DSSSB AE/JE 2026

COMPLETE BASICS OF ELECTRONICS & COMMUNICATION ENGINEERING

Complete Theory • Detailed Hinglish Explanation • Step-by-Step Derivations
Solved Examples • Engineering Applications • Practice Questions

Prepared By

CIVILGYAN WITH SATISH

https://civilgyantests.com

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Accuracy note: Electronics models are stated with their assumptions. Component tolerances, temperature, loading and device limits must be checked in practical work.

Preface

This book develops electronics from carrier physics to complete communication links. The sequence deliberately connects physical operation, circuit models, equations, waveforms, practical limitations and exam decisions so a learner can reason instead of memorizing isolated facts.

The scope follows the five prescribed DSSSB AE/JE units. Advanced detail is included only where it clarifies a listed topic or prevents a common numerical, circuit or waveform mistake.

How to Use This Book

Read the technical explanation first, then the Hinglish Explanation. Redraw every circuit and waveform with labels. Work each formula from its stated assumptions, solve the examples without looking at the result, and attempt all twenty questions at the end of each chapter.

For every answer, verify device region, polarity, units, bandwidth convention and limiting behaviour. Maintain a short error log and revise the chapter formula sheet after one day, one week and before the examination.

Practice rule: Questions are original DSSSB-style practice. Each solution explains only the correct answer, as requested.

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How to use this book: Read Complete Theory, reinforce it with the Hinglish Explanation, review every formula and derivation row, then attempt all twenty questions without viewing the solutions. Questions are original DSSSB-style practice, not claimed verbatim previous-year questions.

Electronics & Communication Units and Conventions

1. 1 A = 1 C/s
2. 1 V = 1 J/C
3. 1 Hz = 1 cycle/s
4. gain in dB = 20 log10(voltage ratio) or 10 log10(power ratio)
5. state peak, RMS, DC and bandwidth conventions clearly.

CHAPTER 1 — SEMICONDUCTOR PHYSICS, DIODES AND DIODE APPLICATIONS

1. Introduction

Semiconductor electronics controls charge carriers to perform rectification, regulation, switching, sensing and wave shaping. This chapter builds energy-band and carrier ideas first, then develops the PN junction, practical diode models, rectifiers, filters, Zener regulation, LED and photodiode operation, and nonlinear applications. Every calculated diode state must finally be checked against its assumed bias condition.

2. Complete Theory

Energy bands, bonding and charge carriers

In an isolated atom electrons occupy discrete levels; in a crystal, interaction between many atoms broadens these levels into bands. The valence band contains bonding electrons and the conduction band contains mobile electrons.

The forbidden energy gap separates them. Conductors have overlapping bands, insulators have a large gap, and semiconductors such as silicon have a moderate gap that can be crossed thermally or optically.

Breaking a covalent bond creates an electron-hole pair. An electric field causes electron drift opposite to conventional current and hole drift with conventional current.

Concentration gradients cause diffusion. Generation and recombination jointly determine carrier population, conductivity and temperature behaviour.

Hinglish Explanation

Silicon crystal ko bonded seats ka network samjho. Heat ya light se ek electron bond chhodkar mobile ho jata hai aur peeche hole reh jata hai.

Dono current carry karte hain. Semiconductor ka temperature badhne par carriers badhte hain, isliye resistance generally ghatta hai.

Intrinsic and extrinsic semiconductors

An intrinsic semiconductor is chemically pure and has equal electron and hole concentrations. Conductivity is $[\sigma]=q(n[\mu]_n+p[\mu]_p)$.

Doping deliberately adds a very small impurity concentration. Pentavalent donor atoms contribute electrons and create N-type material; trivalent acceptors create holes and P-type material.

Majority carriers dominate conduction, but minority carriers remain essential in reverse current and transistor action. The crystal as a whole remains electrically neutral because mobile carriers are balanced by fixed ionized impurities.

Silicon is preferred over germanium for lower leakage, better temperature stability and a larger useful operating range.

Hinglish Explanation

Doping ka matlab crystal ko charged banana nahi hai. N-type mein free electrons majority hote hain, par donor ions fixed positive charge balance karte hain.

P-type mein holes majority hote hain. Material overall neutral hi rehta hai.

PN-junction formation and equilibrium

When P and N regions touch, electrons diffuse from N to P and holes from P to N because of concentration gradients. Recombination near the interface leaves uncovered immobile donor and acceptor ions.

Their space charge forms a depletion region and an internal electric field directed from N to P. This field drives a drift current opposite to diffusion.

At thermal equilibrium the two currents balance and the Fermi level becomes uniform. The barrier potential is about 0.7 V for silicon and 0.3 V for germanium at ordinary temperature, but it is not an independent battery available at external terminals.

Hinglish Explanation

Junction bante hi majority carriers border cross karke recombine karte hain. Border ke paas mobile carriers kam aur fixed ions bach jaate hain; isi ko depletion layer kehte hain.

Internal field further diffusion ko oppose karta hai, aur equilibrium par drift aur diffusion currents balance ho jaate hain.

Forward bias, reverse bias and diode equation

Forward bias connects P to the positive supply and N to the negative supply. It reduces the barrier and depletion width, so majority-carrier diffusion rises exponentially.

Reverse bias enlarges the depletion region; only a small minority-carrier saturation current flows until breakdown. The Shockley equation $I=I_S[\exp(V_D/([eta]V_T))-1]$ describes an ideal junction over its normal range.

Practical analysis may use an ideal short/open model, a constant drop model, or a piecewise-linear model with threshold and dynamic resistance. Dynamic resistance near an operating point is approximately $[eta]V_T/I_D$.

Hinglish Explanation

Forward bias mein external voltage barrier ko kam karta hai, isliye current sharply rise karta hai. Reverse bias mein layer wide hoti hai aur leakage bahut chhota rehta hai.

Circuit solve karne ke baad check karo: assumed ON diode ka current forward hona chahiye.

Breakdown, Zener diode and special diodes

Zener breakdown occurs in a heavily doped, thin junction through field-assisted tunnelling and is associated with lower breakdown voltages. Avalanche breakdown occurs in a wider, lightly doped junction by impact ionization.

Both are safe only when current is externally limited. A Zener regulator operates in reverse breakdown and holds load voltage nearly constant while supply or load changes within design limits.

LEDs convert carrier recombination energy to photons and require forward-current limiting. Photodiodes are normally reverse biased so light-generated carriers produce a current.

Varactor diodes use voltage-dependent junction capacitance for electronic tuning.

Hinglish Explanation

Zener ko reverse breakdown mein intentionally chalate hain, lekin series resistor compulsory hai. LED forward biased light source hai; photodiode usually reverse biased sensor hai.

Varactor mein reverse voltage badhne par depletion width badhti aur capacitance ghat ti hai.

Rectifiers, filters, clippers and clampers

A half-wave rectifier uses one half-cycle and has high ripple. A centre-tapped full-wave rectifier uses two diodes and requires a centre-tapped transformer; a bridge uses four diodes and no centre tap, with two conducting per half-cycle.

Full-wave ripple frequency is twice the supply frequency. A shunt capacitor charges near the peak and discharges slowly through the load, reducing ripple; larger capacitance or load resistance reduces ripple.

Clippers limit selected portions of a waveform using diode orientation and bias. Clampers add a DC level without ideally changing peak-to-peak value, and require the RC time constant to be large compared with the signal period.

Hinglish Explanation

Rectifier AC ko unidirectional banata hai; filter us pulsating DC ko smooth karta hai. Clipper waveform ka part kaat ta hai, jabki clamper poori waveform ko upar ya neeche shift karta hai.

Bridge mein har half-cycle do diode drops count karna mat bhoolna.

4. Engineering Formula Section

Formula Sheet
1. n_i^2=np
2. [σ]=q(n[μ]$_n$+p[μ]$_p$)
3. I=I_S[exp(V_D/([eta]V_T))-1]
4. V_T=kT/q
5. r_d=[eta]V_T/I_D
6. C_j=[ε]A/W
7. V_{DC},HWR=V_m/[π]
8. V_{DC},FWR=2V_m/[π]
9. PIV,HWR=V_m
10. PIV,bridge=V_m
11. PIV,centre-tap=2V_m
12. ripple frequency,FWR=2f
13. r_{HWR}=1.21
14. r_{FWR}=0.482
15. [eta]$_{rect}$,HWR,max=40.6%
16. [eta]$_{rect}$,FWR,max=81.2%
17. V_r(pp) approximately I_L/(f_{rC})
18. Zener resistor R_S=(V_S-V_Z)/(I_Z+I_L)

5. Formula Derivations and Solved Examples

For a full-wave rectified sine, average output equals (1/[π]) integral from 0 to [π] of V_m sin[θ] d[θ] plus the identical second half, giving 2V_m/[π]. With a capacitor-input filter, charge lost between peaks is approximately I_L[Δ]t. Since [Δ]Q=C[Δ]V and [Δ]t=1/f_r, ripple peak-to-peak is approximately I_L/(f_{rC}). Example: I_L=50 mA, f_r=100 Hz and C=1000 [μ]F gives about 0.5 V peak-to-peak ripple.

6. Practical Applications

- Power supplies and mobile chargers.
- Reverse-polarity and surge protection.
- Voltage references and regulators.
- LED indicators and optical sensors.
- Signal limiting, restoration and RF detection.

7. Short Tricks

- P-side to positive means forward bias.
- Silicon practical drop is commonly 0.7 V.
- Full-wave output repeats every half-cycle.
- LED emits; photodiode detects.

8. Concept Diagram

```
BRIDGE RECTIFIER
 AC o-->|--+--|<--o AC
          | +Vo
         [R_L]
          | -Vo
 AC o--<|--+--|>--o AC
Two diagonally opposite diodes conduct in each half-cycle.
```

9. Comparison Table

Comparison	Half-wave	Centre-tapped full-wave	Bridge
Diodes	1	2	4
Diodes conducting	1	1	2
Ripple frequency	f	2f	2f
PIV per diode	V_m	$2V_m$	V_m
Transformer	ordinary	centre tap	ordinary

10. Common Mistakes

- Treating barrier potential as an external source.
- Forgetting two forward drops in a bridge.
- Operating a Zener without current limiting.
- Confusing a clipper with a clamper.
- Using full-wave ripple frequency as f.

11. Important DSSSB Exam Points

- Depletion physics, diode models, PIV, ripple, Zener current limits and waveform recognition are high-yield.
- Always verify the assumed ON/OFF state and breakdown power.

12. Chapter Revision Sheet

Connect band theory to carriers, carriers to junction field, and junction bias to circuit behaviour. Remember that rectification changes direction, filtering reduces ripple, clipping limits amplitude and clamping shifts DC level.

13. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. An intrinsic semiconductor at equilibrium has

(A) equal electron and hole concentrations
(B) electrons
(C) decreases it
(D) heavy doping and a thin depletion layer

Correct Answer: (A)
Every generated electron leaves one hole.

Q2. Majority carriers in N-type silicon are

(A) immobile ionized impurities
(B) electrons
(C) minority carriers
(D) impact ionization

Correct Answer: (B)
Donor doping supplies mobile electrons.

Q3. The depletion region primarily contains

(A) decreases it
(B) 0.7 V
(C) immobile ionized impurities
(D) a current-limiting series resistor

Correct Answer: (C)
Mobile carriers have diffused and recombined near the junction.

Q4. Forward bias does what to the depletion width?

(A) minority carriers
(B) [eta]V_T/I_D
(C) 100 Hz
(D) decreases it

Correct Answer: (D)
External field opposes the junction field.

Q5. Reverse saturation current is mainly due to

(A) minority carriers
(B) 0.7 V
(C) heavy doping and a thin depletion layer
(D) 81.2%

Correct Answer: (A)
Thermally generated minority carriers cross the junction field.

Q6. The approximate silicon forward drop in the constant-voltage model is

(A) [eta]V_T/I_D
(B) 0.7 V
(C) impact ionization
(D) V_m

Correct Answer: (B)
This is the common room-temperature circuit approximation.

Q7. Diode dynamic resistance at bias current I_D is approximately

(A) heavy doping and a thin depletion layer
(B) a current-limiting series resistor
(C) [eta]V_T/I_D
(D) supplying load current between rectified peaks

Correct Answer: (C)
It is the reciprocal local slope of the exponential characteristic.

Q8. Zener breakdown is associated with

(A) impact ionization
(B) 100 Hz
(C) reduces ripple
(D) heavy doping and a thin depletion layer

Correct Answer: (D)
A strong field enables tunnelling.

Q9. Avalanche breakdown is caused by

(A) impact ionization
(B) a current-limiting series resistor
(C) 81.2%
(D) limits selected waveform portions

Correct Answer: (A)
Accelerated carriers create additional electron-hole pairs.

Q10. A Zener regulator must include

(A) 100 Hz
(B) a current-limiting series resistor
(C) V_m
(D) the DC level

Correct Answer: (B)
It keeps diode current and power within rating.

Q11. The ripple frequency of a 50 Hz full-wave rectifier is

(A) 81.2%
(B) supplying load current between rectified peaks
(C) 100 Hz
(D) forward bias

Correct Answer: (C)
Both half-cycles produce output pulses.

Q12. Maximum ideal full-wave rectifier efficiency is about

(A) V_m
(B) reduces ripple
(C) reverse bias
(D) 81.2%

Correct Answer: (D)
Full-wave utilization doubles the ideal limit relative to half-wave.

Q13. PIV of each bridge diode for secondary peak V_m is

(A) V_m
(B) supplying load current between rectified peaks
(C) limits selected waveform portions
(D) reverse voltage increases

Correct Answer: (A)
A nonconducting bridge diode blocks approximately the secondary peak.

Q14. A capacitor filter reduces ripple by

(A) reduces ripple
(B) supplying load current between rectified peaks
(C) the DC level
(D) equal electron and hole concentrations

Correct Answer: (B)
The capacitor discharges slowly through the load.

Q15. Increasing filter capacitance generally

(A) limits selected waveform portions
(B) forward bias
(C) reduces ripple
(D) electrons

Correct Answer: (C)
For the same charge loss, voltage change is inversely proportional to capacitance.

Q16. A clipper primarily

(A) the DC level
(B) reverse bias
(C) immobile ionized impurities
(D) limits selected waveform portions

Correct Answer: (D)
Diode conduction prevents output crossing the designed level.

Q17. An ideal clamper primarily changes

(A) the DC level
(B) forward bias
(C) reverse voltage increases
(D) decreases it

Correct Answer: (A)
Peak-to-peak amplitude is ideally preserved.

Q18. An LED normally operates in

(A) reverse bias
(B) forward bias
(C) equal electron and hole concentrations
(D) minority carriers

Correct Answer: (B)
Forward carrier recombination emits photons.

Q19. A photodiode is commonly operated in

(A) reverse voltage increases
(B) electrons
(C) reverse bias
(D) 0.7 V

Correct Answer: (C)
Reverse field quickly collects light-generated carriers.

Q20. Varactor capacitance decreases when

(A) equal electron and hole concentrations
(B) immobile ionized impurities
(C) [eta]V_T/I_D
(D) reverse voltage increases

Correct Answer: (D)
A wider depletion region gives lower junction capacitance.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 2 — BIPOLAR JUNCTION TRANSISTORS AND JUNCTION FIELD-EFFECT TRANSISTORS

1. Introduction

Transistors permit a small input signal to control a larger output current. The BJT is a bipolar, current-controlled device whose active operation depends on carrier injection and collection. The JFET is a unipolar, voltage-controlled device in which a reverse-biased gate junction controls channel width. Biasing establishes a stable operating point before an AC signal is applied.

2. Complete Theory

BJT construction and transistor action

An NPN transistor has a heavily doped emitter, very thin lightly doped base and moderately doped larger collector. In forward-active operation the emitter-base junction is forward biased and collector-base junction reverse biased.

The emitter injects electrons into the base; only a small fraction recombines to form base current, while the collector field sweeps most carriers into the collector. Thus $I_E=I_C+I_B$, $[\alpha]=I_C/I_E$ and $[\beta]=I_C/I_B$, with $[\beta]=[\alpha]/(1-[\alpha])$.

PNP operation has reversed polarities and carrier directions.

Hinglish Explanation

Emitter carriers inject karta hai, thin base mein thode recombine hote hain, aur collector majority ko collect karta hai. Isi carrier control se small base current large collector current control karta hai.

NPN aur PNP mein polarities reverse hoti hain.

BJT configurations, characteristics and regions

Common-base has low input resistance, high output resistance, current gain below unity and no phase reversal. Common-emitter provides substantial current and voltage gain with 180-degree phase inversion, so it is widely used for amplification.

Common-collector or emitter follower has voltage gain near unity, high input resistance and low output resistance, making it a buffer. Cut-off means both junctions effectively reverse biased; saturation means both forward biased; active region is used for linear amplification.

The DC load line joins the cut-off and saturation intercepts, while the Q-point locates the no-signal operating condition.

Hinglish Explanation

CE amplifier popular hai kyunki power gain achha milta hai, lekin output inverted hota hai. Switch ke liye cut-off OFF aur saturation ON use karo.

Amplifier ke liye Q-point active region mein rakho, ideally swing ke liye suitable centre ke paas.

Biasing and thermal stability

Fixed bias is simple but strongly dependent on $[\beta]$ and temperature. Collector-to-base feedback improves stability by reducing base drive when collector current rises.

Voltage-divider bias makes base voltage relatively independent of transistor $[\beta]$; an emitter resistor introduces negative DC feedback because rising current raises emitter voltage and reduces V_{BE}. A bypass capacitor may short the emitter resistor for AC, recovering gain without losing DC stabilization.

Leakage and V_{BE} changes can create thermal runaway unless bias and heat removal provide negative feedback. Stability factor measures sensitivity of collector current to leakage changes.

Hinglish Explanation

Biasing ka goal sirf transistor ON karna nahi, stable Q-point set karna hai. Emitter resistor self-correction deta hai: current badhe to V_E badhta, V_{BE} ghat ta aur current oppose hota hai.

Bypass capacitor DC stability ko rakhta aur AC gain improve karta hai.

Small-signal CE amplifier and frequency response

A coupling capacitor blocks DC between stages while passing signal frequencies. The emitter bypass capacitor reduces AC degeneration.

At midband these capacitors are effectively short and transistor junction capacitances are often negligible. Low-frequency gain falls because coupling and bypass reactances increase; high-frequency gain falls because internal capacitances and transit time matter.

The lower and upper cut-off frequencies are defined at a gain magnitude 1/[√]2 of midband, or -3 dB. Bandwidth equals f_H-f_L.

Voltage gain sign is negative in CE because increasing base current increases the collector-resistor drop and lowers collector voltage.

Hinglish Explanation

CE input badhe to collector current badhta hai, R_C drop badhta hai aur collector voltage ghat ta hai—isi liye 180 degree inversion. Coupling capacitor low frequency block karne lagta hai; junction capacitance high frequency par signal shunt karti hai.

JFET construction, operation and characteristics

An N-channel JFET has an N-type channel with two P-type gate regions forming reverse-biased junctions. Gate current is nearly zero, so input resistance is high.

Increasing V_{DS} first gives an approximately ohmic region; depletion layers widen toward the drain until pinch-off, after which current is nearly constant. Making V_{GS} more negative widens depletion throughout the channel and reduces drain current.

At $V_{GS}=V_{GS}$(off), the channel is cut off. Shockley's transfer relation is $I_D=I_{DSS}(1-V_{GS}/V_P)^2$ within its valid operating range.

Hinglish Explanation

JFET gate ko reverse bias karke channel ko squeeze karte hain. Gate current almost zero, isliye input loading low.

Pinch-off ka matlab channel current zero nahi; saturation region mein current nearly constant hota hai. Cut-off V_{GS}(off) par hota hai.

JFET biasing, amplifier and BJT comparison

Self-bias connects the gate near ground through a large resistor and places a resistor in the source. Drain current raises source voltage, making V_{GS} negative automatically for an N-channel device.

A common-source amplifier gives voltage gain and phase inversion; common-drain is a source follower buffer. JFETs are voltage controlled, use majority carriers, have high input resistance and low noise, but usually lower transconductance and gain than comparable

BJTs.

BJTs are current controlled and can provide higher transconductance but load the driving source more and are more vulnerable to thermal runaway.

Hinglish Explanation
N-channel self-bias mein source resistor V_S positive banata hai while gate near zero, so V_{GS} automatically negative milta hai. BJT ko base current chahiye; JFET ko gate voltage control karta hai aur gate current ideally almost zero hota hai.

4. Engineering Formula Section

Formula Sheet
1. $I_E=I_C+I_B$
2. $[\alpha]=I_C/I_E$
3. $[\beta]=I_C/I_B$
4. $[\beta]=[\alpha]/(1-[\alpha])$
5. I_C approximately $[\beta]I_B$
6. $V_{CE}=V_{CC}-I_{CRC}-I_{ERE}$
7. load-line intercepts I_C approximately $V_{CC}/(R_C+R_E),V_{CE}=V_{CC}$
8. g_m,BJT=I_C/V_T
9. A_v,CE approximately $-g_{mRC}$
10. bandwidth=f_H-f_L
11. gain at cutoff=midband/[√]2
12. $I_D=I_{DSS}(1-V_{GS}/V_P)^2$
13. $g_m=g_{m0}(1-V_{GS}/V_P)$
14. self-bias $V_{GS}=-I_{DRS}$

5. Formula Derivations and Solved Examples

From $I_E=I_C+I_B$, divide by I_E: $1=[\alpha]+I_B/I_E$. Because $[\beta]=I_C/I_B=[\alpha]I_E/[(1-[\alpha])I_E]$, $[\beta]=[\alpha]/(1-[\alpha])$. For an unbypassed emitter resistor, a rise in I_C raises V_E, reduces V_{BE} and opposes the rise. For a JFET, substituting self-bias $V_{GS}=-I_{DRS}$ into Shockley's equation gives a nonlinear equation; solve for the physically valid root between zero and I_{DSS}.

6. Practical Applications

• Audio and sensor amplifiers.

- Digital switching and relay drivers.
- Impedance buffers.
- Constant-current sources.
- Low-noise front ends and analog switches.

7. Short Tricks

- NPN active: BE forward, BC reverse.
- Cut-off is OFF; saturation is ON for switching.
- Emitter follower has voltage gain near one.
- JFET gate junction is reverse biased.

8. Concept Diagram

```
 CE BIAS AND SIGNAL
  VCC
   |--R_C--o Vout
   |       C
  Vin--C_in--B  NPN
          E--R_E--0 V
 Increasing Vin lowers collector output: 180-degree phase inversion.
```

9. Comparison Table

Feature	BJT	JFET
Control	base current	gate-source voltage
Carriers	bipolar	majority carriers
Input resistance	moderate	very high
Thermal stability	lower	better
Typical gain	higher g_m	lower noise/loading

10. Common Mistakes

- Using $I_E=I_C-I_B$.
- Assuming saturation is the amplifier region.
- Forgetting CE phase inversion.
- Calling JFET pinch-off zero current.
- Using Shockley's equation outside its valid range.

11. Important DSSSB Exam Points

- Current relations, Q-point/load line, bias stability, -3 dB bandwidth, Shockley equation and BJT-JFET comparison are frequent.

12. Chapter Revision Sheet

A BJT uses controlled carrier injection; a JFET uses depletion-controlled channel width. Always establish the DC operating region first, then analyze the small AC signal about the Q-point.

13. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. The correct BJT current relation is

(A) $I_E=I_C+I_B$
(B) BE is forward biased and BC is reverse biased
(C) thin and lightly doped
(D) saturation

Correct Answer: (A)
Emitter current divides into collector and base currents.

Q2. In forward-active NPN operation

(A) emitter
(B) BE is forward biased and BC is reverse biased
(C) [β]=[α]/(1-[α])
(D) all allowed I_C-V_{CE} pairs for the external circuit

Correct Answer: (B)
This injects carriers and collects them through the collector field.

Q3. The most heavily doped BJT region is the

(A) thin and lightly doped
(B) 180 degrees out of phase with input
(C) emitter
(D) its Q-point is less dependent on [β]

Correct Answer: (C)
Strong emitter injection efficiency is required.

Q4. The BJT base is made

(A) [β]=[α]/(1-[α])
(B) an impedance buffer
(C) negative feedback
(D) thin and lightly doped

Correct Answer: (D)
This minimizes recombination and base current.

Q5. The relation between gains is

(A) [β]=[α]/(1-[α])
(B) 180 degrees out of phase with input
(C) saturation
(D) increases AC gain while retaining DC stabilization

Correct Answer: (A)
It follows from $I_E=I_C+I_B$.

Q6. A CE amplifier output is

(A) an impedance buffer
(B) 180 degrees out of phase with input
(C) all allowed I_C-V_{CE} pairs for the external circuit
(D) 0.707 of midband

Correct Answer: (B)
Higher collector current lowers collector voltage.

Q7. The emitter follower is primarily used as

(A) saturation
(B) its Q-point is less dependent on [β]
(C) an impedance buffer
(D) coupling and bypass capacitors

Correct Answer: (C)
It has high input and low output resistance.

Q8. A transistor used as a closed switch operates in

(A) all allowed I_C-V_{CE} pairs for the external circuit
(B) negative feedback
(C) reverse biased
(D) saturation

Correct Answer: (D)
Both junctions are forward biased and V_{CE} is small.

Q9. The DC load line represents

(A) all allowed I_C-V_{CE} pairs for the external circuit
(B) its Q-point is less dependent on [β]
(C) increases AC gain while retaining DC stabilization
(D) majority-carrier device

Correct Answer: (A)
It follows from the collector-loop voltage equation.

Q10. Voltage-divider bias is preferred because

(A) negative feedback
(B) its Q-point is less dependent on [β]
(C) 0.707 of midband
(D) drain current becomes nearly constant

Correct Answer: (B)
The divider approximately fixes base voltage.

Q11. An emitter resistor improves stability through

(A) increases AC gain while retaining DC stabilization
(B) coupling and bypass capacitors
(C) negative feedback
(D) V_{GS} reaches V_{GS}(off)

Correct Answer: (C)
Rising current reduces effective V_{BE}.

Q12. A bypass capacitor across R_E mainly

(A) 0.707 of midband
(B) reverse biased
(C) $I_D=I_{DSS}(1-V_{GS}/V_P)^2$
(D) increases AC gain while retaining DC stabilization

Correct Answer: (D)
It reduces AC emitter degeneration.

Q13. At a -3 dB cutoff, voltage gain magnitude is

(A) 0.707 of midband
(B) coupling and bypass capacitors
(C) majority-carrier device
(D) V_{GS}=-I_{DRS}

Correct Answer: (A)

Power falls to one-half at this amplitude ratio.

Q14. Low-frequency amplifier response is limited mainly by

(A) reverse biased
(B) coupling and bypass capacitors
(C) drain current becomes nearly constant
(D) $I_E=I_C+I_B$

Correct Answer: (B)

Their reactances increase as frequency falls.

Q15. A JFET gate-channel junction is normally

(A) majority-carrier device
(B) V_{GS} reaches V_{GS}(off)
(C) reverse biased
(D) BE is forward biased and BC is reverse biased

Correct Answer: (C)

This gives negligible gate current and controls depletion width.

Q16. An N-channel JFET is primarily a

(A) drain current becomes nearly constant
(B) $I_D=I_{DSS}(1-V_{GS}/V_P)^2$
(C) emitter
(D) majority-carrier device

Correct Answer: (D)

Channel conduction is dominated by electrons.

Q17. JFET pinch-off in the output characteristic means

(A) drain current becomes nearly constant
(B) V_{GS} reaches V_{GS}(off)
(C) V_{GS}=-I_{DRS}
(D) thin and lightly doped

Correct Answer: (A)

Pinch-off begins the saturation region, not cutoff.

Q18. JFET cutoff occurs when

(A) $I_D=I_{DSS}(1-V_{GS}/V_P)^2$
(B) V_{GS} reaches V_{GS}(off)
(C) $I_E=I_C+I_B$
(D) $[\beta]=[\alpha]/(1-[\alpha])$

Correct Answer: (B)

The channel is fully depleted.

Q19. The JFET transfer equation is

(A) V_{GS}=-I_{DRS}
(B) BE is forward biased and BC is reverse biased
(C) I_D=I_{DSS}(1-V_{GS}/V_P)^2
(D) 180 degrees out of phase with input

Correct Answer: (C)

Shockley's square-law describes the normal transfer curve.

Q20. For N-channel JFET self-bias

(A) I_E=I_C+I_B
(B) emitter
(C) an impedance buffer
(D) V_{GS}=-I_{DRS}

Correct Answer: (D)

The source rises above a gate held near ground.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 3 — OPERATIONAL AMPLIFIERS AND THEIR APPLICATIONS

1. Introduction

An operational amplifier is a very-high-gain differential amplifier designed to perform predictable closed-loop operations when external feedback is applied. Ideal rules are powerful only when negative feedback is present and the required output remains within supply and slew-rate limits. This chapter combines ideal analysis with practical parameters and common linear and nonlinear applications.

2. Complete Theory

Differential input and ideal op-amp model

The op-amp produces $V_o=A_{OL}$(V_+-V_-), but open-loop gain is so large that tiny differential voltage can saturate the output. An ideal op-amp has infinite open-loop gain, infinite input resistance, zero output resistance, infinite bandwidth, infinite CMRR and zero offset.

With stable negative feedback and nonsaturated output, input currents are zero and V_+ approximately equals V_-; this is a virtual short, not a physical connection. A virtual ground is a node held near ground potential by feedback but incapable of accepting arbitrary current.

Hinglish Explanation

Ideal rules tabhi lagao jab negative feedback active ho aur output rails par stuck na ho. V_+=V_- approximate hai, terminals short nahi hain.

Input current zero hone ke bawajood feedback resistors mein current flow karta hai.

Inverting, non-inverting and voltage-follower circuits

In an inverting amplifier, the non-inverting input is grounded and the summing node is virtually at zero. KCL gives $V_o/V_i=-R_f/R_{in}$.

The minus sign indicates phase inversion. Its closed-loop input resistance is approximately R_{in}.

In a non-inverting amplifier, feedback divides the output and $V_o/V_i=1+R_f/R_1$, so gain cannot be below unity with this topology. A voltage follower uses full negative feedback and has unity gain, very high input resistance and low output resistance.

It isolates a high-resistance sensor from a heavier load.

Hinglish Explanation

Inverting circuit mein summing node virtual ground hai aur current R_{in} se R_f mein jaata hai. Non-inverting gain 1 plus ratio hota hai; plus 1 bhoolna common trap hai.

Follower signal ko amplify nahi, drive capability ko improve karta hai.

Summing, difference and instrumentation amplifiers

An inverting summer adds weighted input voltages: $V_o=-R_f\ \mathrm{sum}(V_k/R_k)$. An averaging amplifier chooses ratios so the output equals a scaled average.

A difference amplifier rejects common voltage and amplifies the difference when resistor ratios are accurately matched. Its common-mode rejection is very sensitive to mismatch.

An instrumentation amplifier combines buffer inputs with a precision difference stage, providing high input resistance, adjustable differential gain and high CMRR. It is widely used for bridge sensors, strain gauges and low-level biomedical or industrial signals.

Hinglish Explanation

Multiple sensors ko weighted sum dena ho to summing amplifier. Do points ka small difference large common voltage ke saath measure karna ho to instrumentation amplifier.

High CMRR tabhi milega jab resistor matching accurate ho.

Integrator, differentiator and active filters

An ideal integrator uses an input resistor and feedback capacitor, giving V_o=-(1/RC) integral V_i dt. A DC input would drive it to saturation, so a practical integrator places a resistor parallel to the capacitor to limit low-frequency gain.

A differentiator gives V_o=-RC dV_i/dt but amplifies high-frequency noise; practical versions add components to limit bandwidth. Active filters combine op-amps with resistors and capacitors to provide gain and frequency selection without inductors.

First-order cut-off magnitude is -3 dB and roll-off is 20 dB per decade.

Hinglish Explanation

Integrator input area accumulate karta hai; square input se triangular output mil sakta hai. Differentiator slope respond karta hai, isliye noise bhi strongly amplify hota hai.

Practical circuits gain ko extreme frequencies par limit karte hain.

Comparator, Schmitt trigger and waveform generation

A comparator is normally used open-loop: output saturates positive when V_+>V_- and negative for the opposite condition. A zero-crossing detector compares with zero.

Noise near threshold can cause multiple transitions, so a Schmitt trigger applies positive feedback to create two switching thresholds and hysteresis. An op-amp relaxation oscillator combines a Schmitt trigger with an RC charging network; the capacitor voltage moves between thresholds while output alternates between saturation levels.

Comparator analysis must not use the virtual-short rule because negative feedback is absent.

Hinglish Explanation

Comparator mein V_+=V_- rule mat lagao. Schmitt trigger ke do thresholds noise immunity dete hain—input ko upper threshold cross karke HIGH/LOW change karna aur lower threshold cross karke wapas aana hota hai.

Practical limitations and data-sheet parameters

Input offset voltage is the differential DC voltage needed to make output zero; input bias currents are the average input currents, and offset current is their difference. CMRR=A_d/A_{cm} measures rejection of common-mode signals, commonly expressed in dB.

Slew rate limits maximum output slope, causing large-signal distortion when 2[π]fV_p exceeds SR. Gain-bandwidth product is approximately constant for a dominant-pole compensated op-amp, so higher closed-loop gain reduces bandwidth.

Output saturation, input common-mode range, output-current limit, noise and supply rejection must also be respected.

Hinglish Explanation

Real op-amp instant aur infinite output nahi de sakta. Large high-frequency sine ke liye required slope 2[π]fV_p hoti hai; ye slew rate se zyada hui to waveform triangular distort ho jayegi.

Gain badhao to available bandwidth usually ghat ta hai.

4. Engineering Formula Section

Formula Sheet
1. $V_o = A_{OL}(V\_+ - V\_-)$
2. ideal negative-feedback rules I_+=I_-=0,V_+ approximately V_-
3. A_v,inverting=$-R_f/R_{in}$
4. A_v,non-inverting=$1+R_f/R_1$
5. V_o,summing=$-R_f$ sum(V_k/R_k)
6. V_o,difference=$(R_2/R_1)(V_2-V_1)$ for matched ratios
7. V_o,integrator=-(1/RC)integral V_i dt
8. V_o,differentiator=$-RC(dV_i/dt)$
9. $f_c = 1/(2[\pi]RC)$
10. CMRR=A_d/A_{cm}
11. $CMRR_{dB}$=20log10(CMRR)
12. required sine slope=$2[\pi]fV_p$
13. closed-loop bandwidth approximately GBW/noise gain

5. Formula Derivations and Solved Examples

For the inverting amplifier, V_-=0 by virtual ground and no input current enters the op-amp. KCL gives $V_i/R_{in}=(0-V_o)/R_f$, hence $V_o/V_i=-R_f/R_{in}$. For a non-inverting circuit, $V\_-=V_{oR1}/(R_1+R_f)=V_i$, giving $V_o/V_i=1+R_f/R_1$. Example: R_{in}=10 k[ohm] and R_f=100 k[ohm] produce gain -10. A 5 V peak, 100 kHz sine needs SR=$2[\pi](10^5)(5)$=3.14 V/[µ]s.

6. Practical Applications

- Sensor signal conditioning.
- Audio mixing and active filters.
- Precision measurement and bridge interfaces.
- Threshold detection and alarms.
- Waveform generation and control systems.

7. Short Tricks

- Negative feedback plus linear operation permits V_+ approximately V_-.

- Input currents are ideally zero.
- Comparator output chooses a rail.
- GBW trades gain against bandwidth.

8. Concept Diagram

```
INVERTING AMPLIFIER
Vin--R_in--o V-      Vo
           |\      o
  0 V ------|+\______|
           |-/      |
           o---R_f--o
Virtual ground occurs at V- under linear negative feedback.
```

9. Comparison Table

Circuit	Feedback/use	Key result
Inverting	negative	$-R_f/R_{in}$
Non-inverting	negative	$1+R_f/R_1$
Follower	100% negative	gain 1
Comparator	open-loop	two saturated levels
Schmitt trigger	positive	hysteresis

10. Common Mistakes

- Using virtual short in a comparator.
- Forgetting the minus sign of an inverting stage.
- Omitting +1 in non-inverting gain.
- Ignoring output saturation and common-mode range.
- Confusing slew rate with small-signal bandwidth.

11. Important DSSSB Exam Points

- Ideal-rule conditions, standard gains, integrator/differentiator waveforms, comparator polarity, CMRR and slew-rate numericals are high-yield.

12. Chapter Revision Sheet

First decide whether the circuit uses negative feedback, positive feedback or no feedback. Then apply KCL and verify output range, bandwidth and slew-rate feasibility.

13. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. An ideal op-amp has input resistance

(A) infinite
(B) zero
(C) $-R_f/R_{in}$
(D) strong rejection of common-mode signals

Correct Answer: (A)
Ideal input currents are zero.

Q2. An ideal op-amp has output resistance

(A) stable negative feedback and unsaturated operation
(B) zero
(C) $1+R_f/R_1$
(D) the time integral of input

Correct Answer: (B)

It acts as an ideal voltage source at the output.

Q3. The virtual-short rule requires

(A) $-R_f/R_{in}$
(B) unity
(C) stable negative feedback and unsaturated operation
(D) the rate of change of input

Correct Answer: (C)

Only then does high loop gain force a tiny differential voltage.

Q4. Gain of an inverting amplifier is

(A) $1+R_f/R_1$
(B) form a weighted sum of inputs
(C) 20 dB per decade
(D) $-R_f/R_{in}$

Correct Answer: (D)

KCL at the virtual-ground node gives the ratio.

Q5. Gain of a non-inverting amplifier is

(A) $1+R_f/R_1$
(B) unity
(C) strong rejection of common-mode signals
(D) open-loop

Correct Answer: (A)

The feedback divider forces this closed-loop gain.

Q6. A voltage follower has closed-loop gain

(A) form a weighted sum of inputs
(B) unity
(C) the time integral of input
(D) 0 V

Correct Answer: (B)

Its output is directly fed to the inverting input.

Q7. A summing amplifier is used to

(A) strong rejection of common-mode signals
(B) the rate of change of input
(C) form a weighted sum of inputs
(D) positive feedback

Correct Answer: (C)

Each input contributes through its resistor.

Q8. High CMRR means

(A) the time integral of input
(B) 20 dB per decade
(C) noise immunity near the threshold
(D) strong rejection of common-mode signals

Correct Answer: (D)
Differential signals are amplified relative to common signals.

Q9. An ideal integrator produces output proportional to

(A) the time integral of input
(B) the rate of change of input
(C) open-loop
(D) a DC output error

Correct Answer: (A)
The feedback capacitor accumulates charge.

Q10. A differentiator responds to

(A) 20 dB per decade
(B) the rate of change of input
(C) 0 V
(D) $20\log10(A_d/A_{cm})$

Correct Answer: (B)
Its output is proportional to dV_i/dt.

Q11. A first-order active filter rolls off at

(A) open-loop
(B) positive feedback
(C) 20 dB per decade
(D) maximum output voltage slope

Correct Answer: (C)
One pole changes asymptotic slope by 20 dB/decade.

Q12. A comparator is usually operated

(A) 0 V
(B) noise immunity near the threshold
(C) $2[\pi]fV_p$
(D) open-loop

Correct Answer: (D)
High gain drives output to one of the saturation levels.

Q13. A zero-crossing detector compares the input with

(A) 0 V
(B) positive feedback
(C) a DC output error
(D) reduces bandwidth

Correct Answer: (A)
Its reference threshold is ground.

Q14. A Schmitt trigger uses

(A) noise immunity near the threshold
(B) positive feedback
(C) $20\log10(A_d/A_{cm})$
(D) infinite

Correct Answer: (B)

Positive feedback creates separated switching thresholds.

Q15. Hysteresis improves

(A) a DC output error
(B) maximum output voltage slope
(C) noise immunity near the threshold
(D) zero

Correct Answer: (C)

Small threshold-region noise cannot repeatedly switch the output.

Q16. Input offset voltage causes

(A) $20\log10(A_d/A_{cm})$
(B) $2[\pi]fV_p$
(C) stable negative feedback and unsaturated operation
(D) a DC output error

Correct Answer: (D)

Closed-loop gain amplifies the equivalent differential offset.

Q17. CMRR in decibels is

(A) $20\log10(A_d/A_{cm})$
(B) maximum output voltage slope
(C) reduces bandwidth
(D) $-R_f/R_{in}$

Correct Answer: (A)

CMRR is an amplitude-gain ratio.

Q18. Slew rate limits

(A) $2[\pi]fV_p$
(B) maximum output voltage slope
(C) infinite
(D) $1+R_f/R_1$

Correct Answer: (B)

The output cannot change faster than SR.

Q19. A sine wave requires maximum slope

(A) reduces bandwidth
(B) zero
(C) $2[\pi]fV_p$
(D) unity

Correct Answer: (C)

Differentiating V_p sin(2[π]ft) gives this peak slope.

Q20. For a compensated op-amp, increasing closed-loop gain generally

(A) infinite
(B) stable negative feedback and unsaturated operation
(C) form a weighted sum of inputs
(D) reduces bandwidth

Correct Answer: (D)

Gain-bandwidth product is approximately constant.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 4 — FEEDBACK, OSCILLATORS AND ELECTRONIC MEASURING INSTRUMENTS

1. Introduction

Feedback returns a fraction of output to the input and deliberately reshapes gain, stability, distortion, impedance and bandwidth. Positive feedback can sustain oscillations when amplitude and phase conditions are met. Electronic instruments convert signals into calibrated voltage-time displays or digital values, but they can disturb the circuit unless loading and bandwidth are considered.

2. Complete Theory

Negative and positive feedback

For a forward gain A and feedback factor [β], negative feedback gives A_f=A/(1+A[β]); positive feedback gives A_f=A/(1-A[β]) under consistent sign conventions. Negative feedback reduces gain but makes it less sensitive to device variation, reduces nonlinear distortion and noise generated inside the loop, and usually increases bandwidth.

The input and output impedances depend on whether feedback mixes voltage or current in series or shunt. Positive feedback reinforces a signal and is used for hysteresis and oscillation, but uncontrolled positive loop gain causes instability.

Hinglish Explanation

Feedback ka sign result decide karta hai. Negative feedback output error ko oppose karke gain stable banata hai; positive feedback same change ko reinforce karta hai.

Sirf gain formula yaad nahi, sampling aur mixing type se impedance effect bhi samjho.

Feedback topologies and gain sensitivity

Voltage-series feedback samples output voltage and mixes in series, increasing input resistance and decreasing output resistance; it is common in voltage amplifiers. Voltage-shunt lowers both.

Current-series raises both, and current-shunt lowers input while raising output. For large negative loop gain T=A[β], closed-loop gain approaches 1/[β].

Sensitivity of closed-loop gain to A becomes 1/(1+A[β]), so component drift has much less effect. Desensitivity and bandwidth improvement approximately follow 1+A[β], provided the loop remains stable over frequency.

Hinglish Explanation

Voltage amplifier ko source load nahi karna aur load ko stiff voltage dena ho to series-shunt feedback useful hai. Loop gain bada ho to final gain transistor ke uncertain A se kam aur feedback network ke accurate [β] se zyada decide hota hai.

Oscillation criterion and start-up

An oscillator converts DC supply energy into a periodic AC signal without an external periodic input. The Barkhausen condition at oscillation frequency is loop phase 0 degrees or an integer multiple of 360 degrees and loop-gain magnitude unity.

At start-up, noise provides a small signal and loop gain must be slightly greater than one so amplitude grows. Nonlinearity or automatic gain control then reduces effective gain to unity for a stable amplitude.

Barkhausen is a useful steady-state condition, not by itself a complete guarantee of start-up and stability.

Hinglish Explanation

Oscillator energy khud create nahi karta; DC supply ko AC waveform mein convert karta hai. Noise seed signal deta hai.

Start par A[β] thoda 1 se zyada, steady state par amplitude limiting se effective value 1 ho jati hai.

RC, LC and crystal oscillators

A Wien-bridge oscillator uses a lead-lag RC network with zero phase shift at f_0=1/(2[π]RC) for equal components and requires amplifier gain three. RC phase-shift oscillators use three sections providing about 180 degrees plus amplifier inversion; for equal sections f_0 approximately 1/(2[π]RC[√]6).

Hartley and Colpitts oscillators use LC tanks, with feedback division by inductors and capacitors respectively. A quartz crystal behaves as a very high-Q resonator, producing exceptional frequency stability.

RC types suit audio frequencies; LC suits radio frequencies; crystal is selected when accuracy dominates.

Hinglish Explanation

Wien bridge clean audio sine ke liye, LC radio-frequency ke liye, crystal highly stable clock ke liye. Hartley ko split inductance aur Colpitts ko split capacitance se pehchano.

CRO construction and measurement

A cathode-ray oscilloscope has an electron gun, focusing and accelerating system, vertical deflection plates, horizontal deflection plates and phosphor screen. The vertical amplifier scales the input; a time-base sawtooth moves the spot uniformly from left to right and rapidly returns it.

Triggering synchronizes the sweep to produce a stationary trace. Voltage equals vertical divisions times volts/division, and period equals horizontal divisions times time/division.

Frequency is reciprocal of period. Probe attenuation and bandwidth must be included in measurements.

Hinglish Explanation

CRO graph paper jaisa hai: vertical axis voltage, horizontal axis time. Stable waveform ke liye trigger correct set karo.

Probe x10 laga ho to screen reading ko factor ten se correct karna hoga.

Lissajous figures, DSO and digital instruments

In XY mode, two sinusoidal inputs drive horizontal and vertical axes. Equal-frequency signals produce a stationary ellipse, circle or line depending on phase; a straight positive-slope line indicates zero phase and a circle ideally indicates 90 degrees for equal amplitudes.

Frequency ratios can be inferred by counting tangencies or lobes using a stated convention. A DSO samples, quantizes, stores and processes waveforms, enabling single-shot capture, automatic measurements and pre-trigger viewing.

Sampling rate and analog bandwidth are distinct; inadequate sampling causes aliasing. Digital multimeters use input conditioning, analog-to-digital conversion and a numeric display, usually with high input resistance.

Hinglish Explanation

CRO continuous analog beam dikhata hai; DSO waveform samples store karta hai, isliye transient ko freeze kar sakta hai. Sampling rate enough na ho to aliasing se fake low frequency dikhegi.

Analog bandwidth high hona bhi separate requirement hai.

4. Engineering Formula Section

Formula Sheet
1. A_f,negative=A/(1+A[β])
2. A_f,positive=A/(1-A[β])
3. sensitivity=(dA_f/A_f)/(dA/A)=1/(1+A[β])
4. bandwidth with feedback approximately bandwidth without feedback x(1+A[β])
5. Barkhausen |A[β]|=1 and angle A[β]=0 degrees mod 360 degrees
6. f_{Wien}=1/(2[π]RC)
7. f_{RC}-phase approximately 1/(2[π]RC[√]6)
8. f_{LC}=1/(2[π][√](LC))
9. V_{pp}=vertical divisions x volts/div x probe factor
10. T=horizontal divisions x time/div
11. f=1/T
12. phase from equal-frequency ellipse sin[phi]=y_1/y_2 under the stated intercept convention

5. Formula Derivations and Solved Examples

Starting from V_o=A(V_s-[β]V_o), rearrange V_o(1+A[β])=AV_s, so A_f=A/(1+A[β]). The fractional sensitivity to A is 1/(1+A[β]). For the Wien network with equal R and C, phase is zero at [omega]$_0$=1/RC and feedback magnitude is 1/3, so the amplifier must provide gain three. Example: R=10 k[ohm], C=10 nF gives f_0 approximately 1.59 kHz.

6. Practical Applications

- Stable amplifiers and control loops.
- Audio and RF signal generators.
- Clock references.
- Waveform and phase measurement.
- Fault diagnosis, sensors and industrial testing.

7. Short Tricks

- Negative feedback denominator has $1+A[\beta]$.
- Start-up loop gain is slightly above unity.
- CRO time base is a sawtooth.
- DSO can capture a single-shot transient.

8. Concept Diagram

```
FEEDBACK SYSTEM
Vs -> (+) summer -> [ A ] -> Vo
       (-) ^              |
           |----[ beta ]---|
Negative sign gives denominator 1+A beta.
```

9. Comparison Table

Type	Frequency range/use	Recognizing network
Wien bridge	audio sine	lead-lag RC
RC phase shift	audio	three RC sections
Hartley	RF	split inductance
Colpitts	RF	split capacitance
Crystal	precision clock	very high Q

10. Common Mistakes

- Assuming negative feedback always improves stability at every frequency.
- Using Barkhausen unity gain as a start-up condition.
- Swapping Hartley and Colpitts.
- Ignoring probe factor in CRO readings.
- Confusing analog bandwidth with sampling rate.

11. Important DSSSB Exam Points

- Feedback gain/sensitivity, topology effects, oscillator identification, Barkhausen conditions and CRO scale numericals are frequent.

12. Chapter Revision Sheet

Feedback must be classified by sign, sampling and mixing. Oscillators require the correct loop phase and amplitude. Instruments must be read using scale factors without forgetting loading, probe attenuation and sampling limits.

13. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. Negative-feedback closed-loop gain is

(A) $A/(1+A[\beta])$
(B) $A/(1-A[\beta])$
(C) increase
(D) slightly greater than one

Correct Answer: (A)
The returned signal subtracts from the source.

Q2. Positive-feedback closed-loop gain is

(A) less sensitive to device variation
(B) A/(1-A[β])
(C) decrease
(D) 3

Correct Answer: (B)
The returned signal reinforces the source.

Q3. Large negative feedback generally makes gain

(A) increase
(B) 0 degrees modulo 360 degrees
(C) less sensitive to device variation
(D) 1/(2[π]RC)

Correct Answer: (C)
Sensitivity is divided by 1+A[β].

Q4. Voltage-series feedback makes input resistance

(A) decrease
(B) unity
(C) split inductance
(D) increase

Correct Answer: (D)
Series mixing opposes input current and raises input resistance.

Q5. Voltage-series feedback makes output resistance

(A) decrease
(B) 0 degrees modulo 360 degrees
(C) slightly greater than one
(D) split capacitance

Correct Answer: (A)
Output-voltage sampling stiffens the voltage source.

Q6. The Barkhausen phase condition is

(A) unity
(B) 0 degrees modulo 360 degrees
(C) 3
(D) a crystal oscillator

Correct Answer: (B)
Returned signal must reinforce the original oscillation.

Q7. For steady sinusoidal oscillation, loop-gain magnitude is

(A) slightly greater than one
(B) 1/(2[π]RC)
(C) unity
(D) voltage

Correct Answer: (C)
Constant amplitude requires neither growth nor decay.

Q8. At oscillator start-up, loop gain should be

(A) 3
(B) split inductance
(C) a sawtooth
(D) slightly greater than one

Correct Answer: (D)
Noise must grow into a usable waveform.

Q9. A Wien-bridge oscillator commonly requires amplifier gain

(A) 3
(B) 1/(2[π]RC)
(C) split capacitance
(D) the reciprocal of measured period

Correct Answer: (A)
The equal-component bridge attenuation is one-third.

Q10. Equal-component Wien frequency is

(A) split inductance
(B) 1/(2[π]RC)
(C) a crystal oscillator
(D) 90-degree phase difference

Correct Answer: (B)
The lead-lag network has zero phase at this frequency.

Q11. A Hartley oscillator uses

(A) split capacitance
(B) voltage
(C) split inductance
(D) stores sampled waveform records

Correct Answer: (C)
Its feedback divider is inductive.

Q12. A Colpitts oscillator uses

(A) a crystal oscillator
(B) a sawtooth
(C) sampling rate is insufficient
(D) split capacitance

Correct Answer: (D)
Its feedback divider is capacitive.

Q13. The highest frequency stability is normally obtained with

(A) a crystal oscillator
(B) voltage
(C) the reciprocal of measured period
(D) high input resistance

Correct Answer: (A)
Quartz provides very high Q.

Q14. A CRO vertical axis represents

(A) a sawtooth
(B) voltage
(C) 90-degree phase difference
(D) A/(1+A[β])

Correct Answer: (B)

The vertical amplifier drives Y deflection.

Q15. A CRO horizontal time sweep is normally

(A) the reciprocal of measured period
(B) stores sampled waveform records
(C) a sawtooth
(D) A/(1-A[β])

Correct Answer: (C)

It provides uniform forward sweep and rapid retrace.

Q16. CRO frequency is found from

(A) 90-degree phase difference
(B) sampling rate is insufficient
(C) less sensitive to device variation
(D) the reciprocal of measured period

Correct Answer: (D)

f=1/T.

Q17. A stationary equal-frequency Lissajous circle indicates approximately

(A) 90-degree phase difference
(B) stores sampled waveform records
(C) high input resistance
(D) increase

Correct Answer: (A)

Equal amplitudes in quadrature trace a circle.

Q18. A DSO can display pre-trigger data because it

(A) sampling rate is insufficient
(B) stores sampled waveform records
(C) A/(1+A[β])
(D) decrease

Correct Answer: (B)

Memory retains samples acquired before the trigger event.

Q19. Aliasing occurs when

(A) high input resistance
(B) A/(1-A[β])
(C) sampling rate is insufficient
(D) 0 degrees modulo 360 degrees

Correct Answer: (C)

Different input frequencies can produce indistinguishable samples.

Q20. A digital multimeter generally has

(A) A/(1+A[β])
(B) less sensitive to device variation
(C) unity
(D) high input resistance

Correct Answer: (D)

This minimizes voltage-measurement loading.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.

CHAPTER 5 — FUNDAMENTALS OF COMMUNICATION SYSTEMS

1. Introduction

Communication systems transfer information from a source to a destination through a channel while managing bandwidth, propagation loss, interference and noise. Modulation moves baseband information to a carrier suitable for radiation and channel sharing. The chapter develops analog modulation, transmitters and receivers, noise, antennas, propagation, multiplexing, pulse and digital communication, optical fiber, satellite and cellular basics.

2. Complete Theory

Communication model, signals and need for modulation

A basic system contains information source, input transducer, transmitter, channel, receiver, output transducer and destination. A signal is characterized in time and frequency by amplitude, frequency, phase, spectrum and bandwidth.

Baseband occupies frequencies near zero; passband is shifted around a carrier. Modulation is needed because direct radiation of low audio frequencies would require impractically large antennas, different messages would mix, and frequency allocation, multiplexing, directional antennas and efficient propagation would be difficult.

Noise and distortion introduced by the channel limit fidelity.

Hinglish Explanation

Voice ko directly antenna se radiate karna practical nahi: wavelength huge hogi aur antenna bahut bada. High-frequency carrier par information ride karwa kar antenna size, channel allocation aur long-distance transmission manageable hote hain.

Amplitude modulation, spectrum and power

For single-tone AM, $s(t)=A_c[1+m\cos(\omega_m t)]\cos(\omega_c t)$, where $m=A_m/A_c$ for a compatible amplitude definition. The envelope reproduces the message when $0 \le m \le 1$.

Over-modulation makes the envelope cross zero and an ordinary envelope detector produces distortion. Multiplication produces upper and lower sidebands at f_c+f_m and f_c-f_m.

Therefore bandwidth is $2f_m$(max). The carrier carries no information but consumes most power.

For a sinusoidal message, total power is $P_c(1+m^2/2)$, and each sideband carries $P_c m^2/4$.

Hinglish Explanation

AM spectrum mein carrier centre par aur two sidebands symmetric hote hain. Information sidebands mein hai.

m=1 par 100% modulation; m>1 over-modulation aur envelope detector distortion. Bandwidth carrier frequency nahi, highest message frequency ka twice hai.

AM generation, envelope detection and distortion

Nonlinear or switching circuits generate the required product terms for AM. An envelope detector uses a diode followed by an RC network.

The capacitor charges rapidly near carrier peaks and discharges through the load to follow the slowly changing envelope. The time constant must be much larger than the carrier period yet small enough to follow the fastest message variation.

Too large an RC causes diagonal clipping; too small gives excessive carrier ripple. Negative-peak clipping occurs when device or supply limits prevent faithful tracking of deep negative envelope excursions.

Hinglish Explanation
Detector capacitor ko carrier peaks smooth karne hain but message shape follow bhi karni hai. RC bahut chhota hua to RF ripple; bahut bada hua to fast falling envelope follow nahi karega aur diagonal clipping hogi.

FM, PM and analog-modulation comparison

In FM, carrier amplitude stays constant while instantaneous frequency varies with message amplitude. Frequency deviation is Δf and modulation index $\beta = \Delta f / f_m$ for a tone.

Carson's rule estimates transmission bandwidth as $2(\Delta f + f_m)$. FM provides better noise immunity and permits efficient nonlinear power amplification, but uses more bandwidth.

In PM, instantaneous phase varies with message amplitude; frequency deviation depends on the rate of message change. AM varies amplitude, FM varies frequency and PM varies phase.

Limiting can remove much amplitude noise before FM detection.

Hinglish Explanation
FM waveform ki spacing compress-expand hoti hai, amplitude constant rehta hai. AM narrow aur simple hai but noise amplitude ko directly corrupt karta hai.

FM zyada bandwidth leta hai par noise immunity better hoti hai.

Transmitters, superheterodyne receiver and noise

An AM transmitter processes microphone output through audio amplification, combines it with an RF oscillator in a modulator, raises RF power and feeds the antenna. An FM transmitter uses a frequency modulator or controlled oscillator, often with frequency multiplication.

A superheterodyne receiver selects the station, mixes it with a local oscillator and converts it to a fixed intermediate frequency $f_{IF} = |f_{LO} - f_s|$. Fixed IF enables stable high gain and selectivity.

The detector recovers information, the audio stage drives the loudspeaker, and AGC adjusts gain. Thermal-noise power is kTB; SNR and noise figure quantify degradation.

Hinglish Explanation
Receiver har station ko direct same high-selectivity amplifier se handle nahi karta. Mixer sab selected stations ko fixed IF par translate karta hai, jahan stable gain/filtering easy hai.

AGC strong station par gain reduce karke output level control karta hai.

Antennas, propagation and multiplexing

An antenna converts guided electrical energy to electromagnetic radiation and back. A half-wave dipole is approximately $\lambda/2$ long and each monopole over a ground plane approximately $\lambda/4$.

Gain combines directivity and efficiency; polarization describes electric-field orientation. Ground waves follow the earth at low frequencies, sky waves return through ionospheric refraction at HF, and space waves support line-of-sight VHF, UHF, microwave and satellite links.

FDM assigns simultaneous frequency bands; TDM assigns recurring time slots. Guard bands or synchronization prevent overlap.

Hinglish Explanation

Antenna length wavelength se linked hai. Ground wave surface follow karti, sky wave ionosphere use karti, space wave line-of-sight hoti hai.

FDM mein users alag frequency lanes, TDM mein same lane par alag time slots lete hain.

Sampling, PCM and digital modulation

The sampling theorem requires $f_s>=2f_m$(max) for a band-limited signal, with an anti-alias filter before sampling. PAM varies pulse amplitude, PWM pulse width and PPM pulse position.

PCM samples, quantizes and encodes each value into bits; quantization introduces finite error. With L levels, bits per sample $n=\log_{2L}$ and PCM bit rate is nf_s per channel.

ASK, FSK and PSK represent bits by changing carrier amplitude, frequency or phase. PSK usually offers better noise performance than simple ASK for coherent detection.

Hinglish Explanation

Sampling rate highest message frequency se at least twice honi chahiye; practical margin aur anti-alias filter bhi chahiye. PCM chain: sample, quantize, encode.

Levels double karne ke liye one extra bit per sample chahiye.

Optical fiber, satellite and mobile systems

Optical fiber guides light by total internal reflection when the core index exceeds cladding index. Numerical aperture $NA=[\sqrt{}](n_1^{2}-n_2^{2})$ in air and relates to acceptance angle.

Single-mode fiber minimizes modal dispersion; multimode is easier to couple but has lower long-distance bandwidth. Loss arises from absorption, scattering and bending, while dispersion broadens pulses.

A satellite transponder receives an uplink, shifts/amplifies it and retransmits a downlink; a geostationary satellite appears fixed over the equator. Cellular systems divide coverage into cells, reuse frequencies at sufficient separation and perform handover between base stations.

Hinglish Explanation

Fiber mein core ka refractive index cladding se slightly high hota hai, so proper angle par light trapped rehti hai. Satellite uplink receive karke different downlink frequency par retransmit karta hai.

Mobile network cells aur frequency reuse se limited spectrum ko many users ke liye reuse karta hai.

4. Engineering Formula Section

Formula Sheet
1. $c=f[\lambda]$
2. quarter-wave monopole l approximately $[\lambda]/4$
3. AM $s(t)=A_c[1+m\cos([omega]_{mt})]\cos([omega]_{ct})$
4. $m=A_m/A_c$
5. $BW_{AM}=2f_m(max)$
6. $P_{AM}=P_c(1+m^2/2)$
7. P_{each}-sideband$=P_{cm}{}^2/4$
8. $[\beta]_{FM}=[\Delta]f/f_m$
9. $BW_{Carson}=2([\Delta]f+f_m)$
10. $f_{IF}=\|f_{LO}-f_s\|$
11. noise power=kTB
12. $SNR=P_{signal}/P_{noise}$
13. $f_s>=2f_m(max)$
14. $n=\log_{2L}$
15. $R_b=nf_s$
16. $NA=[\sqrt{}](n_1{}^{2-n}{}_2{}^2)$
17. $\sin[\theta]_a=NA/n_0$

5. Formula Derivations and Solved Examples

Expanding AM with cos A cos B=(1/2)[cos(A+B)+cos(A-B)] produces a carrier at f_c and sidebands at f_c+f_m and f_c-f_m. Thus the occupied range is from $f_c-f_m(max)$ to $f_c+f_m(max)$, giving bandwidth $2f_m(max)$. Example: a 5 kHz message requires 10 kHz conventional AM bandwidth. For PCM with f_s=8 kHz and 256 levels, n=8 bits and bit rate is 64 kb/s.

6. Practical Applications

• Broadcast radio and television.

• Mobile and satellite links.

- Industrial telemetry and remote monitoring.
- Optical backbone networks.
- Navigation, emergency and civil-infrastructure communication.

7. Short Tricks

- AM bandwidth is twice highest message frequency.
- FM amplitude is ideally constant.
- Superheterodyne uses fixed IF.
- Anti-alias filtering occurs before sampling.

8. Concept Diagram

```
SUPERHETERODYNE RECEIVER
Antenna -> RF amp -> Mixer -> IF amp -> Detector -> Audio amp -> Speaker
                        ^
               Local oscillator
AGC feeds a control voltage back to RF/IF gain stages.
```

9. Comparison Table

Technique	Varied parameter	Typical feature
AM	amplitude	simple, narrow, poorer noise immunity
FM	frequency	constant envelope, wider bandwidth
PM	phase	related to rate for frequency deviation
ASK	amplitude states	simple digital keying
FSK	frequency states	robust noncoherent option
PSK	phase states	good power efficiency

10. Common Mistakes

- Using carrier frequency to calculate AM bandwidth.
- Calling m>1 valid undistorted envelope AM.
- Using Carson's rule for AM.
- Ignoring the absolute difference in IF.
- Sampling at less than twice the highest message frequency.

11. Important DSSSB Exam Points

- Modulation need, AM spectrum/power, FM index and Carson bandwidth, superheterodyne blocks, noise power, sampling and PCM bit rate are high-yield.

12. Chapter Revision Sheet

Trace information from source to destination. For modulation, identify which carrier parameter varies, then compute index, spectrum and bandwidth. For digital systems, separate sample rate, levels, bits per sample and bit rate.

13. Practice Questions with Solutions

Attempt each question first. The explanation discusses only the correct answer.

Q1. The primary purpose of modulation is to

(A) translate information to a suitable carrier band
(B) amplitude
(C) $2f_m$
(D) diagonal clipping

Correct Answer: (A)
This enables practical radiation, allocation and multiplexing.

Q2. A conventional AM wave varies carrier

(A) not greater than one
(B) amplitude
(C) the sidebands
(D) $[\Delta]f/f_m$

Correct Answer: (B)
Carrier frequency and phase remain nominally fixed.

Q3. For undistorted envelope detection, AM index should be

(A) $2f_m$
(B) $1.5P_c$
(C) not greater than one
(D) $2([\Delta]f+f_m)$

Correct Answer: (C)
Over-modulation makes the envelope cross zero.

Q4. Single-tone conventional AM bandwidth is

(A) the sidebands
(B) a diode and RC network
(C) better noise immunity and wider bandwidth
(D) $2f_m$

Correct Answer: (D)
The two sidebands extend f_m on each side of the carrier.

Q5. Information in conventional AM is carried by

(A) the sidebands
(B) $1.5P_c$
(C) diagonal clipping
(D) a fixed intermediate frequency

Correct Answer: (A)
The unmodulated carrier contains no message variation.

Q6. At m=1, total AM power is

(A) a diode and RC network
(B) $1.5P_c$
(C) $[\Delta]f/f_m$
(D) $|f_{LO}-f_s|$

Correct Answer: (B)
$P_t=P_c(1+m^2/2)$.

Q7. An envelope detector uses

(A) diagonal clipping
(B) $2([\Delta]f+f_m)$
(C) a diode and RC network
(D) kTB

Correct Answer: (C)
The diode rectifies and RC follows the envelope.

Q8. Too large a detector time constant causes

(A) $[\Delta]f/f_m$
(B) better noise immunity and wider bandwidth
(C) $[\lambda]/2$
(D) diagonal clipping

Correct Answer: (D)
The capacitor cannot discharge fast enough to follow the envelope.

Q9. FM modulation index is

(A) $[\Delta]f/f_m$
(B) $2([\Delta]f+f_m)$
(C) a fixed intermediate frequency
(D) the ionosphere

Correct Answer: (A)
It is peak frequency deviation divided by modulating frequency.

Q10. Carson's FM bandwidth is

(A) better noise immunity and wider bandwidth
(B) $2([\Delta]f+f_m)$
(C) $|f_{LO}-f_s|$
(D) frequency bands

Correct Answer: (B)
It includes the significant sideband region approximately.

Q11. Compared with AM, FM generally has

(A) a fixed intermediate frequency
(B) kTB
(C) better noise immunity and wider bandwidth
(D) twice the highest message frequency

Correct Answer: (C)
Constant-envelope FM permits limiting but creates more sidebands.

Q12. A superheterodyne receiver converts the selected station to

(A) $|f_{LO}-f_s|$
(B) $[\lambda]/2$
(C) 8
(D) a fixed intermediate frequency

Correct Answer: (D)
Fixed IF gives stable selectivity and gain.

Q13. Intermediate frequency is

(A) $|f_{LO}-f_s|$
(B) kTB
(C) the ionosphere
(D) core index greater than cladding index

Correct Answer: (A)

Mixing produces sum and difference frequencies.

Q14. Thermal noise power is

(A) [λ]/2
(B) kTB
(C) frequency bands
(D) translate information to a suitable carrier band

Correct Answer: (B)

It grows with temperature and bandwidth.

Q15. A half-wave dipole length is approximately

(A) the ionosphere
(B) twice the highest message frequency
(C) [λ]/2
(D) amplitude

Correct Answer: (C)

It is a resonant basic antenna.

Q16. Sky-wave propagation primarily uses

(A) frequency bands
(B) 8
(C) not greater than one
(D) the ionosphere

Correct Answer: (D)

HF waves are refracted back toward earth.

Q17. FDM separates users by

(A) frequency bands
(B) twice the highest message frequency
(C) core index greater than cladding index
(D) $2f_m$

Correct Answer: (A)

Channels operate simultaneously in distinct bands.

Q18. The minimum ideal sampling rate is

(A) 8
(B) twice the highest message frequency
(C) translate information to a suitable carrier band
(D) the sidebands

Correct Answer: (B)

This is the Nyquist sampling condition.

Q19. For 256 quantization levels, bits per sample are

(A) core index greater than cladding index
(B) amplitude
(C) 8
(D) $1.5P_c$

Correct Answer: (C)

2^8=256.

Q20. Optical-fiber guidance requires

(A) translate information to a suitable carrier band
(B) not greater than one
(C) a diode and RC network
(D) core index greater than cladding index

Correct Answer: (D)

This enables total internal reflection at the core-cladding interface.

Quick Revision: Re-read the formula box, cover the answers, and explain each exam point aloud. A formula is ready for the exam only when its symbols, SI units, assumptions and sign convention are clear.