FORMULA BOOK

for

GATE, IES & PSU’s

(Complete syllabus of Engineering Services)

ELECTRONICS ENGINEERING

Published by Engineers Institute of India
© 2015 By Engineers Institute of India
ALL RIGHTS RESERVED. No part of this work covered by the copyright herein may be reproduced, transmitted, stored or used in any form or by any means graphic, electronic, or mechanical & chemical, including but not limited to photocopying, recording, scanning, digitizing, taping, Web distribution, information networks, or information storage and retrieval systems.

Engineers Institute of India
28-B/7, Jia Sarai, Near IIT Hauz Khas New Delhi-110016
Tel: 011-26514888
For publication information, visit www.engineersinstitute.com/publication
Price: Rs. 290/-
A WORD TO THE STUDENTS.

GATE and Engineering Services Examinations are the most prestigious competitive examinations conducted for graduate engineers. Over the past few years, they have become more competitive as more and more numbers of aspirants are increasingly becoming interested in post graduate qualifications & government jobs for a secured and bright career.

This Formula Book consists of well illustrated concepts, important formulae and diagrams, which will be highly beneficial at the last leg of candidate’s preparation.

It includes all the subjects of Electronics & Communication Engineering, Instrumentation Engineering, which are required for all type of competitive examinations. Adequate emphasis has been laid down to all the major topics in the form of Tips / Notes, which will be highly lucrative for objective and short answer type questions.

Proper strategy and revision is a mandatory requirement for clearing any competitive examination. This book covers short notes and formulae for Electronics & Communication Engineering. This book will help in quick revision before the GATE, IES & all other PSUs.

We are highly thankful to Syed Zahid Ali Quadri (ES Rank16, GATE Rank 34), Ankur Gupta, Ashish Choudhary and the EII Team for their efforts in bringing out this book in the present form. We have tried our best to steer you ahead in the competitive examinations.

With best wishes for future career

R. K. Rajesh
Director
Engineers Institute of India
eii.rkrajesh@gmail.com
This book is dedicated to all
Electronics & Electrical Engineers
Preparing for Engineering Services examinations.

CONTENTS

1. MATERIAL SCIENCE ........................................... 01-14
2. MEASUREMENT & INSTRUMENTATION ............ 15-36
3. ELECTROMAGNETIC THEORY .............................. 37-58
4. NETWORK THEORY ........................................... 59-98
5. SIGNAL AND SYSTEM ........................................ 99-124
6. ELECTRONIC DEVICES & CIRCUITS ................. 125-156
7. COMMUNICATION SYSTEM ................................. 157-190
8. DIGITAL ELECTRONICS ..................................... 191-234
9. CONTROL SYSTEM ............................................. 235-268
10. MICROPROCESSOR ........................................... 269-286
11. COMPUTER ORGANIZATION ............................. 287-300
12. MICROWAVES ............................................... 301-328
13. ANALOG ELECTRONICS ................................... 329-364
Why IES?
Indian engineering services (IES) constitute of engineers that work under the govt. of India to manage a large segment of public sector economy which constitutes of Railroads, Public works, Power, Telecommunications, etc. IES remain the most sought-after careers for the engineering graduates in India. A combined competitive examination is conducted by UPSC for recruitment to the Indian Engineering Services. The exam constitutes of a written exam followed by an interview for personality test.

Why GATE?
In the present competitive scenario, where there is mushrooming of universities and engineering colleges, the only yardstick to measure and test the calibre of engineering students is the GATE.

The GATE Advantage
Many public sector undertakings such as BHEL, IOCL, NTPC, BPCL, HPCL, BARC and many more PSUs are using the GATE score for selecting candidates for their organizations. Students who qualify in GATE are entitled to a stipend of Rs 8,000 per month during their M.Tech. course. Better remuneration is being offered for students of M.Tech./ME as compared to those pursuing B.Tech./B.E. A good rank assures a good job. After joining M.Tech. at IITs and IISc, one can look at a salary package ranging from Rs 7lakh to 30lakh per annum depending upon specialization and performance. Clearing GATE is also an eligibility clause for the award of JRF in CSIR Laboratories.

Proper strategy and revision is a mandatory requirement for clearing any competitive examination. This book covers short notes and formulae for Electronics & Communication Engineering. This book will help in quick revision before the GATE, IES & all other PSUs.
1

MATERIAL SCIENCE

CONTENTS

1. STRUCTURE OF MATERIALS ........................................ 02-03
2. ELECTRIC MATERIALS & PROPERTIES ........................ 04-07
3. CONDUCTIVE MATERIALS ........................................ 08-10
4. MAGNETIC MATERIALS ........................................... 11-14
1. **Structure of Materials**

1. **Simple Cubic (SC):**
   - Distance between adjacent atoms \( d_{sc} = a = 2r \)
   - Coordination number = 6
   - No of atoms per unit cell = 8 corners \( \times \frac{1}{8} \) part = 1
   - Packing efficiency = 52%
     Example → Polonium, Fluorspar

2. **Body Centered Cubic (BCC):**
   - Distance between adjacent atom \( d_{bcc} = 2r = \frac{\sqrt{3}}{2} a \)
   - Coordination number = 8
   - No of atoms per unit cell = \( 8 \times \frac{1}{8} + 1 = 2 \)
   - Packing efficiency = 68%
     Example → Fe, Cr, Na

3. **Face Centered Cubic (FCC):**
   - Distance between adjacent atoms \( d_{fcc} = 2r = \frac{a}{\sqrt{2}} \)
   - Coordination number = 12
   - No of atoms per unit cell = \( 8 \times \frac{1}{2} + 12 \times \frac{1}{8} = 3 \)
   - Packing efficiency = 74%
     Example → Cu, Silver, Gold

**Hexagonal Closed Pack (HCP):**
- Coordination number = 12
- No of atoms per unit cell = \( 12 \times \frac{1}{12} + 3 = 4 \)
- Packing efficiency = 74%
  Example → Cd, Mg

**Different types of unit cell**

<table>
<thead>
<tr>
<th>Type of unit cell</th>
<th>Volume of unit cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cubic</td>
<td>( a^3 )</td>
</tr>
<tr>
<td>Tetragonal</td>
<td>( a^2c )</td>
</tr>
<tr>
<td>Orthorhombic</td>
<td>( abc )</td>
</tr>
</tbody>
</table>
Crystallographic Plane and Miller Indices: Miller indices are used to specify directions and planes and it could be in lattices or in crystals.

Miller Indices for plane $A'B'C'$

$$h = \frac{OA}{OA'}, \ k = \frac{OB}{OB'}, \ \ell = \frac{OC}{OC'}$$

Example:

1. $h = \frac{OA}{OA} = 2$
   
   $k = \frac{OB}{\infty} = 0$
   
   $\ell = \frac{OC}{\infty} = 0$
   
   $(h, k, \ell) = (2, 0, 0)$

2. $h = \frac{OA}{OA} = 1$
   
   $k = \frac{OB}{OB} = 1$
   
   $\ell = \frac{OC}{OC} = 1$
   
   $(h, k, \ell) = (1, 1, 1)$

3. $h = \frac{OA}{OA} = 1$
   
   $k = \frac{OB}{\infty} = 0$
   
   $\ell = \frac{OC}{\infty} = 0$
   
   $(h, k, \ell) = (1, 0, 0)$

Hexagonal $\frac{3\sqrt{3}a^2c}{2}$
2

MEASUREMENT
&
INSTRUMENTATION

CONTENTS

1. MEASURING INSTRUMENT CHARACTERISTICS .......... 16-17
2. CLASSIFICATION OF ELECTRICAL INSTRUMENTS .......... 18-23
3. AC BRIDGES .......................................................... 24-26
4. MEASUREMENT OF POWER & WATTMETERS .......... 27-29
5. MEASUREMENT OF RESISTANCE ......................... 30-30
6. Q-METER ............................................................... 31-31
7. TRANSDUCERS ....................................................... 32-34
8. CRO (CATHODE RAY OSCILLOSCOPE) ................. 35-36
1. MEASURING INSTRUMENT CHARACTERISTICS

Generalized Measuring Instrument: The block diagram of generalized measuring system may be represented as:

\[ \begin{align*}
\text{Primary Sensing Element} & \rightarrow \text{Data Conversion Element} \rightarrow \text{Data Manipulation Element} \rightarrow \text{Data Transmission Element} \rightarrow \text{Data Presentation Element} \\
PSE & \rightarrow \text{DCE} \rightarrow \text{DME} \rightarrow \text{DTE} \rightarrow \text{DPE}
\end{align*} \]

IMPORTANT DEFINITIONS:

Accuracy: Closeness with which an instrument reading approaches the true value of the variable being measured. It can be improved by recalibration.

Precision: It is a measure of the degree to which successive measurement differ from one another.
- It is design time characteristic.
High precision does not mean high accuracy. A highly precise instrument may be inaccurate.
Ex: If reading are 101, 102, 103, 104, 105. Most precise value is 103

Resolution: The smallest change in measured value to which the instrument will respond. It is improved by re-calibrating the instrument.

Sensitivity: It is ratio of change in output per unit change in input quantity of the instrument. It is design time characteristic.

Drift: It means deviation in output of the instrument from a derived value for a particular input.

Reproducibility: It is degree of closeness with which a given value may be measured repeatedly for a given period of time.

Repeatability: It is degree of closeness with which a given input is repeatably indicated for a given set of recordings.

Errors:

1. Absolute Error/Static Error/Limiting Error:
   \[ \delta A = A_m - A_T \]
   \[ A_m \rightarrow \text{Measured value of quantity of actual value} \]
   \[ A_T \rightarrow \text{True value of quantity or nominal value} \]

2. Relative Error:
   \[ \varepsilon_r = \pm \frac{\delta A}{A_T} = \frac{A_m - A_T}{A_T} \]

3. Percent Error:
   \[ \% \varepsilon_r = \frac{\delta A}{A_T} \times 100 \]

   Instrument Error is generally given in percent error.

4. Percentage Error at reading ‘x’:
   \[ \% \varepsilon_{r,x} = \left[ \frac{\text{Full Scale Reading}}{x} \right] \times [\% \varepsilon_r, \text{Full scale}] \]

Error due to combination of quantities:
1. Error due to Sum/Difference of quantities
   \[ X = x_1 \pm x_2 \]
   \[ \% \varepsilon_x = \frac{\delta X}{X} = \pm \left( \frac{x_1}{X} \left( \frac{\delta x_1}{x_1} \right) + \frac{x_2}{X} \left( \frac{\delta x_2}{x_2} \right) \right) \]

2. Error due to product or quotient of quantities
   \[ X = x_1 x_2 x_3 \quad \text{or} \quad \frac{x_1}{x_2 x_3} \quad \text{or} \quad \frac{1}{x_1 x_2 x_3} \]
   \[ \frac{\delta X}{X} = \pm \left( \frac{\delta x_1}{x_1} + \frac{\delta x_2}{x_2} + \frac{\delta x_3}{x_3} \right) \]

3. Composite factors \[ X = x_1^n \cdot x_2^m \]
   \[ \frac{\delta X}{X} = \pm \left( n \frac{\delta x_1}{x_1} + m \frac{\delta x_2}{x_2} \right) \]

CLASSIFICATION OF ERRORS:

Standards of EMF:

(a) **Saturated Weston cell** is used for Primary standard of emf.
   Its emf is 1.01864 volt, maximum current drawn is 100 µA. It contains CdSO₄ crystal and its internal resistance is 600 Ω to 800 Ω.

(b) **Unsaturated Weston cell** is used for secondary standards. Its emf is 1.0180 to 1.0194 volt and does not have CdSO₄ crystal.

Standard of Resistance:

Maganin (Ni + Cu + Mn)

- Nickel 4%
- Magnese 12% [High Resistivity and low temperature coefficient]
- Copper 84%

Inductive effect of resistance can be eliminated, using **Bifilar winding**.

Standard of Time and Frequency:

**Atomic clock** is used as primary standard of time and frequency. Quartz, Rubidium crystal is used as secondary standard of time and frequency. Example: Cesium 133, hydrogen maser etc.
3

ELECTROMAGNETIC THEORY

CONTENTS

1. COORDINATE SYSTEMS AND VECTOR CALCULUS ..... 38-39

2. ELECTROSTATIC FIELDS .............................................. 40-43

3. MAGNETOSTATIC FIELDS ........................................ 44-46

4. MAXWELL'S EQUATIONS ........................................... 47-48

5. ELECTROMAGNETIC WAVES ..................................... 49-53

6. TRANSMISSION LINE ............................................... 54-57

7. ANTENNAS .............................................................. 58-58
1. COORDINATE SYSTEMS AND VECTOR CALCULUS

Vector Calculus:

- **Gradient**: The gradient of scalar $V$ is written as $\nabla V$ and result is vector quantity.

  For Cartesian:  
  
  \[
  \nabla V = \frac{\partial V}{\partial x} \mathbf{\hat{a}_x} + \frac{\partial V}{\partial y} \mathbf{\hat{a}_y} + \frac{\partial V}{\partial z} \mathbf{\hat{a}_z}
  \]

  For Cylindrical:  
  
  \[
  \nabla V = \frac{1}{\rho} \frac{\partial V}{\partial \rho} \mathbf{\hat{a}_\rho} + \frac{\partial V}{\partial \phi} \mathbf{\hat{a}_\phi} + \frac{1}{\rho} \frac{\partial V}{\partial z} \mathbf{\hat{a}_z}
  \]

  For Spherical:  
  
  \[
  \nabla V = \frac{1}{r^2} \frac{\partial V}{\partial r} \mathbf{\hat{a}_r} + \frac{1}{r \sin \theta} \frac{\partial V}{\partial \phi} \mathbf{\hat{a}_\phi} + \frac{1}{r \sin \theta} \frac{\partial V}{\partial \theta} \mathbf{\hat{a}_\theta}
  \]

- **Divergence**: The divergence of vector $\mathbf{A}$ is written as $\nabla \cdot \mathbf{A}$ and result is scalar quantity.

  For Cartesian:  
  
  \[
  \nabla \cdot \mathbf{A} = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}
  \]

  For Cylindrical:  
  
  \[
  \nabla \cdot \mathbf{A} = \frac{1}{\rho} \frac{\partial}{\partial \rho} (\rho A_\rho) + \frac{1}{\rho} \frac{\partial A_\phi}{\partial \phi} + \frac{1}{\rho \sin \theta} \frac{\partial A_\theta}{\partial \theta}
  \]

  For Spherical:  
  
  \[
  \nabla \cdot \mathbf{A} = \frac{1}{r^2} \frac{\partial}{\partial r} (r^2 A_r) + \frac{1}{r \sin \theta} \frac{\partial}{\partial \theta} (r \sin \theta A_\theta) + \frac{1}{r \sin \theta} \frac{\partial A_\phi}{\partial \phi}
  \]

- **Curl of vector**: The curl of vector $\mathbf{A}$ is defined as $\nabla \times \mathbf{A}$ and result is vector quantity.

  For Cartesian:  
  
  \[
  \nabla \times \mathbf{A} = \begin{vmatrix}
  \mathbf{\hat{a}_x} & \mathbf{\hat{a}_y} & \mathbf{\hat{a}_z} \\
  \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\
  A_x & A_y & A_z
  \end{vmatrix}
  \]

  For Cylindrical:  
  
  \[
  \nabla \times \mathbf{A} = \begin{vmatrix}
  \mathbf{\hat{a}_r} & \mathbf{\hat{a}_\phi} & \mathbf{\hat{a}_z} \\
  \frac{\partial}{\partial \rho} & \frac{\partial}{\partial \phi} & \frac{\partial}{\partial z} \\
  A_\rho & A_\phi & A_z
  \end{vmatrix}
  \]

  For Spherical:  
  
  \[
  \nabla \times \mathbf{A} = \begin{vmatrix}
  \mathbf{\hat{a}_r} & \mathbf{\hat{a}_\theta} & \mathbf{\hat{a}_\phi} \\
  \frac{\partial}{\partial r} & \frac{\partial}{\partial \theta} & \frac{\partial}{\partial \phi} \\
  A_r & r A_\theta & r \sin \theta A_\phi
  \end{vmatrix}
  \]

- **Laplacian of Scalar**: Laplacian of scalar field $V$ is written as $\nabla^2 V$. It is the divergence of gradient of $V$. The result is a scalar quantity.
For Cartesian:
\[ \nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} \]

For Cylindrical:
\[ \nabla^2 V = \frac{1}{\rho} \frac{\partial}{\partial \rho} \left( \rho \frac{\partial V}{\partial \rho} \right) + \frac{1}{\rho^2} \frac{\partial^2 V}{\partial \phi^2} + \frac{\partial^2 V}{\partial z^2} \]

For Spherical:
\[ \nabla^2 V = \frac{1}{r^2} \frac{\partial}{\partial r} \left( r^2 \frac{\partial V}{\partial r} \right) + \frac{1}{r^2 \sin \theta} \frac{\partial}{\partial \theta} \left( \sin \theta \frac{\partial V}{\partial \theta} \right) + \frac{1}{r^2 \sin^2 \theta} \frac{\partial^2 V}{\partial \phi^2} \]

- **Laplacian of Vector**: It is a vector quantity.
  \[ \nabla \cdot (A) = \nabla \cdot (A) - \nabla \times \nabla \times (A) \]

- **Divergence** of a curl of vector is always zero
  \( \nabla \cdot (\nabla \times A) = 0 \)

- **Curl** of gradient of a scalar field is always zero
  \( \nabla \times (\nabla \phi) = 0 \)

- The vector field is said to be **solenoidal** or divergence less if\( \nabla A = 0 \)
- A vector field is said to be **irrotational** (or potential) if \( \nabla \times A = 0 \)
- A vector field is said to be harmonic if \( \nabla^2 V = 0 \)
- \( \nabla \times \nabla \times A = \nabla (\nabla \cdot A) - \nabla^2 A \)
- \( \nabla \cdot (A \times B) = B \cdot (\nabla \times A) - A \cdot (\nabla \times B) \)

**Divergence Theorem**: It states that total outward flux of vector field \( A \) through closed surface \( S \) is the same as volume integral of the **divergence** of \( A \).
\[ \oint_S (A \cdot dS) = \int_V \nabla \cdot A \, dv \]

**Stokes’ Theorem**: It states that line integral of a vector field \( A \) over a closed path is equal to surface integral of **curl** of \( A \).
\[ \oint_l (A \cdot dl) = \int_S (\nabla \times A) \cdot dS \]
\[ \nabla \cdot \vec{A} = 0 \quad \nabla \cdot \vec{A} \neq 0 \]
\[ \nabla \times \vec{A} = 0 \quad \nabla \times \vec{A} \neq 0 \]
4

NETWORK THEORY

CONTENTS

1. NETWORK BASICS ................................................................. 60-63

2. METHODS OF ANALYSIS AND THEOREMS ...................... 64-68

3. AC FUNDAMENTALS AND R, L, C CIRCUITS .............. 69-72

4. RESONANCE ................................................................. 73-76

5. TRANSIENTS ................................................................. 77-80

6. GRAPH THEORY .............................................................. 81-84

7. TWO PORT NETWORKS .................................................. 85-88

8. MAGNETIC COUPLED CIRCUITS .................................... 89-90

9. FILTERS ................................................................. 91-94

10. NETWORK SYNTHESIS .................................................... 95-98
**1. NETWORK BASICS**

**Current:** Electric current is the time rate of change of charge flow.

\[ i = \frac{dq}{dt} \] (Ampere)

Charge transferred between time \( t_o \) and \( t \)

\[ q = \int_{t_o}^{t} idt \]

**Sign Convention:** A negative current of \(-5A\) flowing in one direction is same as a current of \(+5A\) in opposite direction.

**Voltage:** Voltage or potential difference is the energy required to move a unit charge through an element, measured in volts.

**Power:** It is time rate of expending or absorbing energy.

- Law of conservation of energy must be obeyed in any electric circuit.
- Algebraic sum of power in a circuit, at any instant of time, must be zero.

\[ \sum P = 0 \]

**Circuit Elements:**

**Resistor:** Linear and bilateral (conduct from both direction)

In time domain \( V(t) = I(t)R \)

In s domain \( V(s) = RI(s) \)

\[ R = \frac{\rho l}{A} \text{ ohm} \]

\( l = \text{length of conductor}, \rho = \text{resistivity}, A = \text{area of cross section} \)

- Extension of wire to \( n \) times results in increase in resistance: \( R' = n^2 R \)
Compression of wire results in decrease in resistance: \[ R' = \frac{R}{n^2} \]

**Capacitor:** All capacitors are linear and bilateral, except electrolytic capacitor which is unilateral.

\[ i(t) = C \frac{dv(t)}{dt} \quad \text{and} \quad v(t) = \frac{1}{C} \int i(t) \, dt \]

\[ I(s) = sCV(s) \]

\[ V(s) = \frac{1}{sC} I(s) \]

- Capacitor doesn’t allow sudden change of voltage, until impulse of current is applied.
- It stores energy in the form of electric field and power dissipation in ideal capacitor is zero.
- Impedance \( Z_c = jX_c \Omega \) and \( X_c = \frac{1}{\omega C} \); \( X_c \rightarrow \) Capacitive reactance; \( \omega = 2\pi f \)

**Inductor:** Linear and Bilateral element

\[ v(t) = L \frac{di(t)}{dt} \quad \text{and} \quad i(t) = \frac{1}{L} \int v(t) \, dt \]

\[ V(s) = L \frac{1}{s} I(s) \]

\[ I(s) = \frac{1}{sL} V(s) \]

- Inductor doesn’t allowed sudden change of current, until impulse of voltage is applied.
- It stores energy in the form of magnetic field.
- Power dissipation in ideal inductor is zero.

**4. Transformer:** 4 terminal or 2-port device.

\[ V_1 \quad N_1 \quad V_2 \quad N_2 \]

\[ I_1 \quad N_1 \quad I_2 \quad N_2 \]

\[ \frac{V_1}{V_2} = \frac{N_1}{N_2} \quad \text{and} \quad \frac{I_1}{I_2} = \frac{N_2}{N_1} \]

Where \( \frac{N_1}{N_2} = K \rightarrow \text{Turns ratio} \).

Transformer doesn’t work as amplifier because current decreases in same amount power remain constant.
5. Gyrator:

\[ R_o \rightarrow \text{Coefficient of Gyrator} \]

\[ V_1 = R_o I_2 \qquad V_2 = -R_o I_1 \]

- If load is capacitive then input impedance will be inductive and vice versa.
- If load is inductive then input impedance will be capacitive.
- It is used for simulation of equivalent value of inductance.

**Voltage Source:**

In practical voltage source, there is small internal resistance, so voltage across the element varies with respect to current.

- **Ideal voltmeter,** \( R_V \rightarrow \infty \) (Internal resistance)

**Current Source:**

In practical current source, there is small internal resistance, so current varies with respect to the voltage across element.

- **Ideal Ammeter,** \( R_a \rightarrow 0 \) (Internal resistance)
Dependent and Independent Source:

**Independent Source:** Voltage or current source whose values doesn’t depend on any other parameters. E.g. Generator, MOSFET etc.

**Dependent Source:** Voltage or current source whose values depend upon other parameters like current, voltage.

The handling of independent and dependent voltage source is identical except:

(i) In **Thevenin** and Norton Theorem       (ii) Superposition Theorem

Where,

(i) All independent voltage sources are short circuited.

(ii) All independent current sources are open circuited.

(iii) All dependent voltage and current sources are left as they are.

- A network in which all network elements are physically separable is known as **lumped network**.
- A network in which the circuit elements like resistance, inductance etc, are not physically separate for analysis purpose, is called **distributed network**. E.g. Transmission line.
- If an element is capable of delivering energy independently, then it is called active element.
  - Example: Voltage source, Current source.
- If it is not capable of delivering energy, then it is **passive element**.
  - Example: Resistor, Inductor, Capacitor.
- If voltage and current across an element are related to each other through a constant coefficient then the element is called as **linear element** otherwise it is called as **non-linear**.
- When elements characteristics are independent of direction of current then element is called **bi-directional** element otherwise it is called as **unidirectional**. E.g. R, L & C.
- Diode is a unidirectional element.
- Voltage and current sources are also unidirectional elements.
- Every linear element should obey the bi-directional property but vice versa as is not necessary.
- Internal resistance of **voltage source** is in series with the source. Internal resistance of ideal voltage source is zero.
- Internal resistance of **current source** is in parallel with the source. Internal resistance of ideal current source is infinite.
5

SIGNAL AND SYSTEM

CONTENTS

1. BASIC PROPERTIES SIGNALS ........................................ 100-103
2. LTI SYSTEMS ............................................................ 104-106
3. FOURIER SERIES ......................................................... 107-108
4. FOURIER TRANSFORM .................................................. 109-112
5. DISCRETE TIME SIGNAL SYSTEMS .................................. 113-115
6. LAPLACE TRANSFORM .................................................. 116-118
7. Z TRANSFORM ............................................................ 119-122
8. DISCRETE FOURIER TRANSFORMS ................................. 123-124
1. BASIC PROPERTIES OF SIGNALS

Operations on Signals:

Time Shifting: \( y(t) = x(t + \alpha) \)
- Shift the signal towards right side by \( |\alpha| \) when \( \alpha < 0 \). This is also called as time delay.
- Shift the signal left towards side by \( |\alpha| \) when \( \alpha > 0 \). This is also called as time advance.

Time Reversal \( y(t) = x(-t) \)
Rotate the signal w.r.t. \( y \)-axis. It is mirror image of signal.
\( y(t) = -x(t) \)
Rotate the signal w.r.t. \( x \)-axis.

Time Scaling \( y(t) = x(\alpha t) \)
- When \( \alpha > 1 \), compress the signal.
- When \( \alpha < 1 \), expand the signal.

Eg. \( y(t) = x(-5t + 3) \)

Steps: 1. First rotate the signal by w.r.t. \( y \)-axis.
2. Compress the signal by 5 times.
3. Shift the signal by \( \frac{3}{5} \) unit towards right side.

Standard Signals: Continuous time signals

Impulse signal (Direct Delta Function)
\[ \delta(t) = \begin{cases} \infty, & t = 0 \\ 0, & t \neq 0 \end{cases} \quad \& \quad \int_{-\infty}^{\infty} \delta(t) dt = 1 \]

**Properties of Impulse Signal**

(i) \( x(t) \delta(t) = x(0) \delta(t) \)

(ii) \( x(t) \delta(t-t_o) = x(t_o) \delta(t-t_o) \)

(iii) \( \delta[\alpha(t - \beta)] = \frac{1}{|\alpha|} \delta(t - \beta) \)

(iv) \( \int_{-\infty}^{\infty} \delta(t) dt = 1 \)

(v) \( \int_{-\infty}^{\infty} x(t) \delta(t-t_o) = x(t_o) \int_{-\infty}^{\infty} \delta(t) dt = x(t_o) \)

(vi) \( x(t) \ast \delta(t-t_o) = x(t-t_o) \)

**Unit Step signal:**

\[ u(t) = \begin{cases} 1, & t \geq 0 \\ 0, & t < 0 \end{cases} \]

**Unit Ramp signal:**

\[ r(t) = t \ u(t) \]

\[ r(t) = \begin{cases} t, & t \geq 0 \\ 0, & t < 0 \end{cases} \]

**Parabolic signal:**

\[ x(t) = \frac{At^2}{2} u(t) \]

\[ x(t) = \begin{cases} \frac{At^2}{2}, & t \geq 0 \\ 0, & t < 0 \end{cases} \]
unit parabolic signal \( x(t) = \begin{cases} \frac{t^2}{2}, & t \geq 0 \\ 0, & t < 0 \end{cases} \)

Unit Pulse signal:
\[
\pi(t) = u(t + \frac{1}{2}) - u(t - \frac{1}{2})
\]

Triangular signal:
\[
x(t) = \begin{cases} 1 - \frac{|t|}{a}, & |t| \leq a \\ 0, & |t| > a \end{cases}
\]

Signum Signal:
\[
x(t) = \text{sgn}(t) = \begin{cases} 1, & t > 0 \\ -1, & t < 0 \end{cases}
\]
\[
\text{sgn}(t) = 2u(t) - 1
\]
\[
\text{sgn} = u(t) - u(-t)
\]

Relationship between \(u(t)\), \(\delta(t)\) and \(r(t): \)
\[
r(t) = tu(t)
\]
\[
r(t) \rightarrow \frac{d}{dt} \rightarrow u(t) \rightarrow \frac{d}{dt} \rightarrow \delta(t)
\]

Even and Odd Signal: Even signal \( x(t) = x(-t) \)
Odd signal \( x(-t) = -x(t) \)

Impulse is an even signal. An arbitrary signal can be divided into even and odd part:

Even part \( x_e(t) = \frac{x(t) + x(-t)}{2} \)
Odd part \( x_o(t) = \frac{x(t) - x(-t)}{2} \)

Periodic Signal:
(i) \( x(t) = x(t + T) \), \( T \) is the time period of signal.
Signal must exist from \(-\infty\) to \(\infty\).

- A constant signal is always periodic with fundamental period undefined.
• Complex exponential signals are always periodic.
• Real exponential signals are always aperiodic.

Power and Energy Signals:

Energy \[ E_x = \int_{-\infty}^{\infty} |x(t)|^2 \, dt \]

Power \[ P_x = \frac{1}{2T} \int_{-T}^{T} |x(t)|^2 \, dt \quad (T \to \infty) \]

\[ P_x = \frac{E_x}{2T} \quad (T \to \infty) \]

(i) When energy is finite; then power is zero (Energy Signal).
(ii) When power is finite, then energy is infinite (Power Signal).

• All periodic signals are power signals but the converse is not true.
• Absolute stable signal is energy signal.
• Unstable signal is neither energy nor power signal.
• Marginally stable signal is power signal.
1. SEMICONDUCTOR BASICS & ENERGY BANDS .......... 126-132
2. JUNCTION DIODE .......................................................... 133-136
3. VARIOUS SEMICONDUCTOR DIODES ...................... 137-140
4. CLIPPERS AND CLAMPERS .................................. 141-142
5. BJT (BIPOLAR JUNCTION TRANSISTOR) ............. 143-145
6. FET (FIELD EFFECT TRANSISTOR) ....................... 146-152
7. FABRICATION OF INTEGRATED CIRCUITS .......... 153-153
8. THYRISTOR ................................................................. 154-156

1. SEMICONDUCTOR BASICS & ENERGY BANDS

Thermal Voltage: \( V_T \) (Voltage Equivalent of Temperature)
\[ V_t = \frac{T}{11600} \text{ volt} \]

Standard room temperature (300 K) \( V_t = 0.0256 \text{ volt} \) \( V_t = 26 \text{ mV} \)

The standard room temperature corresponds to a voltage of 26 mV.

**Leakage Current \( (I_o) \)**

- Also called minority carrier current or thermally generated current.
- In silicon it is in nano ampere range and in germanium it is in micro ampere range.
- \( I_o \) doubles for every 10°C. For 1°C, \( I_o \) increases by 7%.
- \( I_o \) is proportional to the area of the device.
- **Advantages of smaller \( I_o \):**
  - (i) Suitable for high temperature applications
  - (ii) Good Thermal stability
  - (iii) No false triggering

**Energy Gap**: Difference between the lower energy level of conduction band (CB) \( E_C \) and upper energy level of valance band (VB) \( E_V \) is called as energy gap.

**Metals**: VB and CB are overlap to each other.
- This overlapping increases with temperature.
- \( e^- \) is both in CB and VB.

**Insulators**: Conduction band is always empty. Hence no current passes. Band gap: 5 eV – 15 eV.

**Semiconductor**: Energy gap is small and it is in range of 1 eV.
- At room temperature current can pass through a semi conductor.

<table>
<thead>
<tr>
<th>Energy Gap</th>
<th>Ge</th>
<th>Si</th>
<th>Ga As</th>
</tr>
</thead>
<tbody>
<tr>
<td>( E_{gT=0} )</td>
<td>7.85 eV</td>
<td>1.21 eV</td>
<td>XX</td>
</tr>
<tr>
<td>( E_{gT=300 K} )</td>
<td>0.72 eV</td>
<td>1.1 eV</td>
<td>1.47 eV</td>
</tr>
</tbody>
</table>

**Energy gap at temperature \( T \)**

For Ge \( E_{g(T)} = 0.785 – 7.2 \times 10^{-4} T \)

For Si \( E_{g(T)} = 1.21 – 3.6 \times 10^{-4} T \)

Energy gap decreases with temperature.

**Electric Field Intensity**

\[ \varepsilon = \frac{-dv}{dx} \text{ volt/meter} \]
Mobility of charge carriers

\[ \mu = \frac{\text{drift velocity}}{\text{electric field intensity}} = \frac{v}{\varepsilon} \text{ m}^2/\text{sec} \]

Mobility \( V, \varepsilon \) curve

So drift velocity: \( V_d \propto \varepsilon \quad V_d \propto \varepsilon^{1/2} \quad V_d = \text{constant} \)

- Mobility indicates how quick is the \( e^- \) or hole moving from one place to another.
- Electron mobility > hole mobility
- Mobility of charge carriers decreases with the temperature.

\[ \mu \propto T^{-\beta} \]

Mass Action Law: In a semiconductor under thermal equilibrium (at constant temperature) the product of electrons and holes in a semiconductor is always constant and equal to the square of intrinsic concentration.

\[ [n_p o = n_i^2] \]

\( n_o \to \text{Concentration of } e^- \text{ in conduction band} \)

\( P_o \to \text{Concentration of holes in valance band} \)

\( n_i \to \text{Intrinsic concentration at given temperature} \)

Majority carrier concentration = \( \frac{n_i^2}{\text{Minority carrier concentration}} \)

Intrinsic concentration

\[ n_i^2 = A_o T^3 e^{-\frac{E_g}{2kT}} \]

\( n_i \) is a function of temperature and energy gap.

Einstein’s Equation: Relation between diffusion constant, mobility and thermal voltage.

\[ \frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = V_T = K T \]
The unit of \( D/H \) is volts. Where, \( D_n \rightarrow e^- \) diffusion constant

\( D_p \rightarrow \) Hole diffusion constant

**Diffusion and Drift Current:**

**Diffusion Current:** It is defined as migration of charge carriers from higher concentration to lower concentration due to concentration gradient.

**Drift Current:** It is flow of current through the material or device under the influence of voltage or electric field intensity.

Total current density in a semi conductor

\[
J = J_n + J_p
\]

(Total current) (Current carried by \( e^- \)) (Current carried by holes)

\[
J_n = J_n' + J_n''
\]

Current due to \( e^- \) \( e^- \) drift current density \( \mu \) diffusion current density

For \( e^- \)

\[
J_n = nq\mu_e \frac{dN_n}{dx} \text{ cm}^{-2} \text{A}^{-1}
\]

For holes

\[
J_p = pq\mu_p \frac{dN_p}{dx} \text{ cm}^{-2} \text{A}^{-1}
\]

\( e^- \) diffusion length \( L_n = \sqrt{D_n \text{ cm}} \)

Hole diffusion length \( L_p = \sqrt{D_p \text{ cm}} \)

**Conductivity**

**In Metals:** Metals are uni-polar, so current is carried only by \( e^- \)

\[
\sigma = nq\mu_n
\]

In metal, conductivity decreases with temperature.

**In Semi Conductors**

\[
\sigma = nq\mu_n + pq\mu_p
\]

\( n \rightarrow \) Concentration of \( e^- \) in CB

\( e \rightarrow \) Concentration of holes in VB

\( \mu_n, \mu_p \rightarrow \) Mobility of holes and electrons

- Conductivity of pure semi-conductor increases with temperature
In Extrinsic Semiconductor

For \( n \) type \[ \sigma = N_D q \mu_n \] \( N_D \) = donor concentration

For \( p \) type \[ \sigma = N_A q \mu_p \] \( N_A \) = acceptor concentration

In extrinsic semiconductor (SC) below the room temperature, conductivity increases. But above the room temperature their conductivity decreases.

Direct Band Gap Semiconductor

- During the re-combinations the falling \( e^- \) from the conduction band will be releasing energy in the form of light.
- Momentum and direction of \( e^- \) will remain same.
  
  \textit{Example: GaAs, InP, ZnS}

Indirect Band Gap Material

- Most of falling \( e^- \) will directly releasing energy in the form of heat
- Moment of \( e^- \) will change
- Direction of \( e^- \) will change
  
  \textit{Example: Ge and Si}

- Direct band gap materials having higher carrier lifetime and are used for fabrication for LED, laser, tunnel diode, photodiode.

General Properties of Ge and Si

<table>
<thead>
<tr>
<th>Properties</th>
<th>Ge</th>
<th>Si</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic number</td>
<td>32</td>
<td>14</td>
</tr>
<tr>
<td>Density of atoms</td>
<td>(4.42 \times 10^{22})</td>
<td>(5 \times 10^{22})</td>
</tr>
<tr>
<td>Intrinsic concentration</td>
<td>(2.5 \times 10^{13})</td>
<td>(1.5 \times 10^{10})</td>
</tr>
<tr>
<td>( \mu_n ) at 300 K</td>
<td>(3800 \ \text{cm}^2 \ \text{V sec})</td>
<td>(1300 \ \text{cm}^2 \ \text{V sec})</td>
</tr>
<tr>
<td>( \mu_p ) at 300 K</td>
<td>1800</td>
<td>500</td>
</tr>
<tr>
<td>Leakage current</td>
<td>(\mu \text{A})</td>
<td>(\text{nA})</td>
</tr>
<tr>
<td>Temperature range</td>
<td>60º to 75º C</td>
<td>60º to 175º C</td>
</tr>
<tr>
<td>Power handling capacity</td>
<td>Less</td>
<td>High</td>
</tr>
</tbody>
</table>
**Hall Effect**

If a specimen (metal or semi-conductor) carrying the current $I$ is placed in transverse magnetic field $B$, an electric field $E$ is induced in a direction perpendicular to both $I$ and $B$.

- Force experienced by the charge carriers is always same, irrespective of their polarity.

**Force direction**

$$\mathbf{F} = q_e (\mathbf{E} \times \mathbf{B})$$

(For $e^-$ from diagram)

$$= -e(-V_y a_y \times B_z a_z) e^-$$

Direction is in negative $y$

$$\mathbf{F} = e V_y B_z a_z$$

Force is in positive $+x$ direction. So for

**N Type Material**: Plane which is in $+x$ direction should have negative polarity. For P-type material plane which is in $+x$ direction should have positive polarity.

**According to Hall Effect**

**Hall Voltage** $V_H = \frac{BL}{\rho W}$

$B$ → Magnetic field       $\rho$ → charge density

$W$ → Width of specimen (it is in plane of applied $B$)
or \[ V_H = \frac{BIR_H}{W} \] where \( R_H \) → hall coefficient = \( \frac{1}{\rho} \)

**Charge density** \( \rho = nq \)

**Field intensity** \( \mathcal{E} = \frac{V_H}{D} \)

By hall experiment, **mobility** is given by \( \mu = \frac{8}{3\pi} \sigma R_H \)

- By polarity of hall voltage we can determine whether the semiconductor is \( p \) type or \( n \) type.
- By magnitude of hall voltage we can differentiate between metal and semiconductor.
- For metal hall voltage \( V_H \) is less as compared to SC.
- Hall voltage is +ve for **N type** SC and metals
- Hall voltage is –ve for **P type** SC.
- Hall voltage is zero for intrinsic SC.
- **In metals**, \( R_H \) increases with temperature
- **In pure SC**, \( R_H \) decreases with temperature
  - **In extrinsic SC**, \( R_H \) increases with temperature
  - It can be used in finding mobility of charge carriers, concentration of charge carriers, magnetic field intensity.

**Types of Semi Conductors**

**Intrinsic Semi Conductor:** \( n = p = n_i \)

At 0K all valance \( e^- \) are occupied with covalent bonding and therefore charge carriers are zero and the semiconductor behave as insulator.

**Extrinsic Semi Conductor**

**N Type**
- Impurity is penta-valent (phosphorous, arsenic)
- Majority carriers are electrons

\[
\begin{align*}
\Rightarrow & \quad n > n_i \\
& \quad p < n_i
\end{align*}
\]

for **N type semiconductor** (SC)

**P-Type**
- Impurity is trivalent (Boron, Aluminium)
- Majority carriers are holes.
\[ p > n \] for P type semiconductor (SC)

**Law of Electric Neutrality** \( N_D + p = N_A + n \)

Total positive charges = Total negative charges

**Intrinsic SC** \( N_D = 0, \; N_A = 0 \; n = p \)

**N type SC** \( N_D = 0 \; p = N_A + n \; p >> n \; p = N_A \)

**N type SC** \( \rightarrow \; N_A = 0 \; n = N_D + p \)

Since \( n >> p \; n = N_D \)

**Fermi Level**: It is maximum energy possessed by \( e^- \) at absolute 0 of temperature. It is energy state having probability 1/2 of being occupied by an electron.

**Fermi Dirac Function**: It gives the probability that an available energy state \( E \) will be occupied by an electron at absolute temperature \( T \).

\[
f(E) = \frac{1}{1 + \exp \left( \frac{E - E_F}{K T} \right)}
\]

\([1 - f(E)]\) gives the probability that energy state \( E \) will be occupied by hole.

**Concentration of \( e^- \) in conduction band**

\( n_v \rightarrow \) Concentration of \( e^- \) in conduction band

\( E_C \rightarrow \) Conduction band energy level

\( E_F \rightarrow \) Fermi energy level

\[
N_C = 2 \left[ \frac{2\pi m_e \cdot KT}{h^2} \right]^{3/2}
\]

\( N_C \rightarrow \) Effective density of states in conduction band

**Concentration of hole in valance band**

\[
p_v = N_v e^{-\left(\frac{E_F - E_v}{K T}\right)} \quad \text{Where} \quad N_v = 2 \left[ \frac{2\pi m_h \cdot KT}{h^2} \right]^{3/2}
\]

\( N_v \rightarrow \) Density of states in valance band
Fermi Level in Intrinsic SC

\[
E_F = \frac{E_C + E_V}{2} - \frac{K T}{2} \ln \left( \frac{N_C}{N_V} \right)
\]

- At 0 K, fermi level coincides with \( E_C \).
- If \( N_C = N_V \), then fermi level lies in middle of energy gap.
- In intrinsic semiconductor fermi level is a function of temperature only.
- As temperature increases fermi level moves away from the middle of band gap.

Fermi Level in \( n \)-type semiconductor

\[
E_F = E_C - K T \ln \left( \frac{N_C}{N_D} \right)
\]

- In \( n \)-type SC fermi level depends on both temperature and donor concentration
- As temperature increases, fermi level moves towards the middle of band gap therefore conductivity decreases.
- If doping increases, \( E_F \) moves away from center. Hence conductivity increases.

Fermi Level in \( p \)-type semiconductor

\[
E_F = E_V + K T \ln \left( \frac{N_V}{N_A} \right)
\]

- In \( p \) type semiconductor \( E_F \) at 0 K coincides with \( E_V \).
- In \( p \) type semiconductor, fermi level moves away from valance band, as temperature increases.
- If doping increases, \( E_F \) moves towards valance band and conductivity increases.

Note:
- If fermi level moves away from the center then conductivity increases.
- If fermi level moves towards the center of the energy gap then its conductivity decreases.
- Shift in position of fermi level with respect to intrinsic level in \( n \)-type SC is

\[
Shift = E_F - E_{F_i} = K T \ln \left( \frac{N_D}{n_i} \right)
\]

- Shift in position of fermi level with respect to intrinsic level in \( p \)-type SC is

\[
Shift = E_{F_i} - E_F = K T \ln \left( \frac{N_A}{n_i} \right)
\]
## COMMUNICATION SYSTEM

### CONTENTS

1. ANALOG MODULATION .................................................. 158-164
2. PULSE MODULATION TECHNIQUES ................................. 165-170
3. NOISE ........................................................................... 171-172
4. DIGITAL MODULATION SCHEMES ................................. 173-174
5. RANDOM PROCESSES .................................................... 175-176
6. INFORMATION THEORY .................................................. 177-178
7. ANTENNA THEORY ........................................................ 179-181
8. RADAR .......................................................................... 182-183
9. SATELLITE COMMUNICATION ...................................... 184-185
10. OPTICAL COMMUNICATION ........................................ 186-190
1. ANALOG MODULATION

Modulation is the process of placing the message signal over some carrier signal to make it suitable for transmission.

Need for Modulation:
1. Size of antenna required for receiving the wave is reduced if signal is transmitted at high frequency.
2. Many number of signals can be transmitted simultaneously by selecting the carriers of different frequencies.
3. The interference of noise and other signals can be reduced by changing the frequency of transmission.
4. Integration of different communication system is possible.

Amplitude Modulation
Amplitude Modulated Signal:
AM may be defined as a system in which the maximum amplitude of the carrier wave is made proportional to the instantaneous value (amplitude) of the modulating or base band signal.

\[ x_m(t) = A_m \cos \omega_m t \]
\[ x_c(t) = A_c \cos \omega_c t \]
\[ x(t) = A_c \cos \omega_c t + A_c K_m x_m(t) \cos \omega_c t \]

where \( \mu = K_m A_m \)

\[ x(t) = A_c \cos \omega_c t + A_c K_m x_m(t) \cos \omega_c t \]

Amplitude Modulated Signal:

\[ \mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} \]
\[ A_{max} = A_c [1 + \mu] \]
\[ A_{min} = A_c [1 - \mu] \]

A\(_{\text{max}}\) – maximum amplitude
A\(_{\text{min}}\) – minimum amplitude

Frequency spectrum of AM wave:

Bandwidth = \( 2 f_m \)

- Frequency band from \( f_c \) to \( f_c + f_m \) is called as upper sideband

- Frequency band from \( f_c - f_m \) to \( f_c \) is called as lower sideband

\[ \mu = \frac{A_{max} - A_{min}}{A_{max} + A_{min}} \]
\[ A_{max} = A_c [1 + \mu] \]
\[ A_{min} = A_c [1 - \mu] \]
Power Relations in AM wave:

\[ P_{\text{total}} = P_{\text{carrier}} + P_{\text{LSB}} + P_{\text{USB}} \]
\[ P_{\text{carrier}} = \frac{A_c^2}{2} \]
\[ P_{\text{LSB}} = P_{\text{USB}} = \frac{\mu^2 A_c^2}{8} \]

\[ P_{\text{total}} = \frac{A_c^2}{2} + \frac{\mu^2 A_c^2}{8} + \frac{\mu^2 A_c^2}{8} \]
\[ P_{\text{total}} = \left(1 + \frac{\mu^2}{2}\right) P_c \]

Maximum power dissipated in AM wave is \( P_{AM} = 1.5 P_c \) for \( \mu = 1 \) and this is maximum power that amplifier can handle without distortion.

Efficiency of Amplitude Modulated System:

\[ \eta_{AM} = \frac{P_{SB}}{P_t} \times 100\% \]
\[ \eta_{AM} = \left(\frac{\mu^2}{\mu^2 + 2}\right) \times 100\% \]

For satisfactory modulation \( 0 \leq \mu \leq 1 \)

Current relations in AM wave:

\[ P_t = \left(1 + \frac{\mu^2}{2}\right) P_c \]
\[ I_c = \sqrt{1 + \frac{\mu^2}{2}} \]

Multi-tone Modulation: When carrier is modulated simultaneously by more than one sinusoidal signal.

Resultant Modulation Index \( \mu = \sqrt{\mu_1^2 + \mu_2^2 + \mu_3^2 + \ldots} \)

Double side Band Suppressed Carrier modulation DSB-SC:

\[ s(t) = A_c \cos(\omega_c t) \cos(\omega_m t) \]

\( \mu \rightarrow \text{modulation index} \)

In DSB-SC the carrier signal is suppressed at the time of modulation. Only side-bands are transmitted in modulated wave.

Bandwidth = \( 2 f_m \)  \hspace{1cm} Transmitted Power \( P_t = \frac{\mu^2}{2} P_c \)

Power saving = 66.67% (for \( \mu = 1 \))

Single Sideband Modulation (SSB): In this technique, along with modulation carrier one side band gets suppressed from AM modulated wave.

\[ s(t) = A_c m(t) \cos 2\pi f_c t \mp A_c \hat{m}(t) \sin 2\pi f_c t \]

\( \hat{m}(t) \) is Hilbert transform of message signal.

Bandwidth = \( f_m \)  \hspace{1cm} Transmitter Power \( P_t = \frac{\mu^2}{4} P_c \)

Power saving \( \rightarrow 83.3\% \)

Vestigial Sideband (VSB) modulation: In this modulation one side band and vestige of another sideband is
transmitted.

- It is used for transmission of video signal in television broadcasting.
- It is also used for high speed data signal and facsimile.
- Vocal signal transmission of T.V. via F.M.

**AM Modulators:**

- For Generation of AM or DSB/Full carrier wave
  - A. Product Modulator
  - B. Square Law Modulator
  - C. Switching Modulator
- For Generation DSB-SC wave
  - A. Filter method/frequency discrimination method
  - B. Phase shift method/Phase discrimination method
  - C. Third method/Weaver’s method

**Demodulation of Amplitude Modulate wave:**

A. Synchronous or coherent detection
B. Envelop detector

**Envelop Detector:**

- $r(t)$ is received signal and $m(t)$ is message signal and for better reception $RC$ must be selected such as $\frac{1}{f_c} << RC << \frac{1}{W}$
- $f_c$ = carrier frequency
- $w$ is bandwidth of message signal
- To avoid diagonal clipping $\frac{1}{RC} \gg \frac{\mu}{\sqrt{1-\mu^2}}$

**Key points:**

- Demodulation of AM signal is simpler than DSB-SC and SSB systems, Demodulation of DSB-SC and SSB is rather difficult and expensive.
- It is quite easier to generate conventional AM signals at high power level as compared to DSB-SC and SSB signals. For this reason, conventional AM systems are used for broad casting purpose.
- The advantage of DSB-SC and SSB systems over conventional AM system is that the former requires lesser power to transmit the same information.
- SSB scheme needs only one half of the bandwidth required in DSB-SC system and less than that required in VSB also.
- SSB modulation scheme is used for long distance transmission of voice signals because it allows longer spacing between repeaters.

**Angle Modulation:**

- Angle modulation may be defined as the process in which the total phase angle of a carrier wave is varied in accordance with the instantaneous value of modulating or message signal while keeping the amplitude of carrier constant.
Two types of angle modulation schemes:

- **PM (Phase modulation)**
- **FM (Frequency Modulation)**

**Phase Modulation:** The phase of the carrier signal is varied according to message signal.

**Single Tone Modulation:** Let \( m(t) = A_m \cos \omega_m t \)

PM signal in general form \( x(t) = A_c \cos \theta(t) \)

where \( \theta(t) = w_c t + K_p m(t) \)

\[
x(t) = A_c \cos(\omega_c t + k_p m) = A_c \cos(\omega_c t + \beta \cos \omega_m t) \]

\[
x(t) = A_c \cos(\omega_c t + k_p A_m \cos \omega_m t) \]

Where, \( \beta = K_p A_m \)

**Instantaneous Frequency:** \( \omega = \frac{d\theta}{dt} \)

\[
\omega = \frac{d}{dt}(w_c t + \beta \cos \omega_m t) = f_c + \beta f_m \sin \omega_m t
\]

Frequency deviation of signal \( \Delta f = \beta f_m \), \( \Delta f = K_p A_m f_m \)

For Phase Modulation:

Phase deviation = \( K_p |m(t)|_{\text{max}} \)

Frequency deviation = \( K_p A_m f_m \)

**Frequency Modulation:** Frequency of FM wave is varied in direct proportion of the modulating signal.

\[
x(t) = A_c \cos(\omega_c t + 2\pi k_f \int_0^t m(t) \, dt)
\]

If \( m(t) = A_m \cos \omega_m t \)

\[
x(t) = A_c \cos(\omega_c t + \beta \sin \omega_m t)
\]

where \( \beta = \text{Frequency Modulation Index} \)

\[
\beta = \frac{k_f A_m}{f_m} = \frac{\Delta f}{f_m}
\]

Frequency deviation = \( K_f |m(t)|_{\text{max}} = K_f A_m \)

Phase deviation \( 2\pi K_f \int m(t) df|_{\text{max}} \)

Carrier Swing:
The total variation in frequency from the lowest to the highest point is called carrier swing.
Carrier swing = $2 \times \Delta f$

The amount of frequency deviation depends upon the amplitude of the modulating signal. This means that louder the sound, greater the frequency deviation and vice versa.

**Relationship between phase modulation and frequency modulation:**
In PM, the phase angle varies linearly with base band signal $m(t)$ whereas in FM, the phase angle varies with the integral of base band signal $m(t)$.
- To get FM by using PM, we first integrate the base band signal and then apply to Phase Modulator.
- PM wave may be generated by using frequency modulator by first differentiating base band signal $m(t)$ and then applying to the Frequency Modulator.

**Power Carried by FM and PM signals:** Since the Amplitude of Frequency and Phase modulated signal is constant, the power transmitted in FM and PM waves is independent of modulation index

\[ P_t = \frac{A^2}{2} \]

- Because of constant Amplitude, Noise level in FM and PM can be kept within limits. That’s why it is used in Audio Communication.

Classification of FM signals:
(1) Narrow Band FM signals (NBFM)
(2) Wide Band FM signals (WBFM)

**Narrow Band FM signal (NBFM):** For these signals modulation index is less than unity.

\[ \phi(t) = \beta \sin 2\pi f_t \]

\[ x(t) = A_c \cos(\omega_c t + \phi(t)) - A_c \cos \omega_c t \cos \phi(t) - \sin \omega_c t \sin \phi(t) \]

\[ \phi(t) \text{ is small, so } \cos \phi(t) \approx 1, \sin \phi(t) \approx \phi(t) \]

\[ x(t) = A_c \cos \omega_c t - A_c \beta \sin \omega_c \sin \omega_m t \]

\[ = A_c \cos \omega_c t + \frac{A_c \beta}{2} \left[ \cos(\omega_c + \omega_m) - \cos(\omega_c - \omega_m) \right] \]

Above signal is called **NBFM** signal. It has two bands similar to AM wave and both have same bandwidth requirements.
The lower side band of NBFM is inverted version of upper side band of AM signal.
It can be detected using Envelop Detector.

**WBFM signal:**

\[ x(t) = \sum_{n=0}^{\infty} A_c J_n(\beta) \cos(\omega_c + n\omega_m)t \]

A wideband FM signal has infinite number of side bands.
Ideally the Bandwidth requirement of F_m signal is infinite because it has infinite number of side bands.

**Carson’s Law:**
Transmission Bandwidth of FM signal:

\[ BW = 2f_m \text{ if } \beta < 1 \text{(NBFM)} \]
**Formula Book (GATE, IES & PSUs)**

**Electronics**

\[ BW = 2(\Delta f + f_m) \quad \text{If} \quad \beta > 1 \quad (WBFM) \quad \text{or} \quad BW = 2(\beta + 1)f_m \]

**FM over AM**

It is possible to reduce noise still further by increasing the frequency deviation but in AM this is not possible.

- Standard frequency allocations provide a guard band between commercial FM stations. Due to this, there is less adjacent channel interference in FM.
- FM broadcasts operate in upper VHF and UHF frequency ranges at which there happens to be less noise than in the MF and HF ranges occupied by AM broadcasts.

The amplitude of FM wave is constant. Thus, it is independent of the modulation depth. Whereas in AM modulation, modulation depth governs the transmitted power.

**Generation of FM Waves:**

1. **Direct method/Parameter variation method:** The circuit consists of combination of parallel tuned circuit and a voltage variable capacitor such as Varactor diode.

2. **Indirect Method:** The method generates FM wave from NBFM wave due to which it is called indirect method of FM generation. It is also called Armstrong method.

**Detection of FM Waves:**

1. Slope detection method
2. Phase shift discriminator
3. Zero crossing detection
4. Ratio detector
5. Phase locked loop

**Lock Range and Capture Range in PLL:**

Lock Range: It is the difference between highest and lowest frequencies so that the PLL can remain in lock mode.

Capture Range: It is the range of frequencies that the VCO of a PLL can produce.

For PLL satisfactory operation \[ \text{Lock Range} > \text{Capture Range} \]

Interference in FM: The effect of noise is more dominant in FM signal at higher frequencies than AM and PM signal.
- The noise spectral density for AM and PM is constant.
- But in FM noise spectral density increases linearly in case of FM signals.
- In FM, voice spectral density is maximum at lower frequencies and it reduces sharply at higher frequencies.

**Pre-Emphasis:** It is used to boost the level of high frequency voice signals before they are transmitted on FM channel because voice spectral density is low at higher frequencies. A pre-emphasis network is differentiating network and works as a high pass circuit.

**De-Emphasis:** It is used to recover the original signal at the receiver end. It attenuates the high frequency component of received demodulated signal. A De-emphasis network is integrating network and works as a low pass circuit. These networks used only in FM system. It is not used in PM and AM because the noise spectral density in these systems does not increase with increase in frequency.

**When an FM signal is passed through multiplier:**
- \( f_m \) (Modulation frequency is unchanged). \( f_c \) and \( \Delta f \) are multiplied by that factor.

When a FM signals is passed through mixer:
- \( f_m \) is multiplied by that factor and \( \Delta f \) remain unchanged.

Multiplier is incorporated at transmitter side and mixer at receiver side.
DIGITAL ELECTRONICS

CONTENTS

1. NUMBER SYSTEM & CODES ........................................ 192-194
2. BINARY A RITHMETIC ........................................... 195-198
3. LOGIC GATES ....................................................... 199-205
4. DIGITAL LOGIC CIRCUITS .................................. 206-211
5. SEQUENTIAL CIRCUITS ....................................... 212-216
6. SHIFT REGISTERS ............................................... 217-218
7. COUNTERS ......................................................... 219-221
8. DIGITAL LOGIC FAMILY ...................................... 222-228
9. ADCs AND DACs ............................................... 229-232
10. MEMORIES ....................................................... 233-234
1. NUMBER SYSTEM & CODES

Number System and Codes:

A number system with base ‘$r$’, contents ‘$r$’ different digits and they are from 0 to $r - 1$.

Decimal to other codes conversions: To convert decimal number into other system with base ‘$r$’, divide integer part by $r$ and multiply fractional part with $r$.

Other codes to Decimal Conversions: $(x_2x_1x_0 \cdot y_1y_0)_r \rightarrow (A)_{10}$

$$A = x_2 \cdot r^2 + x_1 \cdot r + x_0 + y_1 \cdot r^{-1} + y_0 \cdot r^{-2}$$

Hexadecimal to Binary: Convert each Hexadecimal digit into 4 bit binary.

$$5 \quad A \quad F \rightarrow (0101 \quad 1010 \quad 1111)_{16}$$

Binary to Hexadecimal: Grouping of 4 bits into one hex digit.

$$10101011.11 \rightarrow 0101 \quad 0101 \quad 1100 \rightarrow (35.C)_{16}$$

Octal to Binary and Binary to Octal: Same procedure as discussed above but here group of 3 bits is made.

Codes:

Binary coded decimal (BCD):

- In BCD code each decimal digit is represented with 4 bit binary format.

$$Eg: (943)_{10} \rightarrow \begin{pmatrix} 1001 \\ 0100 \\ 0011 \\ 0 \end{pmatrix}_{BCD}$$

- It is also known as 8421 code

  Invalid BCD codes

  Total Number possible $\rightarrow 2^4 \Rightarrow 16$

  Valid BCD codes $\rightarrow 10$

  Invalid BCD codes $16 - 10 \Rightarrow 6$

These are 1010, 1011, 1100, 1101, 1110, and 1111
Excess-3 code: (BCD + 0011)
- It can be derived from BCD by adding ‘3’ to each coded number.
- It is unweighted and self-complementing code.

Gray Code:
It is also called minimum change code or unit distance code or reflected code.

Binary code to Gray code:

\[
\begin{array}{cccccc}
\text{MSB} & 1 & 0 & 0 & 1 & 0 \text{ Binary} \\
\downarrow & \downarrow & \downarrow & \downarrow & \downarrow & \\
\text{MSB} & 1 & 1 & 0 & 1 & 1 \text{ Gray}
\end{array}
\]

Gray code to Binary code:

Alpha Numeric codes: EBCDIC (Extended BCD Interchange code)
It is 8 bit code. It can represent 128 possible characters.
- Parity Method is most widely used schemes for error detection.
- Hamming code is most useful error correcting code.
- BCD code is used in calculators, counters.

Complements: If base is \( r \) then we can have two complements.
(i) \( (r - 1)’s \) complement
(ii) \( r \)’s complement.

To determine \( (r-1)’s \) complement: First write maximum possible number in the given system and subtract the given number.
To determine \( r \)’s complement: \( (r-1)’s \) complement + 1
First write \( (r-1)’s \) complement and then add 1 to LSB

Example: Find 7\(^{e}\)s and 8\(^{e}\)s complement of 2456

\[
\begin{array}{c|c|c}
\text{7's complement} & \text{8's complement} \\
\hline
7777 & 5321 \\
-2456 & +1 \\
5321 & 5322
\end{array}
\]

Find 2’s complement of 101.110
1’s complement 010.001
For 2’s complement add 1 to the LSB
Data Representation:

Data Representation

Magnitude Representation  Complement Representation

Unsigned +ve  Signed +ve, −ve  1’s complement +ve, −ve  2’s complement +ve, −ve

No sign bit  1’s complement of 6

Sign bit is required

Unsigned Magnitude: Range with n bit → 0 to $2^n - 1$  +5 ⇒ 101  −5 ⇒ Not possible

Signed Magnitude: Range with n bit → −(2^n − 1) to + (2^n − 1)

$+6 \Rightarrow 0110$  $-6 \Rightarrow 1 \ 110 \ 1 \ 000 \ 110$

1’s complement: Range with n bit → −(2^n − 1) to + (2^n − 1)

$+6 \Rightarrow 0110$  $-6 \Rightarrow 1 \ 001$

2’s complement: With n bits Range → $-2^{n-1}$ to $(2^{n-1} - 1)$

$+6 \Rightarrow 0110$  $-6 \Rightarrow 1 \ 010$

In any representation

+ve numbers are represented similar to +ve number in sign magnitude.
CONTROL SYSTEM

CONTENTS

1. BLOCK DIAGRAM ................................................................. 236-238
2. MATHEMATICAL MODELLING ............................................. 239-240
3. TIME RESPONSE ANALYSIS ............................................. 241-246
4. STABILITY ........................................................................ 247-249
5. ROOT LOCUS ................................................................. 250-252
6. FREQUENCY DOMAIN ANALYSIS ..................................... 253-254
7. POLAR PLOTS ................................................................. 255-258
8. BODE PLOTS .................................................................. 259-262
9. COMPENSATORS ............................................................ 263-266
10. STATE SPACE ANALYSIS ................................................. 267-268
1. BLOCK DIAGRAM

Open Loop Control System:
- In this system the output is not feedback for comparison with the input.
- Open loop system faithfulness depends upon the accuracy of input calibration.

\[
\text{Transfer function } G(s) = \frac{C(s)}{R(s)}
\]

When a designer designs, he simply design open loop system.

Closed Loop Control System: It is also termed as feedback control system. Here the output has an effect on control action through a feedback. Ex. Human being

Transfer Function:

\[
\text{Transfer function } = \frac{C(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)}
\]

Comparison of Open Loop and Closed Loop control systems:

Open Loop:
1. Accuracy of an open loop system is defined by the calibration of input.
2. Open loop system is simple to construct and cheap.
3. Open loop systems are generally stable.
4. Operation of this system is affected due to presence of non-linearity in its elements.

Closed Loop:
1. As the error between the reference input and the output is continuously measured through feedback. The closed system works more accurately.
2. Closed loop systems is complicated to construct and it is costly.
3. It becomes unstable under certain conditions.
4. In terms of performance the closed loop system adjusts to the effects of non-linearity present.

Transfer Function: The transfer function of an LTI system may be defined as the ratio of Laplace transform of output to Laplace transform of input under the assumption

\[
G(s) = \frac{Y(s)}{X(s)}
\]

- The transfer function is completely specified in terms of its poles and zeros and the gain factor.
- The T.F. function of a system depends on its elements, assuming initial conditions as zero and is independent of the input function.
To find a gain of system through transfer function put \( s = 0 \)

**Example:**

\[
G(s) = \frac{s + 4}{s^2 + 6s + 9} \quad \text{Gain} = \frac{4}{9}
\]

If a step, ramp or parabolic response of T.F. is given, then we can find Impulse Response directly through differentiation of that T.F.

\[
\frac{d}{dt} \text{ (Parabolic Response)} = \text{Ramp Response}
\]

\[
\frac{d}{dt} \text{ (Ramp Response)} = \text{Step Response}
\]

\[
\frac{d}{dt} \text{ (Step Response)} = \text{Impulse Response}
\]

**Block Diagram Reduction:**

<table>
<thead>
<tr>
<th>Rule</th>
<th>Original Diagram</th>
<th>Equivalent Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Combining blocks in cascade</td>
<td>( X_1 \rightarrow G_1 \rightarrow X_2 )</td>
<td>( X_1 \rightarrow G_1 \rightarrow X_2 \rightarrow G_2 \rightarrow )</td>
</tr>
<tr>
<td>2. Moving a summing point after a block</td>
<td>( X_1 \rightarrow G \rightarrow X_2 )</td>
<td>( X_1 \rightarrow G \rightarrow X_2 \rightarrow )</td>
</tr>
<tr>
<td>3. Moving a summing point ahead of block</td>
<td>( X_1 \rightarrow G \rightarrow X_2 )</td>
<td>( X_1 \rightarrow G \rightarrow X_2 \rightarrow G \rightarrow )</td>
</tr>
<tr>
<td>4. Moving a take off point after a block</td>
<td>( X_1 \rightarrow G \rightarrow X_2 )</td>
<td>( X_1 \rightarrow G \rightarrow X_2 \rightarrow G \rightarrow )</td>
</tr>
</tbody>
</table>
5. Moving a take off point ahead of a block

\[
\begin{aligned}
X_1 & \quad \rightarrow \quad G \\
& \quad \mid \quad X_1G \\
& \quad \mid \quad X_1G \\
\end{aligned}
\]

\[
\begin{aligned}
X_1 & \quad \rightarrow \quad G \\
& \quad \mid \quad X_1G \\
& \quad \mid \quad X_1G \\
\end{aligned}
\]

6. Eliminating a feedback loop

\[
\begin{aligned}
X_1 & \quad \rightarrow \quad G \\
& \quad \mid \quad X_2 \\
& \quad \mid \quad H \\
\end{aligned}
\]

\[
\begin{aligned}
X_1 & \quad \rightarrow \quad G \\
& \quad \mid \quad X_2 \\
& \quad \mid \quad 1+GH \\
\end{aligned}
\]

\[
(GX_1 \pm X_2)
\]

**Signal Flow Graphs:**
- It is a graphical representation of control system.
- Signal Flow Graph of Block Diagram:

\[
\begin{aligned}
R & \quad \rightarrow \quad G_2 \\
& \quad \mid \quad G_1 \\
& \quad \mid \quad H_1 \\
\end{aligned}
\]

\[
\begin{aligned}
G_2 & \quad \rightarrow \quad C \\
G_1 & \quad \rightarrow \quad C \\
H_1 & \quad \rightarrow \quad -H_1 \\
\end{aligned}
\]

**Mason’s Gain Formula:**

\[
\text{Transfer function} = \frac{\sum p_k \Delta_k}{\Delta}
\]

\[
p_k \rightarrow \text{Path gain of } k^{th} \text{ forward path}
\]

\[
\Delta = 1 - \text{[Sum of all individual loops]} + \text{[Sum of gain products of two non-touching loops]} - \text{[Sum of gain products of 3 non-touching loops]} + \ldots \ldots\ldots.
\]

\[
\Delta_k \rightarrow \text{Value of } \Delta \text{ obtained by removing all the loops touching } k^{th} \text{ forward path as well as non-touching to each other.}
\]
10

MICROPROCESSOR

CONTENTS

1. MICROPROCESSOR BASICS .......................................................... 270-274
2. 8085 INSTRUCTIONS .................................................................. 275-282
3. 8086 BASICS .............................................................................. 283-286
1. **MICROPROCESSOR BASICS**

A **Microprocessor** includes ALU, register arrays and control circuits on a single chip.

**Microcontroller:**

A device that includes microprocessor, memory and input and output signal lines on a single chip, fabricated using VLSI technology.

**Architecture of 8085 Microprocessor**

1. **8085 MPU:**
   - 8 bit general – purpose microprocessor capable of addressing 64 K of memory.
   - It has 40 pins, requires a +5V single power supply and can operate with 3 – MHz single phase clock.

2. **8085 programming model:**
   - It has six general purpose register to store – 8 bit data. These are B, C, D, E, H and L. It can be combined as BC, DE, and HL to perform 16 bit operations.
   - B, D, H → high order register and C, E, L → low order register.

**Accumulator:** Is an 8 bit register that is used to perform arithmetic and logic functions.

**Flags:** 5 flags

**Flag Register:**
Carry Flag (CY): If an arithmetic operation result in a carry or borrow, the CY flag is set, otherwise it is reset.
Parity Flag (P):
If the result has an even number of 1s, the flag is set, otherwise the flag is reset.
Auxiliary Carry (AC): In an arithmetic operation
- If carry is generated by \( D_3 \) and passed to \( D_4 \) flag is set.
- Otherwise it is reset.
Zero Flag (Z): Zero Flag is set to 1, when the result is zero otherwise it is reset.
Sign Flag (S): Sign Flag is set if bit \( D_7 \) of the result is 1. Otherwise it is reset.
Program counter (PC): It is used to store the 16 bit address of the next byte to be fetched from the memory or address of the next instruction to be executed.
Stack Pointer (SP): It is 16 bit register used as a memory pointer. It points to memory location in Read/Write memory which is called as stack.

8085 Signals:
Address lines:
There are 16 address lines \( AD_0 - AD_7 \) and \( A_8 - A_{15} \) to identify the memory locations.

Data lines/ Multiplexed address lines:

Multiplexed address lines: The signal lines \( AD_0 - AD_7 \) are bi-directional i.e. they serve dual purpose. The \( AD_7 - AD_0 \) address lines are shared with the data lines. The ALE signal is used to distinguish between address lines and data lines.

Control and Status Signals:
Address Latch Enable (ALE): This is positive going pulse generated every time and indicates that the \( AD_7 - AD_0 \) bits are address bits.

\[ \overline{RD} \]: This is active low signal indicates that the selected I/O or memory device is to be read.

\[ \overline{WR} \]: Active low signal indicates that data on data bus are to be written into a selected memory or I/O location.

\[ \overline{IO/M} \]:
When this signal is high, it indicates an I/O operation.
When it is low it indicates memory operation.

\( S_1 \) and \( S_9 \): These are status signals.
### 8085 Machine cycle status and control signals

<table>
<thead>
<tr>
<th>Machine cycle</th>
<th>Status</th>
<th>Control signals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opcode Fetch</td>
<td>0 1 1</td>
<td>RD = 0</td>
</tr>
<tr>
<td>Memory Read</td>
<td>0 1 0</td>
<td>RD = 0</td>
</tr>
<tr>
<td>Memory write</td>
<td>0 0 1</td>
<td>WR = 0</td>
</tr>
<tr>
<td>I/O Read</td>
<td>1 1 0</td>
<td>RD = 0</td>
</tr>
<tr>
<td>I/O write</td>
<td>1 0 1</td>
<td>WR = 0</td>
</tr>
<tr>
<td>Interrupt Acknowledge</td>
<td>1 1 1</td>
<td>INTA = 0</td>
</tr>
<tr>
<td>Halt</td>
<td>Z 0 0</td>
<td>INTA = 0</td>
</tr>
<tr>
<td>Hold</td>
<td>Z X X</td>
<td>WR = Z</td>
</tr>
<tr>
<td>Reset</td>
<td>Z X X</td>
<td>INTA = 1</td>
</tr>
</tbody>
</table>

**Note:**
- Z = Tri state (High Impedance)
- X = Unspecified

### Externally Initiated Signals Including Interrupts:

The 8085 has five Interrupt signals that can be used to interrupt program execution. (INTR, TRAP, RST 7.5, RST 6.5, RST 5.5).

In addition to the interrupts, three pins – RESET, HOLD & READY accept the externally initiated signals as inputs.

- **Power supply and clock frequency**
  - $V_{CC}$: +5 power supply
  - $V_{SS}$: ground reference

- **X1, X2**: The frequency is internally divided by two. Therefore to operate a system at 3 MHz the crystal should have a frequency of 6 MHz.

- **CLK (OUT)**: Can be used as system clock for other devices.

### Serial I/O ports:

8085 has two signals to implement the serial transmission: SID (serial input data) and SOD (serial output data).

### Interfacing Memory and I/O devices:

It is used so that microprocessor should be able to identify I/O devices with an 8-bit address. It ranges from 00H to FFH.

**Input output interfacing**: It is used so that microprocessor should be able to identify input output devices with an 8-bit address. It ranges from 00H to FFH.

#### Size of memory: $2^n \times m$

- $n \rightarrow$ address lines
- $m \rightarrow$ data lines
Absolute and Partial Decoding:

- When all the address lines are decoded to select the memory chip or input device and no other logic levels can select the chip. This is called absolute decoding.
- When some of the address lines may not be decoded, such lines are used as don’t care. It results in multiple addresses. This technique reduces hardware and also called fold-back or mirror memory space.
- Instruction cycle is time required to complete the execution of an instruction.
- Machine cycle is the time required to complete one operation of accessing memory.
- T-state is one sub version of the operation performed in one clock period.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Memory-Mapped I/O</th>
<th>Peripheral I/O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Device address</td>
<td>16 bit</td>
<td>8 bit</td>
</tr>
<tr>
<td>Control signals for input/output</td>
<td>MEMR / MEMW</td>
<td>IOR / IOW</td>
</tr>
<tr>
<td>Instructions Available</td>
<td>Memory Related</td>
<td>IN and OUT</td>
</tr>
<tr>
<td></td>
<td>Instruction</td>
<td></td>
</tr>
<tr>
<td></td>
<td>STA, LDA</td>
<td></td>
</tr>
<tr>
<td>Data transfer</td>
<td>Between any register and input/output</td>
<td>Only between input/output and the accumulator</td>
</tr>
<tr>
<td>Maximum number of input/output possible</td>
<td>The memory map (64K) is shared between input/output and system memory</td>
<td>The input/output map is independent of the memory map</td>
</tr>
<tr>
<td>Execution speed</td>
<td>3 – 7 states (LDA, STA)</td>
<td>10 – T states</td>
</tr>
<tr>
<td>Hardware Requirements</td>
<td>More hardware is needed to decoded 16 – bit address</td>
<td>Less hardware is needed to be coded 8 – bit address</td>
</tr>
<tr>
<td>Other features</td>
<td>Arithmetic or logical operation can be directly performed with input/output data</td>
<td>Not available</td>
</tr>
</tbody>
</table>

**Instruction word size**

The 8085 instruction set is classified into the following three groups according to word size

1. One – word or 1 – byte instructions
2. Two – word or 2 – byte instructions
3. Three – word or 3 – byte instructions

**One – byte instructions**

A 1 – byte instruction includes the op-code and operand in the same byte. Operands are internal registers and are coded into the instruction.
### One - byte instructions

<table>
<thead>
<tr>
<th>Task</th>
<th>Op-code</th>
<th>Operand</th>
<th>Binary – code</th>
<th>Hex code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copy the contents of the accumulator in the register C.</td>
<td>MOV</td>
<td>C,A</td>
<td>01001111</td>
<td>4FH</td>
</tr>
<tr>
<td>Add the contents of the register B to the contents of the accumulator.</td>
<td>ADD</td>
<td>B</td>
<td>10000000</td>
<td>80H</td>
</tr>
<tr>
<td>Invert (complement) each bit in the accumulator.</td>
<td>CMA</td>
<td></td>
<td>00101111</td>
<td>2FH</td>
</tr>
</tbody>
</table>

### Two – Byte Instructions

In a two – byte instruction, the first byte specifies the op-code and the second byte specifies the operand. Source operand is a data byte immediately following the op code.

<table>
<thead>
<tr>
<th>Task</th>
<th>Op-code</th>
<th>Operand</th>
<th>Binary Code</th>
<th>Hex code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load an 8 – bit data in the accumulator</td>
<td>MVI</td>
<td>A, Data</td>
<td>0011 1110</td>
<td>3E</td>
</tr>
</tbody>
</table>

Assume that the data byte is 32H. The assembly language instruction is written as

<table>
<thead>
<tr>
<th>Mnemonics</th>
<th>Hex Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVI A, 32H</td>
<td>3E 32H</td>
</tr>
</tbody>
</table>

### Three – byte Instructions

In a three byte instruction, the first byte specifies the op-code and the following two bytes specify the 16 – bits address. Note that, the second byte is the low – order address and the third byte is the high – order address. Opcode + data byte + data byte

<table>
<thead>
<tr>
<th>Task</th>
<th>Op-code</th>
<th>Operand</th>
<th>Binary Code</th>
<th>Hex code</th>
<th>Instruction Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transfer the program sequence to the memory location 2085H.</td>
<td>JMP</td>
<td>2085H</td>
<td>1100 0011 1000 0101 0010 0000</td>
<td>C3 85 20</td>
<td>First byte Second byte Third byte</td>
</tr>
</tbody>
</table>
11

COMPUTER ORGANIZATION

CONTENTS

1. PROGRAMMING BASICS ........................................ 288-292
2. MEMORY ACCESS AND DMA .................................... 293-298
3. DATA STRUCTURES ............................................... 299-300
1. PROGRAMMING BASICS

Computer cannot execute a program written in assembly or high level language. The program first must need to be translated to machine language (machine language program is nothing more than sequence of 0s and 1s) which the computer can understand.

**Compiler:** Compiler is a translator, which converts high level language program into assembly language program.

**Assembler:** Assembler is a program that translates assembly language program into machine language (sequence of 0s and 1s) program.

**Linker:** Linker is a computer program that takes one or more object files generated by a compiler and combine them into a single executable program.

**Loader:** Loader is the part of an operating system that is responsible for loading programs. It places programs into memory and prepares them for execution.

### Data types in C:

<table>
<thead>
<tr>
<th>Data type</th>
<th>Size (in bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>char</td>
<td>1</td>
</tr>
<tr>
<td>int</td>
<td>2</td>
</tr>
<tr>
<td>float</td>
<td>4</td>
</tr>
<tr>
<td>double</td>
<td>8</td>
</tr>
</tbody>
</table>

int i = 10;
This declaration tells the C compiler to:

(a) Reserve space (2B) in memory to hold the integer value.
(b) Associate the name i with this memory location.
(c) Store that value of i at this location

\[
i \rightarrow \text{Location name} \\
10 \rightarrow \text{Value at location} \\
1000 \rightarrow \text{Address}
\]

```c
main ( )
{
    int i = 10;
    printf ("%u", &i);
    printf ("%d", i);
    printf ("%d", *(&i));
}
```

**Output:**

```
/*printf ("%u", &i); */  1000
/*printf("%d", i); */   10
```
/*printf("%d", *(&i));  *(1000) = 10
* is called “value at address” operator.

**Pointer**: Pointers are variables which holds the address of another variable.

**Example:**

```c
main( )
{
    int x = 5;
    int * y = &x;
    int**z = &y;

    printf("%u",&x);
    printf("%u",y);
    printf("%u",z);

    printf("%d",x);
    printf("%d",*y);
    printf("%d",**z);
}

**Solution:**

```

<table>
<thead>
<tr>
<th>x</th>
<th>1000 1001</th>
</tr>
</thead>
<tbody>
<tr>
<td>y</td>
<td>2000 2001</td>
</tr>
<tr>
<td>z</td>
<td>3000 3001</td>
</tr>
</tbody>
</table>
```

printf("%u",&x); 1000
printf("%u",y); 1000
printf("%u",z); 2000

printf("%d",x); 5
printf("%d",*y); *1000=5
printf("%d",**z); **2000=*1000=5

**Note**: Every pointer variable takes 2 byte

**Parameter Passing Techniques:**
1. Call by value
2. Call by reference

**Call by value:**
Actual values of the parameter are passed to the called function.

**Example:** What is the output of the following program using Call by value as parameter passing technique?

```c
main( ) swap(int c, int d)
{
    int a=10; int t;
    int b=20; t=c;
    printf("%d%d",a,b);
    c=d;
    swap(a,b);
    d=t;
    printf("%d%d",a,b);
}
```

**Solution:**
Execution of program always starts from main ( )

Here, the changes will not reflect because we are passing the value of parameter to the function.

**Call by reference:**
In Call by reference, addresses of variables are passed as parameter to the called function.

**Example:** What is the output of above program, if compiler uses call by reference as parameter passing technique?

**Solution:** If compiler uses call by reference parameter passing technique, following changes are made to the program by the compiler.

```c
main( ) swap(int*c, int*d)
{
    int a=10; int t;
    int b=20; t=*c;
    printf("%d%d",a,b);
    *c=*d;
    swap(&a,&b);
    *d=t;
    printf("%d%d",a,b);
}
```
Execution of program starts from main ( )

```c
main ( )
{
    int x = 5;
    printf ("%d", ++x);  // Output = 6.
}
```

In pre-increment operator, increment is done first then execution is done.

Post increment operator:
In post increment operator, increment is done after the execution of expression.

```c
main ( )
{
    int x = 5;
    printf ("%d", x + +);  // Output = 5
}
```
Pre-decrement operator:
\(-x\) is equivalent to \(x = x - 1\) but decrementation is done first then execution of line.

Post decrement operator:
\(x --\) is equivalent to \(x = x - 1\) but execution of line is done first then decrementation.

**Recursive Programs:**
Recursive program are the programs which recursively calls itself again and again.

**Example:**

```c
main( )
{
    printf("Hello");
    main( );
}
```

**o/p:** Hello Hello _ _ _ _ _...

**Example:**

```c
main( )
{
    while(1)
    printf("Hi");
}
```

**o/p:**
Hi Hi _ _ _ _ _...

**Four storage class specifier:**

**Auto:** Local variable known only to the function in which it is declared.
Default is auto.

**Static:** Local variable which exists and retains its value even after the control is transferred to controlling function.

**Extern:** Global variable known to all functions in the file.

**Register:** Local variable which is stored in register.
12

MICROWAVES

CONTENTS

1. MICROWAVE BASICS AND TRANSMISSION LINES .... 302-304
2. WAVEGUIDES .................................................. 305-308
3. MICROWAVE HYBRID CIRCUITS ................. 309-311
4. MICROWAVE MEASUREMENT DEVICES ............ 312-312
5. MICROWAVE TUBES AND CIRCUITS ............... 313-317
6. MICROWAVE SEMICONDUCTOR DEVICES .......... 318-324
7. MICROWAVE COMMUNICATIONS .................... 325-328
1. MICROWAVE BASICS AND TRANSMISSION LINES

- Microwaves are electromagnetic waves of which frequency ranges from 1 GHz to 1000 GHz.
- Microwaves behave more like rays of light than ordinary radio waves.
- Microwave frequency cannot be used for ground wave communication.

Advantages of Microwaves:
1. Increased bandwidth availability  
2. Improved directive properties  
3. Low fading effect and low power requirements

IEEE bands For microwave

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency</th>
<th>Wavelength</th>
<th>Propagation characteristics</th>
<th>Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELF</td>
<td>30 – 300 Hz</td>
<td>10 – 1 Mm</td>
<td>Penetration into earth and sea</td>
<td>Communication with submarines.</td>
</tr>
<tr>
<td>VLF</td>
<td>3 – 30 kHz</td>
<td>100–10 km</td>
<td>Surface wave up to 1000 km. Sky wave in the night extends range. Low attenuation during day and night.</td>
<td>Long distance point to point communication, Sonar navigation.</td>
</tr>
<tr>
<td>LF</td>
<td>30 – 300 kHz</td>
<td>10 – 1 km</td>
<td>Surface wave and sky wave at night. Surface wave attenuation greater than VHF.</td>
<td>Point-to-point marine communication, Time standard frequency broadcast.</td>
</tr>
<tr>
<td>MF</td>
<td>300–3000 kHz</td>
<td>1000–100m</td>
<td>Ground wave in day and sky wave in night. Attenuation is high in day and low in night.</td>
<td>AM broadcasting, direction finding, coastguard and marine communication.</td>
</tr>
<tr>
<td>HF</td>
<td>3 – 30 MHz</td>
<td>100 – 10 m</td>
<td>Reflection from ionosphere.</td>
<td>Moderate and long distance</td>
</tr>
</tbody>
</table>
Microwave Transmission Lines

Multi-conductor lines:

Coaxial cable: It is used up to 3GHz and it behaves like a LPF.
- Coaxial cables support TEM wave and has no cut off frequency.
- There is high radiation loss in coaxial cable at high frequencies.

Coaxial cable resistance:
\[ R = \frac{1}{2\pi\sigma\delta} \left( \frac{1}{a} - \frac{1}{b} \right) \Omega/m \]

\( \delta \rightarrow \) Skin depth  \( \sigma \rightarrow \) Conductivity

\( a \rightarrow \) Inner conductor radius  \( b \rightarrow \) Outer conductor radius

Inductance: \( L = \frac{b}{2\pi} \ln \frac{b}{a} \) H/m

Capacitance: \( C = \frac{2\pi\varepsilon}{\ln \frac{b}{a}} \) F/m

Characteristic Impedance: \( Z_o = \sqrt{\frac{L}{C}} = \frac{1}{2\pi\sqrt{\varepsilon\varepsilon_r}} \ln \left( \frac{b}{a} \right) \Omega \)

\[ Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln \frac{b}{a} \]

Breakdown power in coaxial cable: \( P_{bd} = 3600 a^2 \ln \left( \frac{b}{a} \right) KW \)

Strip Lines:
- These are modifications of coaxial lines and used at frequency from 100 MHz to 100 GHz.
- The dominant mode is TEM mode and has no radiation losses.
- These have higher isolation between adjacent circuits and no fringing fields after a certain distance from the edges of a conductor.
- It is difficult to mount active components on strip lines (i.e. line diode, circulators).

**Characteristic Impedance:**

\[
Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{4b}{\pi d}\right)
\]

- \(d\) → Diameter of circular conductor
- \(b\) → Thickness between ground plates

**Micro strip lines:**
- Cost is lower than strip line, coaxial cable or waveguide.
- Open structure of microstrip line leads to greater coupling and it is large to mount passive or active components.
- Open structure also leads to higher radiation losses and interference due to nearby conductors.
- Due to this interference a discontinuity in electric and magnetic field presents and this leads to impure TEM or quasi TEM modes.

**Characteristic Impedance:**

\[
Z_o = \frac{60}{\sqrt{\varepsilon_r}} \ln\left(\frac{4b}{d}\right)
\]

If \(h \gg d\)

\[
Z_o = \frac{377}{\sqrt{\varepsilon_r}} w
\]

If \(w \gg h\)

- \(w\) → Strip line width
- \(h\) → Distance between the line and ground plane
13

ANALOG ELECTRONICS

CONTENTS

1. VOLTAGE REGULATORS & RECTIFIERS ........................................ 330-331
2. BJT & TRANSISTOR BIASING .................................................. 332-335
3. MULTISTAGE & POWER AMPLIFIERS ..................................... 336-338
4. SMALL SIGNAL ANALYSIS ...................................................... 339-343
5. FEEDBACK AMPLIFIERS ........................................................ 344-347
6. OSCILLATORS ........................................................................ 348-351
7. OPERATIONAL AMPLIFIERS .................................................. 352-364
Voltage Regulator Circuits:

% Regulation \( = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\% \)

Full load current \( = I_{FL} = \frac{V_{FL}}{R_L} \)

\( V_{NL} \) - No load
\( V_{FL} \) - Full load

Smaller the regulation better is the circuit performance.

**Zener Voltage Regulator Circuit:**

Unregulated \( V_i \)

Regulated voltage \( V_L \)

Since Zener diode is conducting

\( V_L = V_z = V_{Ir} \)

\( V_L = I_z R_z \)

\( V = I R \)

\( I = I_z + I_L \)

If Zener current is maximum then load current is minimum and vice versa.

\( I = I_{z,\text{max}} + I_{L,\text{min}} \)

\( I = I_{z,\text{min}} + I_{L,\text{max}} \)

For satisfactory operation of circuit

\( I \geq I_{z,\text{min}} + I_L \)

\( \frac{V_z - V_L}{R_z} \geq I_{z,\text{min}} + I_L \)

The power dissipated by the Zener diode is \( P_z = V_z I_z \)

**Rectifier:** To convert a bi-directional current or voltage into a unidirectional current or voltage

**Ripple factor:**

\( r = \frac{\text{rms value of AC component}}{\text{DC value}} \)

\( r = \sqrt{\left(\frac{V_{\text{rms}}}{V_{dc}}\right)^2 - 1} \)
**Form factor:**
\[
F = \frac{\text{rms value}}{\text{dc value}} = \frac{V_{\text{rms}}}{V_{\text{dc}}}
\]
\[
r = \sqrt{F^2 - 1}
\]

Crest factor = \[
\frac{\text{Peak value}}{\text{RMS value}}
\]

Rectifier Efficiency = \[
\frac{\text{DC power output}}{\text{AC power input}} \times 100\%
\]

**TUF (Transformer utilization factor):**
\[
\text{TUF} = \frac{\text{DC power output}}{\text{AC rating of transformer}}
\]

**Half Wave Rectifier:** Average value of current and voltage
\[
I_{\text{dc}} = \frac{I_m}{\pi}, \quad V_{\text{dc}} = \frac{V_m}{\pi}
\]

**RMS value of current and voltage:**
\[
I_{\text{rms}} = \frac{2I_m}{\pi}, \quad V_{\text{rms}} = \frac{2V_m}{\pi}
\]

Efficiency \( \eta = 40.6\% \)
Ripper factor = 1.21
Form factor = 1.57
Frequency of ripple voltage = \( f \)
Peak inverse voltage = \( V_m \)
TUF = 0.286

**Full Wave Rectifier:** Average value of current and voltage
\[
I_{\text{dc}} = \frac{2I_m}{\pi}, \quad V_{\text{dc}} = \frac{2V_m}{\pi}
\]

**RMS value of current and voltage:**
\[
I_{\text{rms}} = \frac{I_m}{\sqrt{2}}, \quad V_{\text{rms}} = \frac{V_m}{\sqrt{2}}
\]

Efficiency \( \eta = 81.2\% \)
Ripper factor = 0.48
From factor = 1.11
Crest factor = \( \sqrt{2} \)
TUF = 0.692
Frequency of ripple voltage = \( 2f \)
Peak inverse voltage = \( 2V_m \)

**Bridge Rectifier:** All the parameters are same as full wave rectifier except

Peak inverse voltage = \( V_m \)
Transformer utilization factor = 0.812

**Advantage of Bridge Rectifier:**
1. The current in both the primary and secondary of the transformer flows for entire cycle.
2. No center tapping is required in the transformer secondary. Hence it is cheap device.
3. The current in the secondary winding of transformer is in opposite direction in two half cycles. Hence net DC current flow is zero.

4. As two diode currents are in series, in each of the cycle inverse voltage appear across diode gets shared. Hence the circuit can be used for high voltage application.

SAMPLE FILE ONLY…Missing

2. BJT & TRANSISTOR BIASING

General Equation of Transistor:  

- In CE mode:  
  \[ I_C = \beta I_B + \alpha I_C \]  

- In CB mode:  
  \[ I_C = \alpha I_E + I_C \]

Typical values for  \( V_{BE} \):

- 0.2 (Ge Transistor)
- 0.7 (Si Transistor)
- 1.3 (GaAs Transistor)

\( \beta \) and \( \alpha \)

(a) Condition to keep transistor in cut off:  
\[ V_{BE} < 0.7V \]

(b) Condition for transistor under active region:

1.  \( V_{BE} = 0.7V \)  
2.  \( I_C = \beta I_B = \alpha I_E \)  
3.  \( I_B < \frac{I_{sat}}{\beta} \)

(c) Transistor under saturation region:
To find whether transistor is in active mode or saturation mode

\[ V_{BE} = 0.7V \]
\[ I_C \neq \beta I_B \neq \alpha I_E \]
\[ V_{CEsat} = 0.2V \]

I. If \( I_C \) active > \( I_C \) (saturation)
then transistor is in saturation and Q point is \( (I_C \) (saturation),0.2).

II. If \( I_C \) (saturation) > \( I_C \) (active)
then transistor is in active region and Q point is \( (I_C \) (active),\( V_{CE} \)).

Transistor DC Load Line and Q Point

- DC load line is a straight line which joins \( I_{Cmax} \) and \( V_{CC} \) or which joins saturation and cutoff point.
- DC load line is the locus of all possible operating points at which it remains in active region.
- Q point is called quiescent point or operating point and it is a function of \( I_B \), \( I_C \), and \( V_{CC} \).
- For best performance of amplifier in the BJT the Q point must be located at the center of D.C. load line.

Stability Factor:
\( I_C \) is a function of \( I_{CO} \), \( V_{BE} \), \( \beta \) (Temperature dependent parameter)

\[ \text{Stability } S = \frac{\partial I_C}{\partial I_{CO} V_{BE} \beta} \]
Smaller the values of S better will be thermal stability.
The general equation for stability factor $S$:

$$S = \frac{1 + \beta}{1 - \beta \frac{\partial I_B}{\partial I_C}}$$

Transistor Biasing Circuits and Their Stability:

A. Fixed Bias Circuit (Base – Bias)

$$I_C = \frac{V_{CC} - V_{CE}}{R_C}$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

Stability $S = 1 + \beta$

Fixed bias circuit is unstable.

B. Collector to base bias circuits

$$I_B = \frac{V_{CC} - V_{BE}}{(\beta + 1)R_C}$$
$$I_C = \beta I_B$$

Stability $S = \frac{1 + \beta}{\beta R_C}$

The circuit is having good thermal stability.

C. Self bias circuit → (Potential divider bias circuit)

Emitter bias circuit

It is popularly used in biasing circuit.
It gives 180° phase shift.

when,

$$V_{th} = \frac{V_{CC}R_2}{R_1 + R_2}$$
$$I_C = \frac{V_{CC} - V_{CE}}{R_C + R_E}$$

$$R_{th} = \frac{R_1R_2}{R_1 + R_2}$$
$$I_E = \frac{V_{th} - B_{th}}{R_E + \left(\frac{R_{th}}{B + 1}\right)}$$
Stability factor

\[
S = \frac{1 + \beta}{1 + \beta \frac{R_E}{R_{th} + R_E}} = \frac{\beta}{\beta \frac{R_E}{R_{th} + R_E}}
\]

\[
S = 1 + \frac{R_{th}}{R_E}
\]

Thermal Runaway:

- The self destruction of the transistor due to the excess heat produced within the device is called thermal runaway.
- It is due to \( I_{co} \)
- BJT suffers from thermal runaway.
- In FET, there is no thermal runaway.

Conditions to eliminate thermal runaway:

\[
V_{CE} \leq \frac{V_{CC}}{2} \quad \text{and} \quad \frac{dP_c}{dT_j} < \frac{1}{\theta}
\]

Thermal resistance (J)

\[
\theta = \frac{C}{\text{watt} \text{/ C}^\circ \text{or} \quad \text{K} \text{/ watt}}
\]

\( T_j \rightarrow \) Junction temperature (collector junction)

\( T_A \rightarrow \) Ambient temperature

\( P_D \rightarrow \) Power dissipated across collector junction

A transistor is thermally stable if

\[
\frac{dP_C}{dT_j} \leq \frac{dP_D}{dT_j}
\]

\( \frac{dP_C}{dT_j} \rightarrow \) Rate at which heat is released

\( \frac{dP_D}{dT_j} \rightarrow \) Rate at which heat is dissipated

Current Mirror Circuit: In current mirror circuit, the output current is forced to approximately equal to the input current.
They are widely used to designing the differential amplifier and op amps.
Both the transistor are equal, their current and voltage are equal i.e.

\[ I_{b3} = I_{b4} \]
\[ I_{c3} = I_{c4} \]
\[ V_{bc3} = V_{bc4} \]

\[ I_2 = I_{c4} + I_1 \]
\[ I_2 = I_{c3} + 2I_{b4} \]
\[ I_2 = I_{c4} \left( \frac{1}{1 + \frac{2}{\beta}} \right) \]
\[ I_{c3} = \frac{I_2}{1 + \frac{2}{\beta}} \]

\[ I_{c3} = I_2 \]

To Buy Online call at 0-9990657855