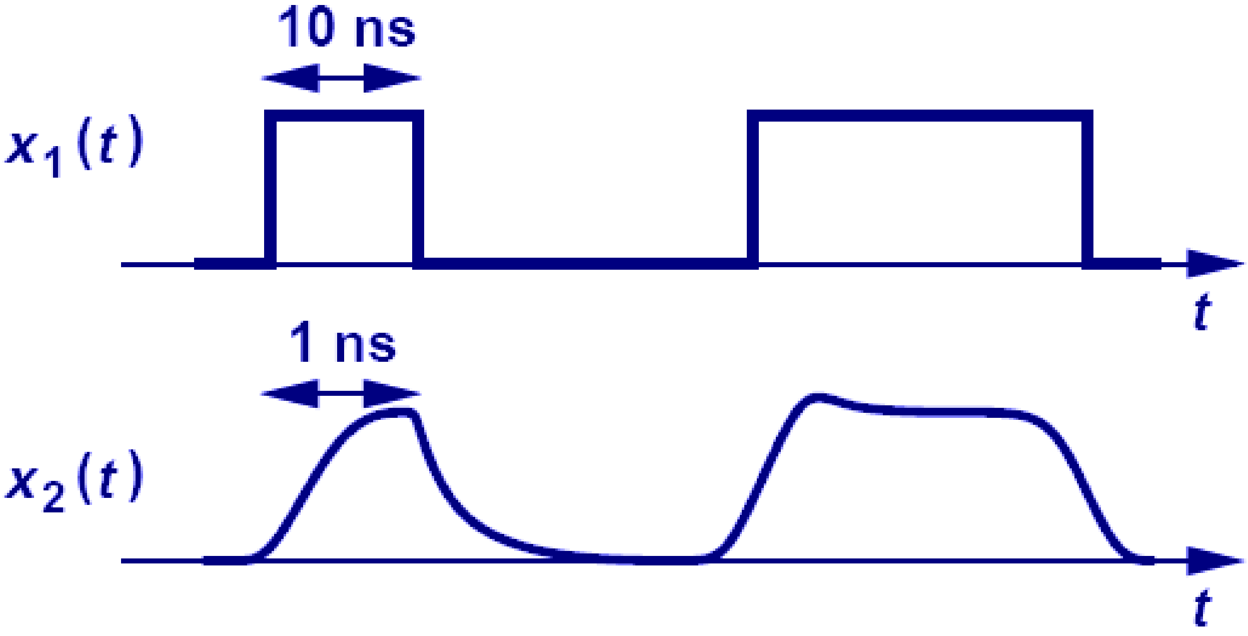
IEEE Notation

- Subscript convention
  - $V_{DS} \equiv V_D - V_S$, $V_{GS} \equiv V_G - V_S$, *etc.*
- Double-subscripts denote DC sources
  - V_{DD} , V_{CC} , I_{SS} , *etc.*
- To distinguish between DC and AC components of an electrical quantity, the following convention is used:
  - DC quantity: upper-case letter with upper-case subscript
    - I_D , V_{DS} , *etc.*
  - AC quantity: lower-case letter with lower-case subscript
    - i_d , v_{ds} , *etc.*
  - Total (DC + AC) quantity:

    lower-case letter with upper-case subscript
    - i_D , v_{DS} , *etc.*
  - rms value:
    - » I_d, $V_{ds,}$ etc.

Introduction

Digital or Analog Signal?



Passive and Active components

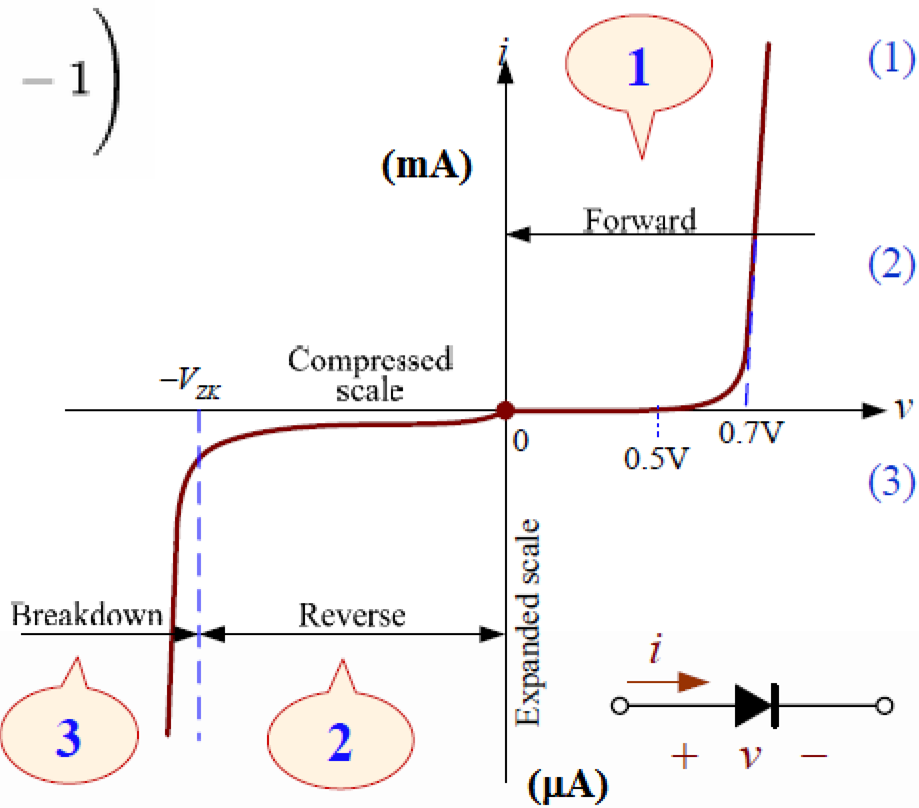
- **Passive components** can't introduce net energy into the circuit. They also can't rely on a source of power, except for what is available from the (AC) circuit they are connected to. As a consequence they can't amplify (increase the power of a signal), although they may increase a voltage or current (such as is done by a transformer or resonant circuit). Passive components include two-terminal components such as resistors, capacitors, inductors, and transformers.

- **Active components** rely on a source of energy (usually from the DC circuit, which we have chosen to ignore) and usually can inject power into a circuit, though this is not part of the definition. Active components include amplifying components such as transistors, triode vacuum tubes (valves), and tunnel diodes.

Non-linear device

- In an electric circuit, a nonlinear element or nonlinear device is an electrical element which does not have a linear relationship between current and voltage. A diode is a simple example. The current I through a diode

$$I = I_S\left(e^{\frac{V_D}{nV_T}} - 1\right)$$



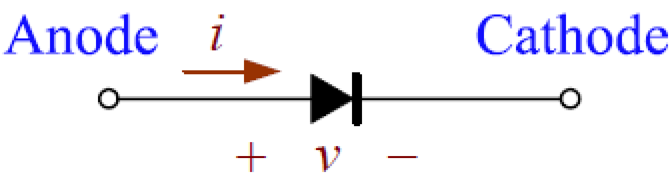
(1) The forward-bias region determined by $v > 0$

(2) The reverse-bias region determined by $-V_{ZK} < v < 0$

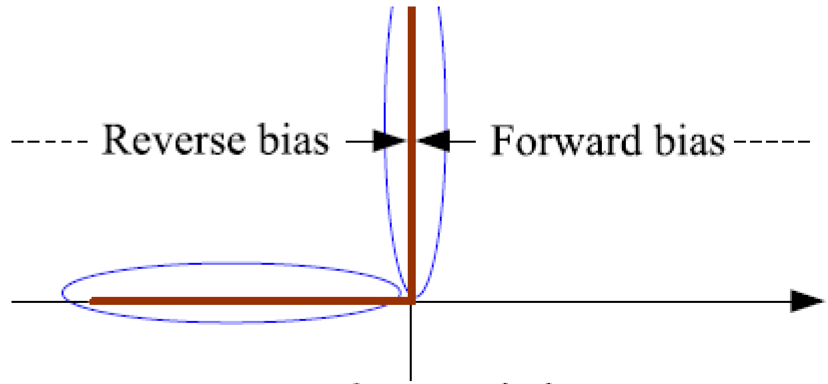
(3) The breakdown-bias region determined by $v < -V_{ZK}$

Modeling of the diode characteristic

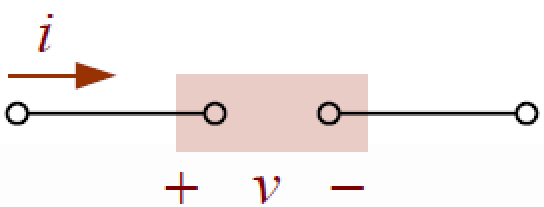
1. The Ideal Diode Model



(a) diode circuit symbol

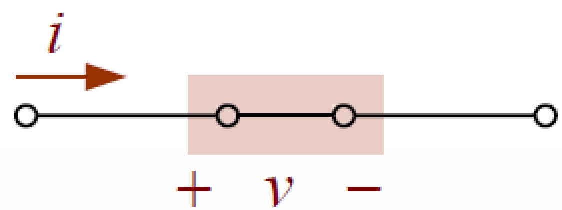


(b) i–v characteristic



$$v < 0 \Rightarrow i = 0$$

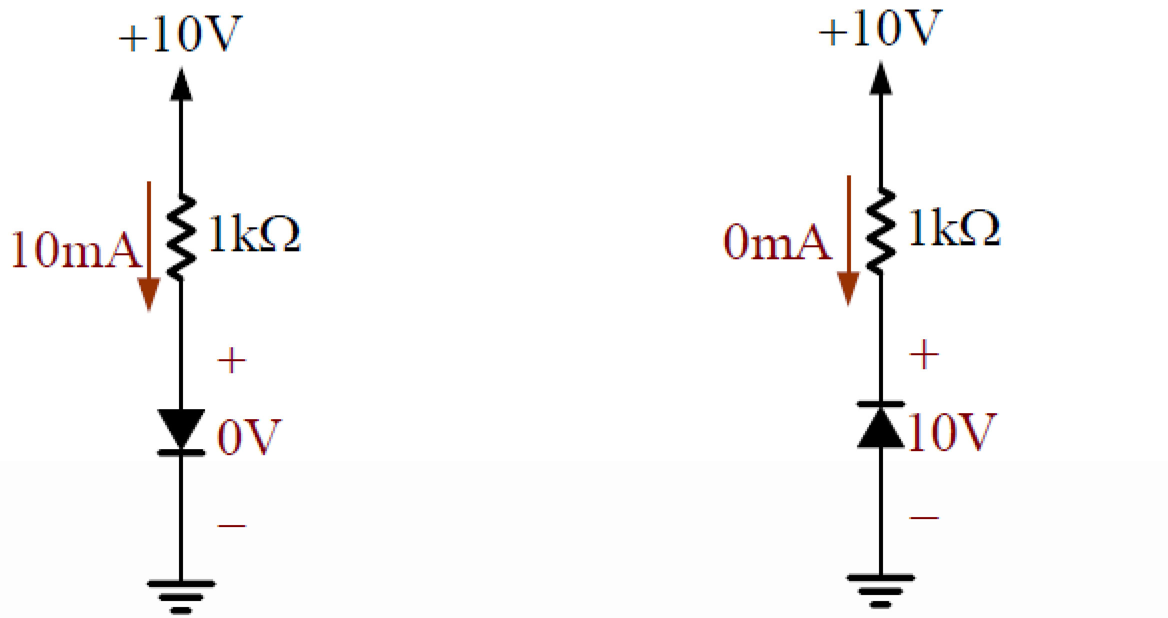
(c) equivalent circuit in the reverse direction



$$i > 0 \Rightarrow v = 0$$

(d) equivalent circuit in the forward direction.

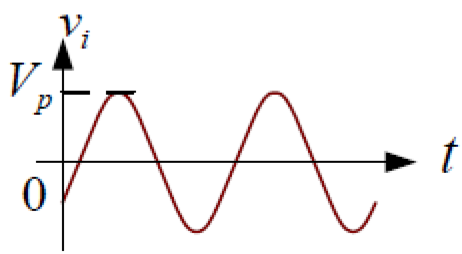
Forward and reverse bias



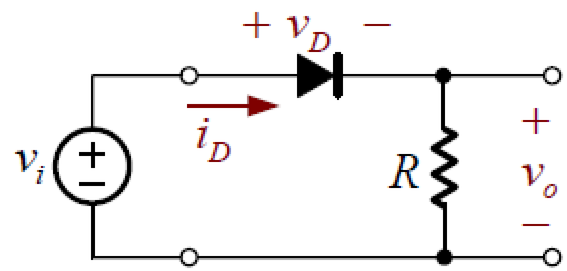
(a) the forward current

(b) the reverse voltage

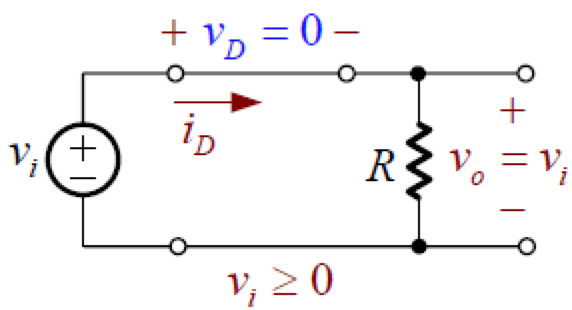
Simple diode circuits



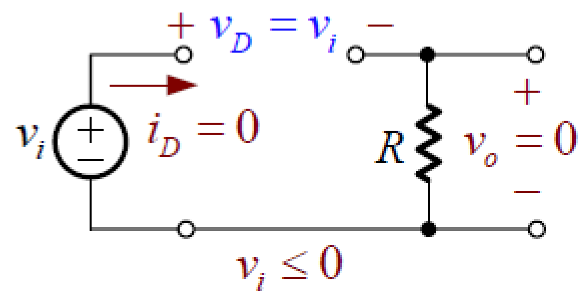
(a) Input waveform.



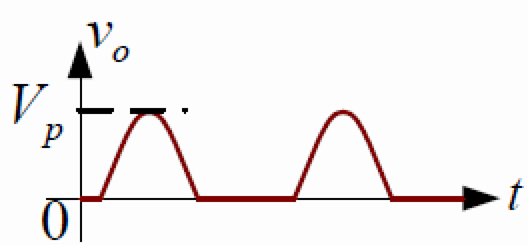
(b) Rectifier circuit.



(c) Equivalent circuit when $v_i \geq 0$.



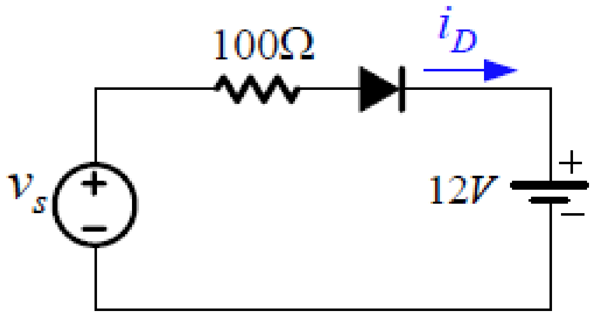
(d) Equivalent circuit when $v_i \leq 0$

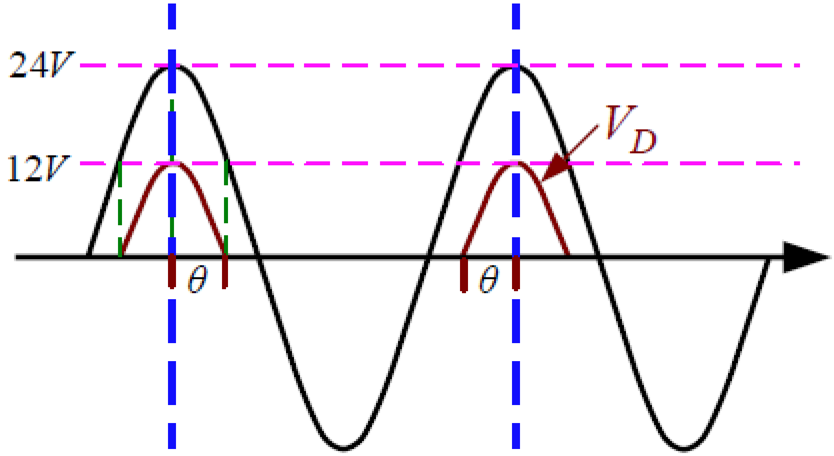


(e) Output waveform.

Simple diode circuits

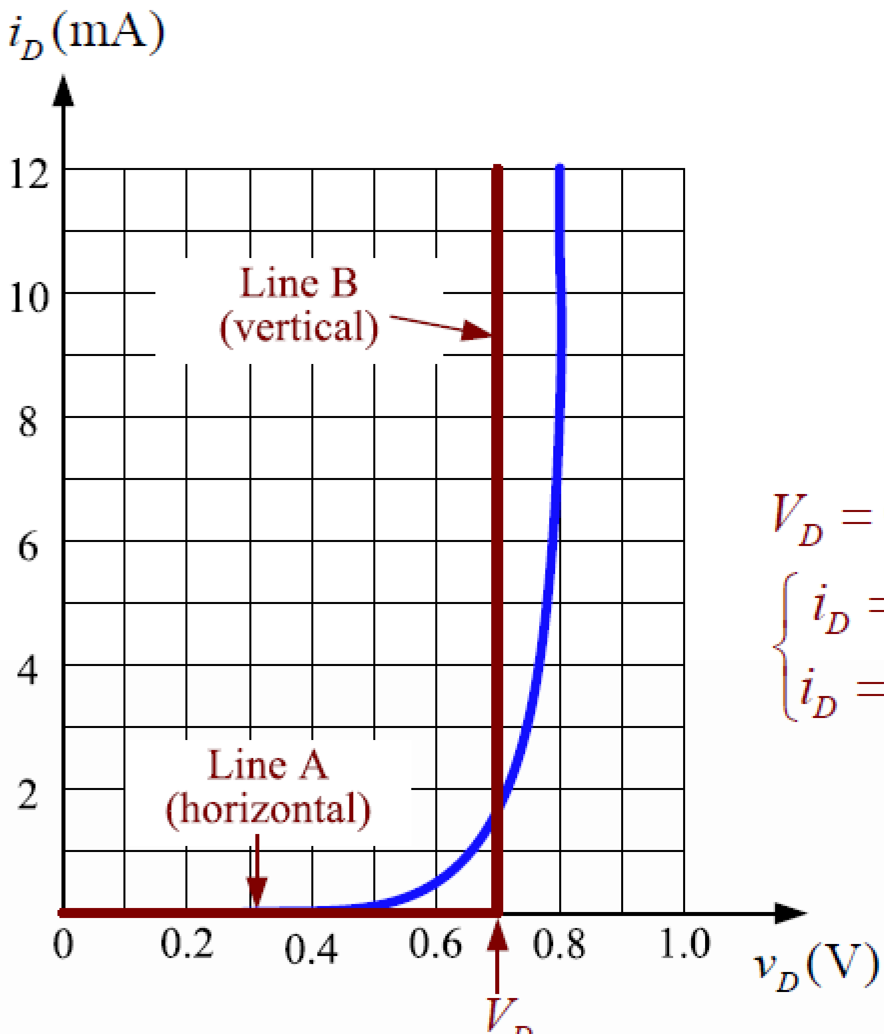
If v_s is sinusoid with 24-V peak amplitude, (a) Find the fraction of each cycle during which the diode conducts. (b) Also find the peak value of the diode current and (c) the maximum reverse-bias voltage that appears across the diode.

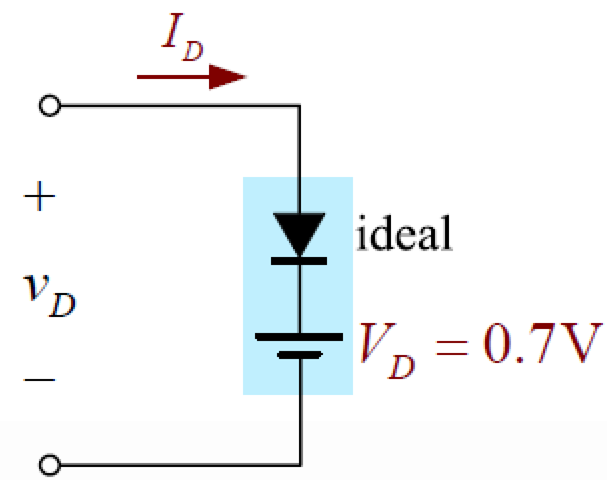




Modeling the diode forward characteristic

- **The offset voltage model/ The Constant-**



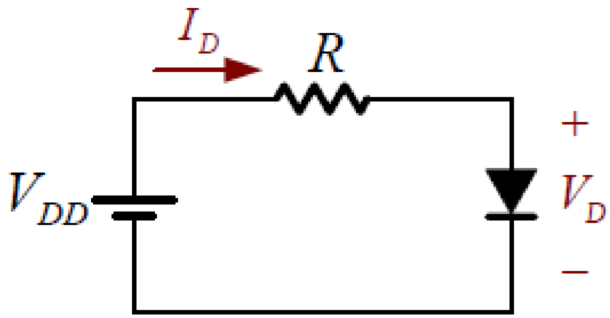


$$V_D = 0.7\text{V}$$

$$\begin{cases} i_D = 0, & v_D \le 0.7\text{V} \\ i_D = (v_D - 0.7\text{V})/\text{R} & v_D \ge 0.7\text{V} \end{cases}$$

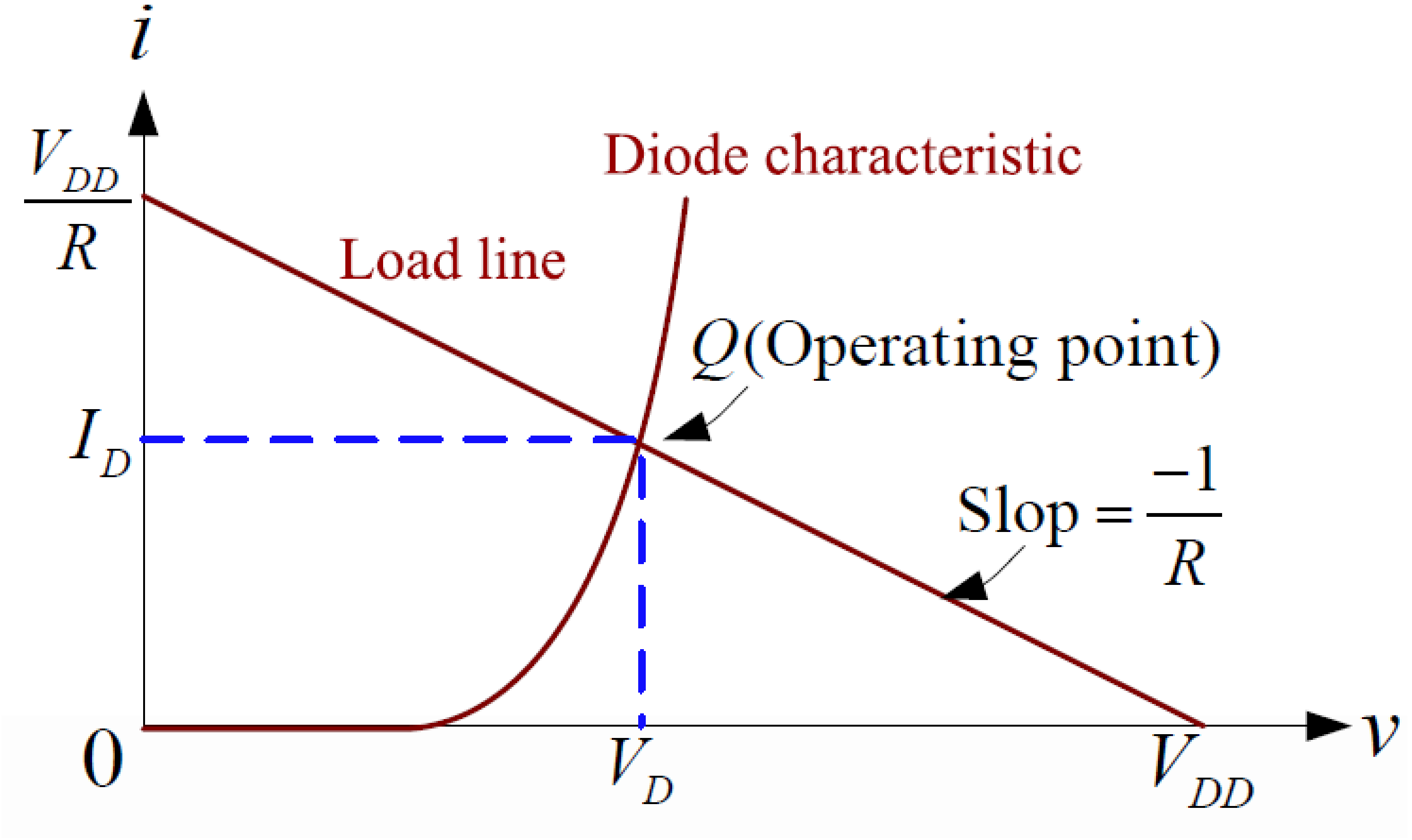
Modeling the diode characteristic

$$\text{Assuming that } \begin{cases} V_{DD} > 0.5\text{V} \\ I_D > I_s \end{cases} \Rightarrow I_D = I_s e^{V_D / nV_T}$$



The other equation that governs circuit operation is obtained by writing a loop equation by KVL resulting in $I_D = \dfrac{V_{DD} - V_D}{R}$

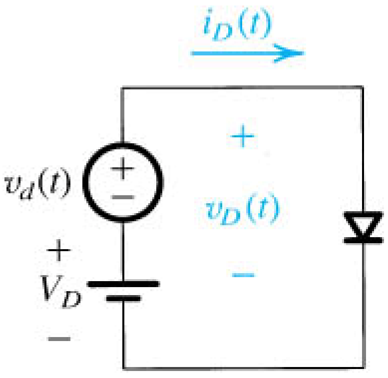
Modeling the diode characteristic



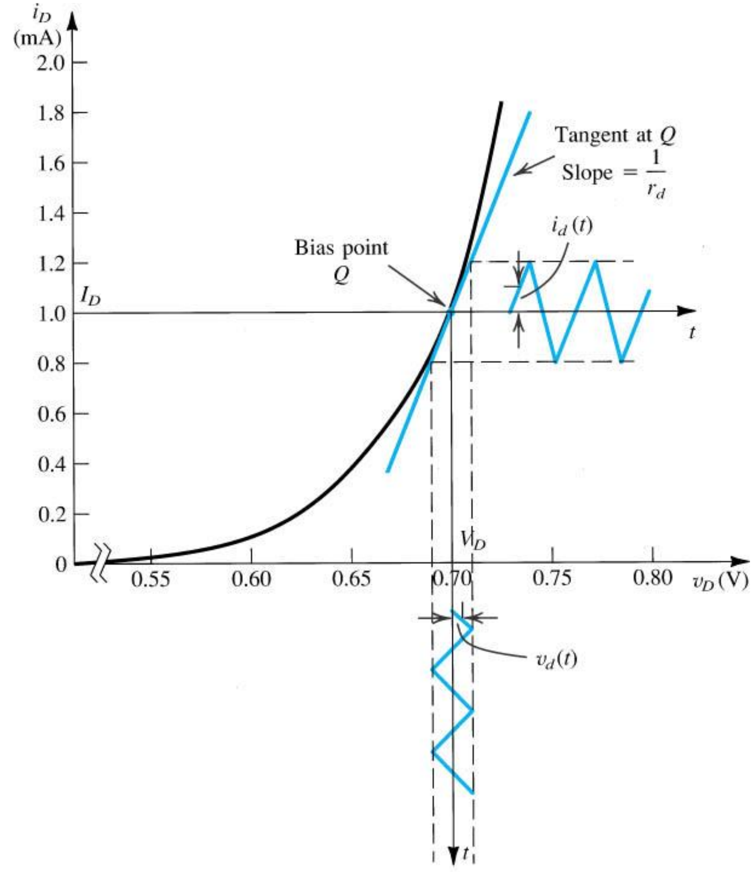
Graphical analysis of the circuit in using the exponential diode model.

Modeling the diode forward characteristic

- **The Diode Small-Signal Model**



(a)



(b)

$$i_D = I_S e^{v_D / nV_T}$$

$$v_D(t) = V_D + v_d(t)$$

Small-Signal Model

$$i_D(t) = I_S e^{v_D(t)/nV_T} = I_S e^{[V_D + v_d(t)]/nV_T}$$

$$= \underbrace{I_S e^{V_D/nV_T}}_{I_D} \cdot e^{v_d(t)/nV_T}$$

$$= I_D \cdot e^{v_d(t)/nV_T}$$

If the signal $v_d(t)$ is kept sufficiently small

such that $\dfrac{v_d(t)}{nV_T} << 1$

Thus, the approximate expression

$$\underbrace{i_D(t) = I_D \cdot \left(1 + \frac{v_d}{nV_T}\right)}_{\text{Small-signal approximation}}$$

We have

$$i_D(t) = I_D + \underbrace{\frac{I_D}{nV_T} v_d}_{i_d}$$

where $i_d = \dfrac{I_D}{nV_T} v_d$

$$r_d \equiv \frac{v_d}{i_d} = \frac{nV_T}{I_D}$$

r_d is the diode small-signal resistance, and called incremental resistance/ **dynamic resistance**

Small-Signal Model

- the slope of the tangent to the - curve at the operating point Q is equal to the small-signal conductance.

$$r_d = \frac{1}{\left[\frac{\partial i_d}{\partial v_d}\right]_{i_d = I_D}}$$

Assignment

Example : Consider the circuit shown in Fig a string of three diode is used to provide a constant voltage of about 2.1V, we want to calculate the percentage change in this regulated voltage cause by :

(a) •10% change in the power-supply voltage

(b) Connection of a 1kΩ load resistance. Assume n=1