Rajeev Gandhi Memorial College of Engineering and Technology, Nandyal
Autonomous
Department of Electronics and Communication Engineering

COURSE FILE

ACADEMIC YEAR : 2022-23

SUBJECT : Electronic Circuits- Analysis & Design

YEAR/SEM : II B. Tech II-Sem

DEPARTMENT : Electronics & Communication Engineering

FACULTY NAME : Dr. Y. Madhu Sudhana Reddy

Dr. Kethepalli Mallikarjuna
HOD of ECE

Dr. KETHEPALLI MALLIKARJUNA
B.E, M.Tech, Ph.D, FIETE, MIE
Professor & HOD
Department of ECE
RGM College of Engg. & Tech. (Autonomous)
NANDYAL - 518 501, Kurnool (Dist), A.P.

Dr.T. Jayachandra Prasad
Principal

Dr. T. JAYACHANDRA PRASAD
M.E.,Ph.D.,
PRINCIPAL
RGM College of Engg. & Tech.,
(Autonomous)
NANDYAL-518 501, Nandyal (Dt), A.P.

R.G.M.COLLEGE OF ENGINEERING & TECHNOLOGY, NANDYAL – 518 501
DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

II B.Tech., II-Semester **Academic Year: 2022-23**

w.e.f: 16-03-2023

A-Section : RB2130 B-Section : RB2010
C-Section : RB2020 D-Section : RB2030

Period/ Day	Section	1	2	3	4	5	6	7
		9.00 AM To 9.50 AM	**9.50 AM To 10.40 AM**	**11.00 AM To 11.50 AM**	**11.50 AM To 12.40 PM**	**1.50 PM To 2.40 PM**	**2.40 PM To 3.30 PM**	**3.30 PM To 4.20 PM**
MON	A	RVRP	ECA&D	EMFT&L	COU	PP	ARMMCI	AARC
	B	ARMMCI	PP Lab			RVRP	PP	EMFT&L
	C	ECA&D	AMRP Lab/ECA&D Lab			AARC	RVRP	ARMMCI
	D	PP	ECA&D	RVRP	AARC	ARMMCI	EMFT&L	LIB
TUE	A	RVRP	AMRP Lab/ECA&D Lab			ECA&D	EMFT&L	PP
	B	ECA&D	EMFT&L	PP	AARC	AMRP Lab/ECA&D Lab		
	C	PP	ECA&D	COU	ARMMCI	EMFT&L	RVRP	LIB
	D	ARMMCI	EMFT&L	ECA&D	PP	PP Lab		
WED	A	PP	EMFT&L	ECA&D	ARMMCI	AMRP Lab/ECA&D Lab		
	B	RVRP	ARMMCI	EMFT&L	PP	COU	ECA&D	LIB
	C	PP	EMFT&L	AARC	RVRP	PP Lab		
	D	RVRP	AMRP Lab/ECA&D Lab			ARMMCI	AARC	ECA&D
THU	A	PP	ECA&D	RVRP	AARC	ARMMCI	EMFT&L	LIB
	B	PP	ECA&D	ARMMCI	EMFT&L	RVRP	IEI/ISTE	AARC
	C	PP	EMFT&L	ECA&D	ARMMCI	AMRP Lab/ECA&D Lab		
	D	ECA&D	ARMMCI	IEI/ISTE	EMFT&L	PP	RVRP	COU
FRI	A	ARMMCI	PP Lab			ARRC	PP	RVRP
	B	ECA&D	RVRP	ARRC	ARMMCI	AMRP Lab/ECA&D Lab		
	C	RVRP	EMFT&L	IEI/ISTE	AARC	ARMMCI	ECA&D	PP
	D	EMFT&L	AMRP Lab/ECA&D Lab			RVRP	PP	AARC
SAT	A	ARMMCI	IEI/ISTE	ECA&D	EMFT&L	RVRP	**EAA**	
	B	RVRP	EMFT&L	PP	ARMMCI	ECA&D		
	C	ECA&D	PP	ARMMCI	EMFT&L	RVRP		
	D	PP	EMFT&L	ECA&D	RVRP	ARMMCI		

Subject	Section	Name of the Faculty
PP	A	Dr.A.Sathish
ARMMCI	A	Smt.R.Sireesha
ECA&D	A	Mr.P.Anand Rao
EMFT&L	A	Dr.M.Chennakesavulu
RVRP	A	Mr.T.Tirumalesh
AARC	A	Smt.Y.Akhila
PP Lab	A	**Dr.AS**/Dr.NR/Dr.AKS/DBKR
ARMP Lab	A	**Smt.RS**/Mr.JLMK
ECA&D Lab	A	**Smt.VS**/Mr.YSPD/Smt.KSR
COU	A	Mr.D.Rajesh Setty
IEI/ISTE	A	Smt.V.Saraswathi

Subject	Section	Name of the Faculty
PP	B	Mr.D.B Krishna Reddy
ARMMCI	B	Smt.R.Sireesha
ECA&D	B	Mr.Y.M Sudhana Reddy
EMFT&L	B	Mr.K.Mastan Vali
RVRP	B	Smt.V.Saraswathi
AARC	B	Smt.Y.Akhila
PP Lab	B	**Mr.DBKR**/Dr.AS/Dr.AKS
ARMP Lab	B	**Mr.PR**/Smt.RS
ECA&D Lab	B	**Mr.YMSR**/Smt.VS/Smt.KSR
COU	B	Mr.D.Rajesh Setty
IEI/ISTE	B	Smt.V.Saraswathi

Subject	Section	Name of the Faculty
PP	C	Dr.Ajit Kumar Singh
ARMMCI	C	Dr.P.V.Gopi Krishna Rao
ECA&D	C	Smt.B.Geetha Rani
EMFT&L	C	Dr.V.N.V.Satya Prakash
RVRP	C	Mr.P.Chandra Sekar
AARC	C	Mr.E.V.Raghavendra
PP Lab	C	**Dr.AKS**/Dr.NR/Dr.AS/DBKR
ARMP Lab	C	**Mr.JLMK**/Mr.YSPS(MON)
ECA&D Lab	C	**Smt.BGR**/Mr.TT/Smt.GILP
COU	C	Smt.B.Nazma
IEI/ISTE	C	Smt.V.Saraswathi

Subject	Section	Name of the Faculty
PP	D	Dr.N.Ramanjaneyulu
ARMMCI	D	Mrs.P.Prasanthi
ECA&D	D	Dr.C.Venkataiah
EMFT&L	D	Mrs.G.I.Lakshmi Prasanna
RVRP	D	Mr.P.Chandra Sekar
AARC	D	Mr.E.V.Raghavendra
PP Lab	D	**Dr.NR**/Mr.DBKR/Dr.AKS
ARMP Lab	D	**Dr.PVGKR**/Mr.DBKR(FRI)
ECA&D Lab	D	**Dr.CV**/Smt.BGR/Mr.TT
COU	D	Smt.B.Nazma
IEI/ISTE	D	Smt.V.Saraswathi

Dr.K.Mallikarjuna
HOD OF ECE

Dr. KETHEPALLI MALLIKARJUNA
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R G M COLLEGE OF ENGINEERING AND TECHNOLOGY
AUTONOMOUS
ELECTRONICS AND COMMUNICATION ENGINEERING

II B.Tech, II-Sem(ECE)

L	T	C
2	1	3

(A0409204) ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN

COURSE OBJECTIVES:

- To study the analysis and design of single stage and multistage amplifiers at low and high frequencies.
- Electrical equivalent model of transistor at low and high frequencies.
- Study of small signal and large signal amplifiers and their area of applications.
- To understand the concepts of feedback and their applications (Voltage feedback amplifiers and oscillators)

COURSE OUTCOMES:

- Design and analyze single stage amplifiers using BJT and MOSFET at low frequencies.
- Design and analyze multi stage amplifiers using BJT and MOSFET at low frequencies.
- Discuss frequency response of single stage BJT and MOSFET amplifiers at low and high frequencies.
- Explain effect of negative feedback on amplifier characteristics.
- Discuss basic principles for analyzing RC & LC oscillator circuits using BJT and MOSFET.
- Design and analyse different types of large signal amplifiers.

MAPPING WITH COs & POs:

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12	PSO1	PSO2	PSO3
CO1	1	3	2		1							1	3	1	
CO2	2	2			2							2	3	2	
CO3	2	3	2	2	1							2		2	1
CO4	1	3	2	2								1	1	2	1
CO5	3	1	2		1							2		2	1
CO6	2	1	2	2	1								2	1	1

UNIT I

Small Signal Analysis of BJT: Basic CE amplifier circuit. Circuit with Emitter resistance, AC load line analysis. Small signal analysis-input and output impedances. Voltage gain. Current gain of CE,CB, CC amplifiers using h-parameter model and simplified model, Problem solving.

Small Signal Analysis of MOSFETs: Graphical and Load line analysis , small signal parameters, Small signal equivalent circuit, Small signal analysis of Common source, Common drain, Common gate amplifiers, Comparison of the three basic amplifier configurations, Problem solving.

UNIT II

Differential and Multistage Amplifiers:

The MOS Differential Pair, Small-Signal Operation of the MOS Differential Pair, The BJT Differential Pair, Other Non-ideal Characteristics of the Differential Amplifier, The Differential Amplifier with Active Load, Multistage Amplifiers – RC coupled amplifier – Darlington pair – Cascode amplifier, Problem solving.

UNIT III

Frequency Response:

Introduction. Low-Frequency Response of the CS and CE Amplifiers. Internal Capacitive Effects and the High-Frequency Model of the MOSFET and the BJT. High-Frequency Response of the CS and CE Amplifiers. Useful Tools for the Analysis of the High-Frequency Response of Amplifiers. A Closer Look at the High-Frequency Response of the CS and CE Amplifiers. High-Frequency Response of the CG and Cascode Amplifiers. High-Frequency Response of the Source and Emitter Followers. High-Frequency Response of Differential Amplifiers. Other Wideband Amplifier Configurations. Multistage Amplifier Examples, Problem solving.

UNIT IV

Feedback Amplifiers:

Introduction, The General Feedback Structure, Some Properties of Negative Feedback, The Four Basic Feedback Topologies, The Feedback Voltage Amplifier (Series—Shunt), The Feedback Transconductance

Amplifier. The Feedback Transresistance Amplifier (Shunt—Shunt). The Feedback Current Amplifier (Shunt—Series). Summary of the Feedback Analysis Method. Determining the Loop Gain. Problem solving.

UNIT V

Power Amplifiers:

Introduction, Classification of Output Stages, Class A Output Stage, Class B Output Stage, Class AB Output Stage, Biasing the Class AB Circuit, CMOS Class AB Output Stages, Power BJTs, Variations on the Class AB Configuration, IC Power Amplifiers, MOS Power Transistors, Problem solving.

UNIT VI

Oscillators and Tuned Amplifiers:

Oscillators: General Considerations, Classification of Oscillators, LC Oscillators using BJT and FET-Heatly and Colpit's Oscillators , RC Oscillators using BJT and FET- Phase Shift and Wien-Bridge Oscillators, Crystal Oscillators, Illustrative Problems.

Tuned Amplifiers: Basic Principle, Inductor losses, use of transformers, Amplifiers with multiple tuned circuits.

TEXT BOOKS:

1) Adel S. Sedra and Kenneth C. Smith, "Micro Electronic Circuits". Oxford University Press International 6th edition. 2013.
2) Donald A Neamen. "Electronic Circuits – analysis and design". 3rd Edition. McGraw Hill (India), 2019.

REFERENCES:

1) J. Milliman and C Halkias, "Integrated electronics", 2nd Edition, Tata McGraw Hill, 1991.
2) Behzad Razavi, "Microelectronics", Second edition, Wiley, 2013.
3) R.L. Boylestad and Louis Nashelsky, "Electronic Devices and Circuits," 9th Edition, Pearson, 2006.
4) Jimmie J Cathey, "Electronic Devices and Circuits," Schaum's outlines series, 3rd edition, McGraw-Hill (India), 2010.

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(AUTONOMOUS)

DAPARTMENT OF ECE

LESSON PLAN

Name of the Faculty: **Dr. Y. MADHU SUDHANA REDDY** Academic Year: **2022-23**

Class and Semester: **II B.Tech II-Sem** Branch: **ECE - B**

Subject: **ELECTRONIC CIRCUITS- ANALYSIS & DESIGN** Regulation: **RGM-R20**

UNIT NO.	TOPIC	NO. OF PERIODS
I	**Small Signal Analysis of BJT:** Basic CE amplifier circuit and Circuit with Emitter resistance, AC load line analysis Small signal analysis-input and output impedances, Voltage gain, Current gain of CE, CB, CC amplifiers using h-parameter model and simplified model of CE, CC and CB configurations and its analysis Problem solving. **Small Signal Analysis of MOSFETs**: Graphical and Load line analysis small signal parameters and small signal equivalent circuit Small signal analysis of Common source, Common drain, Common gate amplifiers Comparison of the three basic amplifier configurations Problem solving.	01 01 03 02 02 01 02 02 01 02
II	**Differential and Multistage Amplifiers:** The MOS Differential Pair Small-Signal Operation of the MOS Differential Pair The BJT Differential Pair Other Non-ideal Characteristics of the Differential Amplifier The Differential Amplifier with Active Load Multistage Amplifiers – RC coupled amplifier – Darlington pair – Cascode amplifier Problem solving.	01 02 01 01 02 02 02
III	**Frequency Response:** Introduction Low-Frequency Response of the CS and CE Amplifiers Internal Capacitive Effects and the High-Frequency Model of the MOSFET and the BJT High-Frequency Response of the CS and CE Amplifiers Useful Tools for the Analysis of the High-Frequency Response of Amplifiers A Closer Look at the High-Frequency Response of the CS and CE Amplifiers High-Frequency Response of the CG and Cascode Amplifiers High-Frequency Response of the Source and Emitter Followers High-Frequency Response of Differential Amplifiers	01 02 01 01 01 01 01 01 01 01

	Other Wideband Amplifier Configurations	01
	Multistage Amplifier Examples	01
	Problem solving.	01
IV	**Feedback Amplifiers:**	
	Introduction	01
	The General Feedback Structure	01
	Some Properties of Negative Feedback	01
	The Four Basic Feedback Topologies	01
	The Feedback Voltage Amplifier (Series—Shunt)	01
	The Feedback Transconductance Amplifier	01
	The Feedback Transresistance Amplifier (Shunt—Shunt)	01
	The Feedback Current Amplifier (Shunt—Series)	01
	Summary of the Feedback Analysis Method	01
	Determining the Loop Gain, Problem solving.	01
V	**Power Amplifiers:**	
	Introduction	01
	Classification of Output Stages	01
	Class A Output Stage	01
	Class B Output Stage	01
	Class AB Output Stage	01
	Biasing the Class AB Circuit	01
	CMOS Class AB Output Stages	01
	Power BJTs	01
	Variations on the Class AB Configuration	01
	IC Power Amplifiers, MOS Power Transistors	01
	Problem solving.	01
VI	**Oscillators and Tuned Amplifiers:**	
	Oscillators: General Considerations	01
	Classification of Oscillators	01
	LC Oscillators using BJT and FET-Heatly and Colpit's Oscillators	02
	RC Oscillators using BJT and FET- Phase Shift and Wien-Bridge Oscillators	02
	Crystal Oscillators	01
	Illustrative Problems.	01
	Tuned Amplifiers: Basic Principle	01
	Inductor losses, use of transformers	01
	Amplifiers with multiple tuned circuits.	01

TOTAL CLASSES REQUIRED: **71**

Signature of the Faculty

Signature of the HOD

RGM COLLEGE OF ENGINEERING & TECHNOLOGY
(AUTONOMOUS)
NANDYAL - 518 501. Kurnool (Dist.) A.P.

EDUCATION FOR PEACE
(ESTD-1995)

ATTENDANCE REGISTER

ACADEMIC YEAR : 2022-23 **SEM** : I / [✓ II]

COURSE : B.Tech **CLASS :** B.Tech

BRANCH / SECTION : ECE - B

SUBJECT & CREDITS : 03 Electronic Circuit - Analysis & Design

FACULTY : Mr. Y. Madhu Sudhana Reddy.

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Class : B.Tech

Branch : ECE-B

Semister / Year II / II

Academic Year from

	Date	16/03/23	16/03/23	17/03/23	18/03/23	21/03/23	23/03/23	24/03/23	25/03/23	03/04/23	08/04/23	08/04/23	11/04/23
Roll No.	Name	1	2	3	4	5	6	7	8	9	10	11	12
21091A0465	Y. Jaya Sreenivas Reddy	A	A	A	A	A	A	A	A	1	2	3	4
466	P. Jayasurya	A	A	A	A	A	A	A	A	1	2	3	4
467	P. Jithendra Reddy	A	A	A	A	A	A	A	1	2	3	A	4
468	N. Johnson Kumar	A	A	A	A	A	A	A	1	A	2	A	A
469	B. Kailashnath Reddy	A	A	A	A	A	A	A	1	2	3	4	5
470	K. Kalyani	A	A	1	A	2	3	4	5	6	7	8	9
471	Y. Karthik Kumar Reddy.	A	A	A	A	A	A	A	A	1	2	3	A
472	U. Karthik	A	A	A	A	A	A	A	A	1	2	A	A
473	B. Kasi Eswari	A	A	A	A	1	2	3	4	5	6	7	8
474	D. Kasim Sahab	A	A	A	A	A	A	A	1	2	3	4	5
475	N. Keerthi	A	A	A	A	A	A	1	2	3	4	A	5
476	P. Khadar Basha	A	A	A	A	A	A	A	A	1	2	A	3
477	K. Kiran Kumar Naik	A	A	A	A	A	A	A	A	1	2	3	4
478	B. Krupakar	A	A	A	A	A	1	2	A	3	4	5	6
479	M. Lakshmi Devi	A	A	A	A	A	1	2	3	4	5	6	7
480	S. Lakshmi Narasimhulu	A	A	1	A	2	A	A	A	3	4	A	A
481	B. Lavanya	1	2	A	A	A	A	A	3	4	5	6	A
482	K. Lavanya	A	A	1	A	2	3	4	5	6	7	8	9
483	K. Likhitha	A	A	A	A	A	A	1	2	A	3	4	5
484	B. Lomith Reddy.	1	2	3	4	5	A	6	7	8	9	10	11
485	P. Mabulhussain	A	A	A	A	A	1	2	3	4	5	6	7
486	B. Madhavi	A	A	1	A	2	3	4	5	6	7	8	9
487	M. Madhu	A	A	A	A	A	A	A	1	2	3	4	5
488	G. MadhuSudhan Reddy	A	A	A	A	A	A	1	2	3	4	5	6
489	E. MadhuSudhan Goud	A	A	A	A	A	A	A	1	2	3	4	5
490	G. Madhu Sudhan	A	A	A	A	A	A	A	A	1	2	A	3
491	G.G. Mahammad Basha	A	A	A	A	A	A	1	2	3	4	5	6
493	U. Mahesh	A	A	A	A	A	A	1	A	2	3	4	5
494	Y. Mahesh	A	A	A	A	A	A	A	A	1	2	3	4
495	S. Mahitha	A	A	A	A	A	A	1	2	3	4	A	5
Signature of Teacher													
Signature of H.O.D.													
Signature of Principal													

	25/04/23	27/04/23	28/04/23	02/05/23	02/05/23	03/05/23	03/05/23	04/05/23	05/05/23	05/05/23	05/05/23
Roll No.	13	14	15	16	17	18	19	20	21	22	23
65	5	6	A	7	8	9	10	11	12	13	14
66	5	A	6	7	8	9	10	11	12	13	14
67	5	A	6	7	8	9	10	11	12	13	14
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73	9	10	A	11	12	13	14	15	16	17	18
74	6	7	A	8	9	10	11	12	13	14	15
75	6	7	A	8	9	10	11	12	13	14	A
76	4	5	A	6	7	8	9	10	11	12	13
77	5	6	7	8	9	10	11	12	13	14	15
78	7	8	A	9	10	11	12	A	13	14	15
79	8	9	10	11	12	13	14	15	16	17	15
80	5	6	A	7	8	9	10	11	12	13	14
81	7	8	9	10	11	12	13	14	15	16	17
82	10	11	A	12	13	14	15	16	17	18	19
83	6	7	A	8	9	10	11	12	13	14	15
84	12	13	A	14	15	16	17	18	19	20	21
85	8	9	10	11	12	13	14	15	16	17	18
86	10	11	A	12	13	14	15	16	17	18	19
87	6	7	A	8	9	10	11	A	12	13	14
88	7	8	9	10	11	12	13	14	15	16	17
89	6	7	A	8	9	10	11	A	12	13	14
90	4	5	A	A	A	6	7	8	9	10	11
91	7	8	9	10	11	12	13	14	15	16	17
93	6	7	8	9	10	11	12	13	14	15	16
94	5	6	A	7	8	9	10	11	12	13	14
95	6	7	A	8	9	10	11	12	13	14	15

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Academic Year from

Class : B.Tech

Branch : ECE-B

Roll No.	Name	Date 16/03/23 1	
21091A0 465	Y. Jaya Sreenivas Reddy	A	
466	P. Jayasurya	A	
467	P. Jithendra Reddy	A	A
468	N. Johnson Kumar	A	A
469	B. Kailashnath Reddy	A	A
470	K. Kalyani	A	A
471	Y. Karthik Kumar Reddy.	A	A
472	U. Karthik	A	A
473	B. Kasi Eswari	A	A
474	D. Kasim Saheb	A	A
475	N. Keerthi	A	A
476	P. Khadar Basha	A	A
477	K. Kiran Kumar Naik	A	A
478	B. Krupakar	A	A
479	M. Lakshmi Devi	A	A
480	S. Lakshmi Narasimhulu	A	A
481	B. Lavanya	1	[illegible]
482	K. Lavanya	A	A
483	K. Likhitha	A	A
484	B. Lomith Reddy.	1	[illegible]
485	P. MabulHussain	A	A
486	B. Madhavi	A	A
487	M. Madhu	A	A
488	G. MadhuSudhan Reddy	A	A
489	E. MadhuSudhan Goud	A	A
490	G. Madhu Sudhan	A	A
491	G.G. Mahammad Basha	A	A
493	U. Mahesh	A	A
494	Y. Mahesh	A	A
495	S. Mahitha	A	A
Signature of Teacher			
Signature of H.O.D.			
Signature of Principal			

	08/05/23	09/05/23	10/05/23	10/05/23	11/05/23	12/05/23	23/05/23	08/06/23	09/06/23	12/06/23	13/06/23
Roll No.	24	25	26	27	28	29	30	31	32	33	34
65	A	15	16	17	18	19	20	A	A	21	22
66	A5	16	17	18	19	20	A	A	A	21	22
67	A	15	A	A	16	17	18	A	A	19	20
68	A	14	15	16	17	18	19	A	A	A	20
69	16	17	18	19	20	A	21	A	A	22	A
70	20	21	22	23	24	25	26	27	28	29	30
71	15	16	17	18	19	A	A	A	A	A	A
72	15	16	17	18	A	A	19	A	A	20	21
73	A	19	20	21	22	23	24	25	26	27	28
74	16	17	18	19	20	21	A	A	A	22	23
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76	14	A	A	A	15	16	17	A	A	18	19
77	16	17	18	19	20	21	22	A	A	23	24
78	16	17	18	19	20	21	22	A	A	23	24
79	19	20	21	22	23	A	24	A	A	25	26
80	15	16	17	18	19	A	A	A	A	A	A
81	18	19	20	21	A	22	A	A	A	23	24
82	20	21	22	23	24	25	26	A	27	A	28
83	16	17	18	19	20	21	22	A	23	24	25
84	22	23	24	25	26	27	A	28	29	30	31
85	19	A	20	21	A	22	A	23	24	25	26
86	A	20	21	22	23	24	25	26	27	28	29
87	15	16	17	18	19	20	A	A	A	21	22
88	18	19	A	A	20	21	22	23	24	15	26
89	15	16	17	18	19	20	21	A	22	23	24
90	12	13	14	15	16	17	18	A	A	19	20
91	18	19	20	21	22	23	24	25	26	27	28
93	17	18	19	20	21	22	23	A	A	24	A
94	15	16	17	18	19	A	20	A	A	A	21
95	16	17	18	19	20	21	A	A	A	A	22

	14/06/23	15/06/23	16/06/23	19/06/23	20/06/23	21/06/23	21/06/23	22/06/23	23/06/23	27/06/23	29/06/23
Roll No.	35	36	37	38	39	40	41	42	43	44	45
65	23	24	25	26	27	28	29	30	31	32	33
66	23	24	25	26	27	28	29	30	31	32	33
67	21	22	A	23	24	25	26	27	28	29	30
68	21	22	A	23	24	A	A	25	A	A	A
69	23	24	25	26	27	28	29	30	31	32	33
70	31	32	33	34	35	36	37	38	39	40	41
71	20	21	22	23	24	A	A	25	A	26	27
72	22	23	24	25	26	27	28	29	30	31	32
73	29	30	31	32	33	34	35	36	37	38	39
74	24	25	26	27	28	29	30	31	A	32	33
75	24	25	26	27	28	29	30	31	32	33	34
76	20	21	22	23	24	25	26	27	28	29	30
77	25	26	27	28	29	30	31	32	A	33	34
78	25	26	A	A	A	27	28	29	A	30	31
79	27	28	29	30	31	A	A	32	33	34	35
80	A	A	20	21	22	23	24	25	26	27	28
81	25	A	26	27	28	29	30	31	32	A	A
82	29	30	31	32	33	34	35	36	37	38	39
83	26	27	28	29	30	31	32	33	34	35	36
84	32	A	33	34	35	36	37	38	39	40	41
85	27	A	A	28	29	A	A	30	31	32	33
86	30	31	32	33	34	35	36	37	38	A	A
87	23	A	24	25	26	27	28	29	30	31	32
88	27	28	29	30	31	32	33	34	35	36	37
89	A	25	26	27	28	29	30	31	A	32	33
90	21	22	A	A	23	24	25	26	27	28	29
91	29	30	31	32	33	34	35	36	37	38	A
93	25	26	27	28	29	30	31	32	33	34	35
94	22	23	24	25	26	27	28	29	30	31	32
95	23	24	25	26	27	28	29	30	31	32	33

R.G.M. COLLEGE OF ENGINEERING

ATTENDANCE

Class : B.Tech

Branch : ECE-B

Roll No.	Name	Date 16/03/23 1
21091A0465	Y. Jaya Sreenivas Reddy	A
466	P. Jayasurya	A
467	P. Jithendra Reddy	A
468	N. Johnson Kumar	A
469	B. Kailashnath Reddy	A
470	K. Kalyani	A
471	Y. Karthik Kumar Reddy.	A
472	U. Karthik	A
473	B. Kasi Eswari	A
474	D. Kasim Saheb	A
475	N. Keerthi	A
476	P. Khadar Basha	A
477	K. Kiran Kumar Naik	A
478	B. Krupakar	A
479	M. Lakshmi Devi	A
480	S. Lakshmi Narasimhulu	A
481	B. Lavanya	1
482	K. Lavanya	A
483	K. Likhitha	A
484	B. Lomith Reddy.	1
485	P. MabulHussain	A
486	B. Madhavi	A
487	M. Madhu	A
488	G. MadhuSudhan Reddy	A
489	E. MadhuSudhan Goud	A
490	G. Madhu Sudhan	A
491	G.G. Mahammad Basha	A
493	U. Mahesh	A
494	Y. Mahesh	A
495	S. Mahitha	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

	28/06/23	30/06/23	01/07/23	04/07/23	05/07/23	06/07/23	07/07/23	07/07/23			
Roll No.	46	47	48	49	50	51	52	53	54	55	56
65	34	35	36	37	38	39	40	41			
66	34	35	36	37	38	39	40	41			
67	31	32	33	34	35	36	A	A			
68	26	27	A	28	29	30	31	32			
69	34	35	36	37	38	39	40	41			
70	42	43	44	45	46	47	48	A			
71	28	29	30	31	32	33	34	35			
72	33	34	35	36	37	38	39	40			
73	A	40	41	42	43	44	45	A			
74	34	35	36	37	38	39	40	41			
75	35	36	37	38	39	40	A	A			
76	31	32	A	33	34	35	36	37			
77	35	36	37	38	39	40	41	A			
78	32	33	34	35	36	37	38	39			
79	36	37	38	A	39	40	A	A			
80	29	30	31	32	33	34	35	36			
81	33	34	35	A	36	37	A	A			
82	40	41	42	43	44	45	46	47			
83	37	38	39	40	41	42	43	A			
84	42	43	A	44	45	46	47	A			
85	34	35	36	37	38	39	40	A			
86	39	40	A	41	42	43	44	45			
87	33	34	35	36	37	38	39	40			
88	38	39	40	41	42	43	44	A			
89	34	35	36	37	38	39	40	A			
90	30	31	32	33	34	35	36	37			
91	39	40	41	42	43	44	45	46			
93	36	37	38	39	40	41	42	43			
94	A	33	34	35	36	37	38	A			
95	34	35	36	37	38	39	A	A			

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomou

ATTENDANCE REGISTER

Class : B.Tech

Branch : ECE-B

Semister / Year II/III

Academic Year from

Roll No.	Name Date	16/03/23	16/03/23	17/03/23	18/03/23	21/03/23	23/03/23	24/03/23	25/03/23	03/04/23	06/04/23	08/04/23	11/04/23
		1	2	3	4	5	6	7	8	9	10	11	12
21091A0 496	R.B.N.R.G. Maheswari	A	A	A	A	A	A	A	A	1	2	3	4
497	G. Manasa	A	A	A	A	A	A	1	2	3	4	A	5
498	M. Manasa	A	A	A	A	A	A	A	1	2	3	4	5
499	M. Mani Kumar Naik	A	A	A	A	A	A	A	A	1	2	3	A
4A0	V. Mani Kanta	A	A	A	A	A	A	A	A	1	2	3	A
4A1	P. Manisha	A	A	A	A	A	A	A	A	1	2	A	3
4A2	G. Manjula	A	A	A	A	A	A	1	2	3	4	5	A
4A3	B. Manoj Kumar Reddy	A	A	A	A	A	A	A	A	A	1	2	3
4A4	M. Manoj Kumar	A	A	A	A	A	A	A	1	2	3	4	5
4A5	K. Manoj	A	A	A	A	A	A	A	1	2	3	A	4
4A6	V. Maria Dhathri	A	A	A	A	1	A	2	3	4	5	A	6
4A7	V. Maruthi	A	A	A	A	A	A	A	A	1	2	A	3
4A8	M. Meenakshi	A	A	A	A	A	A	A	A	1	2	A	A
4A9	A. Meghana	A	A	A	A	1	2	3	4	A	5	6	7
4B0	C.T. Mithunteja	A	A	A	A	A	A	A	A	A	A	A	1
4B1	S. Mohhammad Abbas	A	A	A	A	1	A	2	3	A	A	4	A
4B2	S. Mohammad Irfan	A	A	A	A	1	A	2	3	A	4	5	A
4B3	S. Mohammad Arif	A	A	A	A	1	2	3	4	5	6	7	8
4B4	P. Mounika	A	A	A	A	1	A	2	3	A	4	5	6
4B5	M. Mythili	A	A	A	A	1	2	3	4	A	5	A	6
4B6	B. Naga Sowjanya	A	A	A	A	A	A	1	A	A	2	A	A
4B7	B. Naga Udayeswar Reddy	A	A	A	A	A	A	A	1	2	3	4	5
4B9	B. Nagaraju.	A	A	A	A	A	A	A	1	2	3	4	5
4C0	R-G. Nagesh	A	A	A	A	A	A	A	A	1	2	A	3
4C1	B. Naveen	A	A	A	A	1	2	3	4	5	A	A	6
4C2	R. Naveen	A	A	A	A	A	1	2	3	4	5	6	7
4C3	D. Nisheth	A	A	A	A	A	A	A	1	2	3	4	5
4C4	P. Nishitha	A	A	A	A	A	A	1	2	3	4	5	A
4C5	R. Pavan Kumar Reddy	A	A	A	A	A	A	A	1	2	3	A	A
4C6	S. Pavan Kumar Reddy	A	A	A	A	A	A	A	A	1	2	3	4
Signature of Teacher													
Signature of H.O.D.													
Signature of Principal													

	25/04/23	26/04/23	28/04/23	01/05/23	02/05/23	03/05/23	03/05/23	04/05/23	05/05/23	05/05/23	05/05/23
Roll No.	13	14	15	16	17	18	19	20	21	22	23
96	5	6	7	8	9	10	11	12	13	14	15
97	6	7	A	8	9	10	11	12	13	14	15
98	6	7	8	9	10	11	12	13	14	15	16
99	4	5	A	6	7	8	9	10	11	12	13
A0	4	5	A	A	A	6	7	8	9	10	11
A1	4	5	6	7	8	9	10	11	12	13	14
A2	6	7	8	9	10	11	12	13	14	15	16
A3	4	5	A	6	7	A	A	8	9	10	11
A4	6	7	8	9	10	11	12	A	13	14	15
A5	5	6	A	7	8	9	10	11	12	13	14
A6	7	8	A	9	10	11	12	13	14	15	16
A7	4	5	A	A	A	6	7	8	9	10	11
A8	3	4	A	5	6	7	8	9	10	11	12
A9	8	9	A	10	11	A	A	12	13	14	15
B0	2	3	A	4	5	6	7	8	9	10	11
B1	5	6	7	8	9	10	11	12	A	A	13
B2	6	7	8	9	10	11	12	13	A	A	14
B3	9	10	11	12	13	14	15	16	17	18	19
B4	7	8	A	9	10	11	12	13	14	15	16
B5	7	8	9	10	11	12	13	A	14	15	16
B6	3	4	5	6	7	8	9	10	A	A	A
B7	6	7	8	9	10	11	12	13	14	15	16
B9	6	7	8	9	10	11	12	13	14	15	16
C0	4	5	6	7	8	9	10	11	12	13	14
C1	7	8	9	10	11	12	13	14	15	16	17
C2	8	9	10	11	12	13	14	15	16	17	18
C3	6	7	8	9	10	11	12	13	14	15	16
C4	6	7	8	9	10	11	12	13	14	15	16
C5	4	5	6	7	8	9	10	11	12	13	14
C6	5	6	7	8	9	10	11	12	13	14	15

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomo

ATTENDANCE REGISTER

Academic Year fron

Class : B.Tech

Branch : ECE-B

Roll No.	Name	Date 16/03/23 1	2
21091A0 496	R.B.N.R.G. Mahiswari	A	A
497	G. Manasa	A	A
498	M. Manasa	A	A
499	M. Mani Kumar Naik	A	A
4A0	V. Mani Kanta	A	A
4A1	P. Manisha	A	A
4A2	G. Manjula	A	A
4A3	B. Manoj Kumar Reddy	A	A
4A4	M. Manoj Kumar	A	
4A5	K. Manoj	A	
4A6	V. Maria Dhathri	A	
4A7	V. Maruthi	A	
4A8	M. Meenakshi	A	A
4A9	A. Meghana	A	
4B0	C.T. Mithunteja	A	
4B1	S. Mohhamad Abbas	A	A
4B2	S. Mohammad Irfan	A	
4B3	S. Mohammad Arif	A	
4B4	P. Mounika	A	
4B5	M. Mythili	A	
4B6	B. Naga Sowjanya	A	
4B7	B. Naga Udayeswar Reddy	A	
4B9	B. Nagaraju.	A	A
4C0	R.G. Nagesh	A	
4C1	B. Naveen	A	
4C2	R. Naveen	A	
4C3	D. Nisheth	A	
4C4	P. Nishitha	A	
4C5	R. Pavan Kumar Reddy	A	
4C6	S. Pavan Kumar Reddy	A	
Signature of Teacher			
Signature of H.O.D.			
Signature of Principal			

Roll No.	06/05/23 24	09/05/23 25	10/05/23 26	10/05/23 27	11/05/23 28	12/05/23 29	23/05/23 30	05/06/23 31	09/06/23 32	12/06/23 33	13/06/23 34
96	16	17	18	19	20	21	22	A	23	24	25
97	16	17	18	19	A	20	A	A	A	A	21
98	17	18	19	20	21	22	A	A	A	A	A
99	A	14	15	16	17	18	19	A	20	21	22
A0	A	12	13	14	15	16	17	18	19	20	21
A1	15	16	17	18	A	19	A	A	A	20	21
A2	17	18	19	20	21	22	A	A	23	24	25
A3	12	13	14	15	16	A	17	18	19	20	21
A4	A16	17	A	A	18	A	19	A	20	21	A
A5	15	16	17	18	19	A	20	A	A	21	22
A6	17	A	18	19	20	21	A	22	23	24	25
A7	13	14	15	16	17	18	19	A	A	20	21
A8	13	14	15	16	A	17	A	A	A	18	19
A9	16	17	18	19	20	21	A	22	23	24	25
B0	12	13	14	15	16	17	18	A	19	20	21
B1	A	14	A	A	A	A	A	A	A	15	16
B2	15	16	17	18	19	A	20	A	21	A	22
B3	20	21	22	23	24	25	26	27	28	29	30
B4	17	A	A	A	18	19	20	21	22	A	23
B5	A	17	A	A	A	18	19	20	21	22	23
B6	A	A	A	A	A	11	12	A	13	14	15
B7	17	18	A	A	A	A	A	A	19	20	21
B9	17	18	19	20	21	A	22	A	A	23	24
C0	15	16	17	18	19	20	21	A	22	23	24
C1	18	19	20	21	22	23	A	24	25	26	27
C2	19	A	20	21	22	A	23	24	25	A	26
C3	17	18	19	20	21	A	22	A	23	24	25
C4	A	17	18	19	20	21	22	23	24	25	26
C5	A	16	17	18	19	20	21	A	A	A	22
C6	16	17	18	19	20	21	22	A	A	A	23

Roll No.	14/06/23 35	15/06/23 36	16/06/23 37	17/06/23 38	20/06/23 39	21/06/23 40	21/06/23 41	22/06/23 42	23/06/23 43	23/06/23 44	24/06/23 45
96	26	27	28	29	30	31	32	33	34	35	36
97	22	23	24	25	26	27	28	29	30	31	32
98	A	A	A	A	A	A	A	A	A	23	24
99	23	24	25	26	27	28	29	30	31	32	33
A0	22	23	24	25	26	27	28	29	30	31	32
A1	22	23	24	25	26	27	28	29	30	31	32
A2	26	27	28	29	30	31	32	33	34	35	36
A3	22	23	A	24	25	26	27	28	29	30	31
A4	A	22	23	A	24	25	26	27	28	29	30
A5	23	24	25	26	27	28	29	30	31	32	33
A6	26	27	28	29	30	A	A	31	32	33	34
A7	22	23	24	25	26	27	28	29	30	31	32
A8	20	21	22	23	24	25	26	27	28	29	30
A9	26	27	28	29	30	31	32	33	34	35	36
B0	22	23	24	A	25	26	27	28	29	30	31
B1	17	18	19	20	21	22	23	24	25	26	27
B2	23	24	25	A	26	27	28	29	A	30	31
B3	31	32	33	34	35	36	37	38	39	40	41
B4	A	24	25	26	27	28	29	30	31	32	33
B5	24	25	26	27	28	29	30	31	A	32	33
B6	16	17	18	19	20	21	22	23	24	25	26
B7	22	23	24	25	26	27	28	29	30	31	32
39	25	26	27	28	29	30	31	32	A	33	34
C0	25	26	27	28	29	30	31	32	33	34	35
C1	28	29	30	31	32	33	34	35	36	37	38
C2	27	A	28	29	30	31	32	33	34	35	36
C3	26	27	28	29	30	31	32	33	34	35	36
C4	27	28	A	29	30	31	32	33	34	35	36
C5	23	24	25	26	27	28	29	30	31	32	33
C6	24	25	26	27	28	29	30	31	32	33	34

R.G.M. COLLEGE OF ENGINEERING

ATTENDANCE

Class : B.Tech

Branch : ECE-B

	Date	16/03/23	
Roll No.	Name	1	2
21091A04 96	R.B.N.R.G. Mahiswari	A	A
497	G. Manasa	A	A
498	M. Manasa	A	A
499	M. Mani Kumar Naik	A	A
4A0	V. Mani Kanta	A	A
4A1	P. Manisha	A	A
4A2	G. Manjula	A	A
4A3	B. Manoj Kumar Reddy.	A	
4A4	M. Manoj Kumar	A	
4A5	K. Manoj	A	
4A6	V. Maria Dhathri	A	
4A7	V. Maruthi	A	
4A8	M. Meenakshi	A	A
4A9	A. Meghana	A	
4B0	C.T. Mithunteja	A	
4B1	S. Mohhamad Abbas	A	A
4B2	S. Mohammad Irfan	A	
4B3	S. Mohammad Arif	A	
4B4	P. Mounika	A	
4B5	M. Mythili	A	
4B6	B. Naga Sowjanya	A	
4B7	B. Naga Udayeswar Reddy	A	
4B9	B. Nagaraju.	A	A
4C0	R.G. Nagesh	A	
4C1	B. Naveen	A	
4C2	R. Naveen	A	
4C3	D. Nisheth	A	
4C4	P. Nishitha	A	
4C5	R. Pavan Kumar Reddy	A	A
4C6	S. Pavan Kumar Reddy	A	
Signature of Teacher			
Signature of H.O.D.			
Signature of Principal			

	28/06/23	30/06/23	01/07/23	04/07/23	05/07/23	06/07/23	07/07/23	07/07/23			
Roll No.	46	47	48	49	50	51	52	53	54	55	56
96	37	38	39	40	41	42	A	A			
97	33	34	35	36	37	38	A	A			
98	25	26	27	28	29	30	31	32			
99	34	35	36	37	38	39	40	A			
A0	33	34	35	36	37	38	39	A			
A1	33	34	35	36	37	38	A	A			
A2	37	38	39	40	41	42	43	44			
A3	32	33	34	35	36	37	38	A			
A4	31	32	33	34	35	36	37	38			
A5	34	35	36	37	38	39	40	41			
A6	35	A	36	37	38	39	40	A			
A7	A	A	33	34	35	36	37	38			
A8	31	32	33	34	35	36	A	37			
A9	37	38	39	40	41	42	43	A			
B0	32	33	34	35	36	37	38	39			
B1	28	29	30	31	32	33	34	35			
B2	32	A	33	34	35	36	37	38			
B3	42	43	44	45	46	47	48	A			
B4	34	A	35	36	37	38	39	40			
B5	34	A	35	36	37	38	A	39			
B6	27	28	29	30	31	32	33	34			
B7	33	34	35	36	37	38	39	40			
B9	35	A	36	37	38	39	40	41			
C0	A	36	37	38	39	40	41	A			
C1	39	40	41	42	43	44	A	A			
C2	37	38	39	40	41	42	43	A			
C3	37	38	39	40	41	42	43	44			
C4	37	38	39	40	41	42	43	44			
C5	34	35	36	37	38	39	40	A			
C6	35	36	37	38	39	40	41	A			

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous

ATTENDANCE REGISTER

Class : B.Tech

Branch : ECE-B

Semister / Year II II

Academic Year from....

	Date	16/03/23	16/03/23	17/03/23	18/03/23	21/03/23	23/03/23	24/03/23	25/03/23	03/04/23	04/04/23	06/04/23	11/04/23
Roll No.	Name	1	2	3	4	5	6	7	8	9	10	11	12
21091A0 407	C. Pavan Kumar	A	A	A	1	A	A	A	2	3	4	5	6
22095A0 407	K. Deveswar Reddy	A	A	A	A	A	A	A	A	1	2	3	4
408	G. Dharma Teja	A	A	A	A	A	A	A	A	1	2	3	4
409	K. Elizabeth Rani	A	A	A	A	A	A	1	2	3	4	5	6
411	G. Gangothri	A	A	A	A	A	A	A	1	2	3	4	5
413	K. Harika	A	A	A	A	A	A	A	1	2	3	4	5
415	Z. Hemanth Kumar	A	A	A	A	A	A	1	2	3	4	5	6
417	J. Jayavardan	1	2	3	4	5	6	7	8	9	10	11	12
422	P. Mani Teja	A	A	A	A	A	A	A	1	2	3	A	4
428	P. Rameeja	A	A	A	A	A	A	A	A	A	A	A	A
429	S. Ruksana	A	A	A	A	A	A	A	1	2	A	3	4
435	K. Sreenivas	A	A	A	A	A	A	1	A	2	3	4	5
436	N. Varun Kumar	A	A	A	A	A	A	A	A	1	2	3	4

Signature of Teacher

Signature of H.O.D.

Signature of Principal

	25/04/23	27/04/23	28/04/23	01/05/23	02/05/23	03/05/23	03/05/23	04/05/23	05/05/23	05/05/23	05/05/23
Roll No.	13	14	15	16	17	18	19	20	21	22	23
07	7	8	9	10	11	12	13	14	15	16	17
7	5	6	A	7	8	9	10	11	12	13	14
8	5	6	7	8	9	10	11	12	13	14	15
9	7	8	A	A	A	A	A	A	9	10	11
11	6	7	8	9	10	11	12	13	14	15	16
13	6	7	A	8	9	10	11	12	13	14	15
15	7	8	9	10	11	12	13	14	15	16	17
17	13	14	A	15	16	17	18	19	20	21	22
22	5	6	A	A	A	7	8	9	10	11	12
28	A	A	A	A	A	A	A	A	A	A	A
29	5	6	7	8	9	10	11	12	13	14	15
35	6	7	8	9	10	11	12	13	14	15	16
36	5	6	7	8	9	10	11	12	13	14	15

R.G.M. COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous)

ATTENDANCE REGISTER

Academic Year from.....

Class : B.Tech

Branch : ECE-B

Roll No.	Name	Date 16/03/23 1
209 1A0 4C7	C. Pavan Kumar	A
22095A0 407	K. Deveswar Reddy	A
408	G. Dharma Teja	A
409	K. Elizabeth Rani	A
411	G. Gangothri	A
413	K. Harika	A
415	Z. Hemanth Kumar	A
417	J. Jayavardan	1
422	P. Mani Teja	A
428	P. Rameeja	A
429	S. Ruksana	A
435	K. Sreenivas	A
436	N. Varun Kumar	A

Signature of Teacher

Signature of H.O.D.

Signature of Principal

	06/05/23	09/05/23	10/05/23	10/05/23	11/05/23	12/05/23	23/05/23	08/06/23	09/06/23	12/06/23	13/06/23
Roll No.	24	25	26	27	28	29	30	31	32	33	34
C7	18	19	20	21	22	23	A	A	A	24	A
7	15	16	17	18	19	20	21	A	22	23	24
8	16	17	18	19	20	A	A	A	A	A	21
9	12	13	14	15	16	A	17	A	18	19	20
11	17	18	19	20	21	A	22	23	24	25	26
13	16	17	18	19	20	21	22	A	23	24	25
15	A	18	19	20	21	22	23	A	24	25	A
17	23	24	A	A	A	A	A	25	26	27	A
22	13	14	15	16	17	A	18	A	19	20	21
28	A	A	A	A	A	A	A	A	A	A	A
29	A	16	17	18	19	A	20	A	21	22	23
35	A	17	18	19	20	A	21	A	A	22	23
36	A	16	17	18	19	20	A	21	22	23	24

	14/06/23	15/06/23	16/06/23	17/06/23	20/06/23	21/06/23	21/06/23	22/06/23	23/06/23	23/06/23	23/06/23
Roll No.	35	36	37	38	39	40	41	42	43	44	45
C7	25	26	A	27	28	29	30	31	32	33	34
7	25	26	27	28	29	30	31	32	33	34	35
8	22	23	24	25	26	27	28	29	30	31	32
9	21	22	23	24	25	26	27	28	29	30	31
11	27	28	29	30	31	32	33	34	35	A	A
13	26	27	28	29	30	31	32	33	34	35	36
15	26	27	28	A	29	30	31	32	33	34	35
17	A	28	29	30	31	32	33	34	35	36	37
22	22	23	24	25	26	27	28	29	30	31	32
28	A	A	A	A	A	A	A	A	A	A	A
29	24	25	26	27	28	29	30	31	32	33	34
35	24	25	26	A	27	28	29	30	31	32	33
36	25	26	27	A	28	29	30	31	32	33	34

R.G.M. COLLEGE OF ENGINEERING
ATTENDANCE

Class : B.Tech

Branch : ECE-B

Roll No.	Name	Date 16/03/23
		1
21091A0407	C. Pavan Kumar	A
22095A0407	K. Deveswar Reddy	A
408	G. Dharma Teja	A
409	K. Elizabeth Rani	A
411	G. Gangothri	A
413	K. Harika	A
415	Z. Hemanth Kumar	A
417	J. Jayavardan	1
422	P. Mani Teja	A
428	P. Rameeja	A
429	S. Ruksana	A
435	K. Sreenivas	A
436	N. Varun Kumar	A
Signature of Teacher		
Signature of H.O.D.		
Signature of Principal		

	28/06/23	30/06/23	01/07/23	04/07/23	05/07/23	06/07/23	07/07/23	07/07/23			
Roll No.	46	47	48	49	50	51	52	53	54	55	56
07	35	36	37	38	39	40	41	42			
7	A	36	37	38	39	40	41	42			
8	33	34	35	36	37	38	39	40			
9	32	33	34	35	36	37	A	A			
11	36	37	38	39	40	41	42	A			
13	37	38	39	40	41	42	43	A			
15	36	37	A	38	39	40	41	A			
17	38	39	40	41	42	43	A	A			
22	33	34	35	36	37	38	39	A			
28	A	A	A	A	A	A	A	A			
29	35	36	37	38	39	40	41	A			
35	34	35	36	37	38	39	40	41			
36	35	36	37	38	39	40	A	A			

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER

Academic Year from 2022-23 to .... Teacher YMSR

Subject & Credits ECA&D Dept ECE

INTERNAL / RECORD MARKS

Roll No.	Assignments 1	Assignments 2	Assignments Average (A)	Internal Test 1	Internal Test 2	Internal Marks 75% of MAX	Internal Marks 25%of MIN	Internal Marks Total (I)	Final Internal (I+A)	Remarks
65	10	10	10	07	16	12	1.75	13.75	24	
66	10	10	10	06	13	9.75	1.5	11.25	22	
67	10	10	10	07	12	9	1.75	10.75	21	
68	10	10	10	03	05	3.75	0.75	4.5	15	
69	10	10	10	13	12	9.75	3	12.75	23	
70	10	10	10	13	19	14.25	3.25	17.5	28	
71	10	10	10	10	11	8.25	2.5	10.75	21	
72	10	10	10	07	10	7.5	1.75	9.25	20	
73	10	10	10	14	19	14.25	3.5	17.75	28	
74	10	10	10	05	07	5.25	1.25	6.5	17	
75	10	10	10	13	19	14.25	3.25	17.5	28	
76	10	10	10	10	07	7.5	1.75	9.25	20	
77	10	10	10	09	10	7.5	2.25	9.75	20	
78	10	10	10	05	10	7.5	1.25	8.75	19	
79	10	10	10	08	09	6.75	2	8.75	19	
80	9	8+1	9	01	07	5.25	0.25	5.5	15	
81	10	10	10	13	16	12	3.25	15.25	26	
82	10	10	10	13	19	14.25	3.25	17.5	28	
83	10	10	10	09	10	7.5	2.25	9.75	20	
84	10	10	10	03	09	6.75	0.75	7.5	18	
85	10	10	10	09	11	8.25	2.25	10.5	21	
86	10	10	10	14	18	13.5	3.5	17	27	
87	10	10	10	11	16	12	2.75	14.75	25	
88	10	10	10	11	16	12	2.75	14.75	25	
89	10	18	10	03	11	8.25	0.75	9	19	
90	10	08	9	09	14	10.5	2.25	12.75	22	
91	10	10	10	10	17	11.75	2.5	14.25	26	
92	10	10	10	13	19	14.25	3.25	17.5	28	
94	10	10	10	15	12	11.25	3	14.25	25	
95	10	10	10	09	18	13.5	2.25	15.75	26	

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER Academic Year from.....................to.....................Teacher...YMSR...

Subject & Credits.......ECA2D 203.......Dept.......ECE.......

INTERNAL / RECORD MARKS

Assignments				Internal Test		Internal Marks			Final Internal (I+A)	Remarks
Roll No.	1	2	Average (A)	1	2	75% of MAX	25%of MIN	Total (I)		
96	10	10	10	15	18	13.5	3.75	17.25	28	
97	10	10	10	13	19	14.25	3.25	17.5	28	
98	10	10	10	05	10	7.5	1.25	8.75	18	
99	10	10	10	14	19	14.25	3.5	17.75	28	
A0	10	10	10	05	10	7.5	1.25	8.75	18	
A1	10	10	10	09	14	10.5	2.25	12.75	23	
A2	10	10	10	10	14	10.5	2.5	13	23	
A3	9	9	9	07	17	12.75	1.75	14.5	24	
A4	10	10	10	14	19	14.25	3.5	17.75	28	
A5	10	10	10	09	14	10.5	2.25	12.75	23	
A6	10	10	10	07	13	9.75	1.75	11.5	22	
A7	10	10	10	09	15	11.25	2.25	13.5	24	
A8	10	10	10	13	19	14.25	3.25	17.5	28	
A9	10	10	10	10	15	11.25	2.5	13.75	24	
B0	10	10	10	09	15	11.25	2.25	13.5	24	
B1	8	9	9	02	11	8.25	0.5	8.75	18	
B2	9	9	9	03	10	7.5	0.75	8.25	18	
B3	10	10	10	11	17	12.75	2.75	15.5	26	
B4	10	10	10	04	05	3.75	1	4.75	15	
B5	10	10	10	10	11	8.25	2.5	10.75	21	
B6	10	10	10	05	07	5.25	1.25	6.5	17	
B7	10	10	10	07	12	9	1.75	10.75	21	
B9	10	10	10	06	15	11.25	1.5	12.75	23	
C0	10	10	10	17	19	14.25	4.25	18.5	29	
C1	10	10	10	06	11	8.25	1.5	9.75	20	
C2	10	9	9.5	01	06	4.5	0.25	4.75	15	
C3	10	10	10	13	18	13.5	3.25	16.75	27	
C4	10	10	10	11	19	14.25	2.75	17	27	
C5	10	10	10	11	19	14.25	2.75	17	27	
C6	10	10	10	18	19	14.25	4.5	18.75	29	

& TECHNOLOGY (Autonomous), NANDYAL.

REGISTER

Academic Year from......................to......................Teacher YMSR

Subject & Credits ECA2D 2.03 Dept ECE

INTERNAL / RECORD MARKS

Assignments				Internal Test		Internal Marks			Final Internal (I+A)	Remarks
Roll No.	1	2	Average (A)	1	2	75% of MAX	25%of MIN	Total (I)		
02	10	10	10	09	11	8.25	2.25	10.5	21	
7	10	10	10	14	19	14.25	3.5	17.75	28	
8	10	10	10	07	14	10.5	1.75	12.25	23	
9	10	10	10	15	14	11.25	3.5	14.75	25	
11	10	10	10	15	19	14.25	3.75	18	28	
13	10	10	10	15	19	14.25	3.75	18	28	
15	10	10	10	13	15	11.25	3.25	14.5	25	
17	10	10	10	14	19	14.25	3.5	17.75	28	
22	10	10	10	17	19	14.25	4.25	18.5	29	
28	00	00	00	A	A	00	00	00	00	
29	10	10	10	14	19	14.25	3.5	17.75	28	
35	10	10	10	09	19	14.25	2.25	16.5	27	
36	10	10	10	10	17	12.75	2.5	15.25	26.	

LECTURE RECORD

Subject : ECA&D
Total Exams........2........

Credits : 03
Each for........2........hrs.

Internal Mid Exam Marks : 02
Total quizes –

Internal Quiz Marks : –
No. of Assignment........2........

S.No.	Date	Topic Covered / Exercise Completed	Remarks
1	1Ø03/23	No class due to less strength	1 1
2	16/03/23	No class due to less strength	1 2
3	17/03/23	No class due to less strength	1 3
4	18/03/23	Introduction to electronic circuits	1 4
5	21/03/23	Introduction to diode, transistors	1 5
6	23/03/23	Review of EDC	1 6
7	24/03/23	Introduction to ECA&D	1 7
8	25/03/23	IEEE Seminar on usage of IEEE membership	1 8
9	03/04/23	Basic CE and CE with Re amplifier	1 9
10	04/04/23	Analysis of DC and AC load line	1 10
11	06/04/23	Introduction to h-parameters	1 11
12	11/04/23	Definations & typical values of h-parameters	1 12
13	25/04/23	Analysis of general transistor amplifier	1 13 K Malle 13/4/23
14	27/4/23	Analysis of CE amplifier using exact model	1 14
15	28/4/23	Analysis of CB amplifier using exact model	1 15
16	02/05/23	Problems on CE & CC	1 16
17	02/05/23	Simplified model of CE	1 17
18	03/05/23	CE amplifier with Re resistor	1 18
19	03/05/23	Problems on CE. CC, CB.	1 19
20	04/05/23	Analysis of CS amplifier	1 20
21	05/05/23	Analysis of CD amplifier	1 21
22	05/05/23	Analysis of CG amplifier	1 22
23	05/05/23	Introduction to multistage amplifier & classification.	1 23 — Unit - II
24	06/05/23	RC coupled, transformer coupled, Direct coupled amplifier	1 24
25	09/05/23	Analysis of CE-CE, CE-CC amplifiers	1 25
26	10/05/23	Analysis of CE-CB, CC-CC Amplifier	1 26
27	10/05/23	Introduction to differential amplifier - classification	1 27
28	11/05/23	Modes of MOSFET differential amp.	1 28
29	12/05/23	Modes of BJT differential amp.	1 29
30	23/05/23	Introduction to feedback Amplifier	1 30 Unit - IV
31	08/06/23	Classification & Block diagram	1 31
32	09/06/23	Characteristics of -ve fb on gain & stability	1 32
33	12/06/23	Noise, Distortion & BW	1 33
34	13/06/23	Change in i/p & o/p impedances	1 34
35	14/06/23	Problems.	1 35

LECTURE RECORD

S.No.	Date	Topic Covered / Exercise Completed	Remarks
36	15/06/23	Analysis of voltage series fb amp	1 36
37	16/06/23	Analysis of current series fb amp.	1 37
38	17/06/23	Analysis of voltage shunt fb amp.	1 38
39	20/06/23	Analysis of current shunt fb amp.	1 39
40	21/06/23	Introduction to oscillators & classification	1 40 unit -VI
41	21/06/23	RC phase shift oscillator	1 41
42	22/06/23	wein bridge oscillator	1 42
43	23/06/23	Problems on above two oscillators	1 43 26/6/23
44	27/06/27	LC oscillators- Heartley	1 44
45	27/06/23	Colpits oscillator	1 45
46	28/06/23	Crystal oscillator	1 46
47	30/06/23	Fraquency & Amplitude stability	1 47
48	01/07/23	Tuned amplifier	1 48
49	04/07/23	Introduction to power Amplifier & classification	unit -V 1 49
50	05/07/23	class A power Amplifier - direct fed & transformer coupled	1 50
51	06/07/23	class B PA- Push pull & complementary & Symmetry	1 51
52	07/07/23	Class AB power amplifier	1 52 7/7/23

Assignment - I

Name :- M.Sharmi

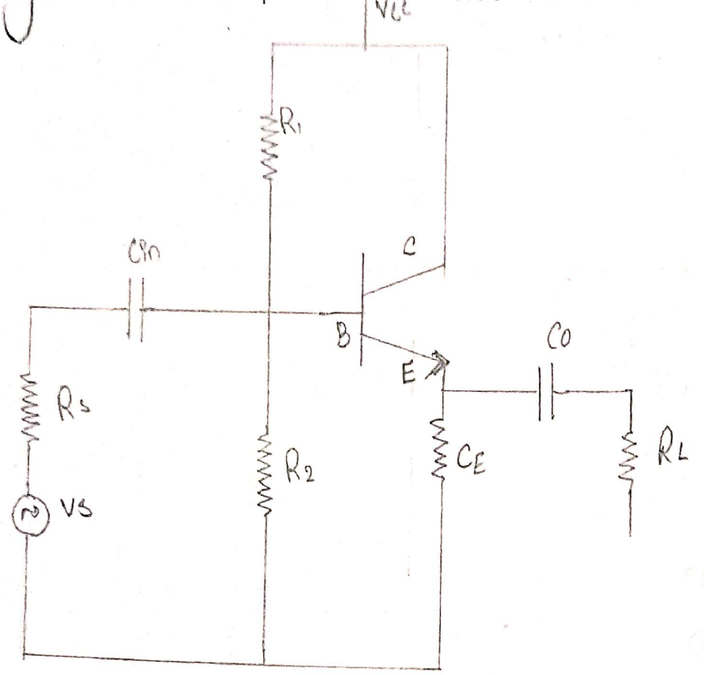
Regd no:- 21091A0413 year :- II / II sem

10

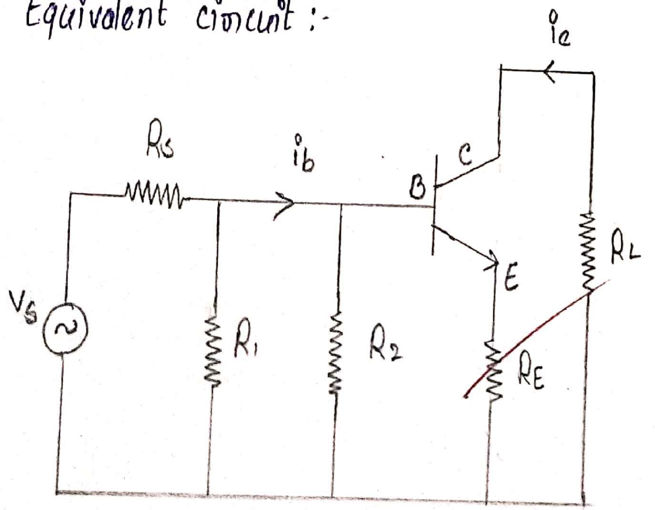
Subject :- Eca&d

Branch :- ECE

1) Analysis of cc amplifier in Exact Model.

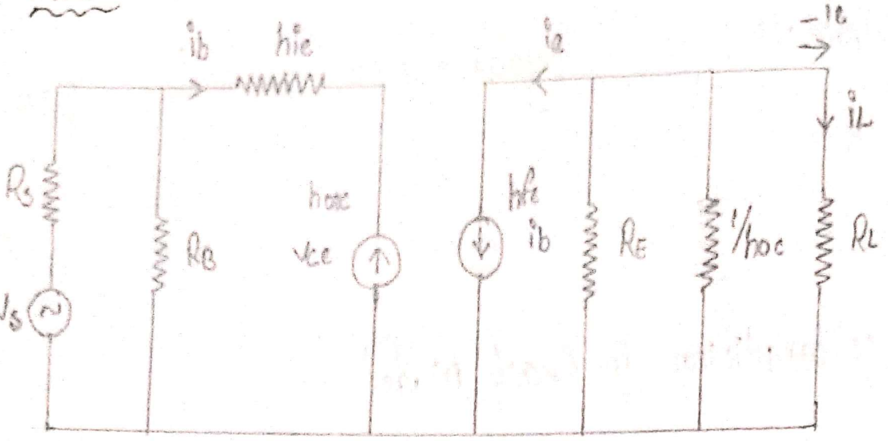


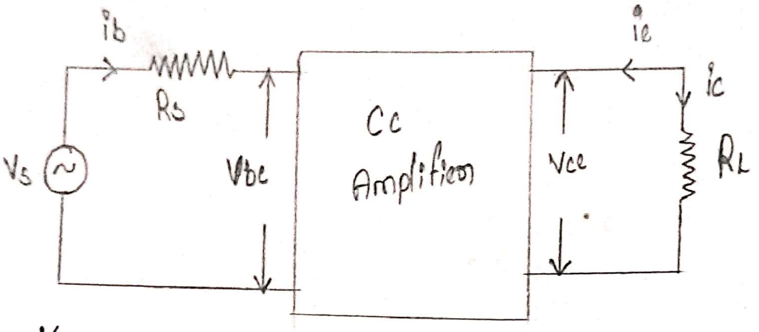
AC Equivalent circuit :-



* Reduce all dc Sources are connected to ground
* All capacitors are short Circuited

Hybrid Model :-





$V_1 = h_{11} i_1 + h_{12} V_2$

$i_2 = h_{21} i_1 + h_{22} V_2$

$V_{bc} = h_{ie} i_b + h_{rc} V_{ce} \longrightarrow (1)$

$i_e = h_{fc} i_b + h_{oc} V_{ce} \longrightarrow (2)$

i_L (or) $i_2 = -\frac{V_{ce}}{R_L} \longrightarrow (3)$

Input impedence :-

$Z_{in} = \frac{V_{be}}{i_b} \longrightarrow (4)$

Sub eqn(3) in eqn (4)

$$Z_{in} = \frac{h_{ic} i_b + h_{rc} V_{ce}}{i_b}$$

$$Z_{in} = h_{ie} + \frac{h_{rc} V_{ce}}{i_b} \longrightarrow (5)$$

From eqn (2) and eqn (3)

$$-\frac{V_{ce}}{R_L} = h_{fe}\, i_b + h_{oe} V_{ce}$$

$$h_{fe}\, i_b = \frac{-V_{ce}}{R_L} - h_{oe} V_{ce}$$

$$h_{fe}\, i_b = -V_{ce}\left(1/R_L + h_{oe}\right)$$

$$\frac{V_{ce}}{i_b} = \frac{-h_{fe}}{1/R_L + h_{oe}} \longrightarrow (6)$$

eqn (6) in eqn (5)

$$Z_{in} = h_{ie} + h_{oe}\left(\frac{-h_{fe}}{1/R_L + h_{oe}}\right)$$

$$\boxed{Z_{in} = h_{ie} - \frac{h_{fe} h_{oe}}{1/R_L + h_{oe}}}$$

Current gain :-

$$A_I = i_c / i_b$$

From eqn (3) $i_c = -\frac{V_{ce}}{R_L}$

$$V_{ce} = -i_c R_L$$

eqn (2) $i_c = h_{fe}\, i_b + h_{oe} V_{ce}$

$$i_c = h_{fe}\, i_b + h_{oe}(-i_c R_L)$$

$$i_c = h_{fe}\, i_b - h_{oe}\, i_c R_L$$

$$h_{fe}\, i_b = i_c (1 + h_{oe} R_L)$$

$$\frac{i_c}{i_b} = \frac{-h_{fe}}{1 + h_{oe} R_L'}$$

$$\boxed{A_I = \frac{-h_{fe}}{1 + h_{oe} R_L'}}$$

Voltage gain :-

$$A_V = \frac{V_{ce}}{V_{be}}$$

From eqn(4) $Z_{in} = \frac{V_{bc}}{i_b}$

$$V_{bc} = Z_{in}\, i_b$$

$$A_V = \frac{V_{ce}}{Z_{in}\, i_b}$$

$$\boxed{A_V = \frac{-h_{fe}}{1/R_L + h_{oe}} \times \frac{1}{Z_{in}}}$$

Output Impedence :-

$$Z_o = \frac{V_{ce}}{i_e}$$

From eqn (2)

$$i_e = h_{fe} I_b + h_{oe} V_{ce}$$

divide by V_{ce}

$$\frac{i_e}{V_{ce}} = \frac{h_{fe} i_b + h_{oe} V_{ce}}{V_{ce}}$$

$$\frac{i_e}{V_{ce}} = \frac{h_{fe} i_b}{V_{ce}} + h_{oe} \longrightarrow (7)$$

From eqn (1)

$$V_{bc} = h_{ie} i_b + h_{re} V_{ce}$$

$$V_{bc} = 0$$

$$h_{ie} i_b = -h_{re} V_{ce}$$

$$\frac{i_b}{V_{ce}} = \frac{-h_{re}}{h_{ie}} \longrightarrow (8)$$

From (7) and (8)

$$\frac{i_e}{V_{ce}} = h_{fe}\left(\frac{-h_{re}}{h_{ie}}\right) + h_{oe}$$

$$\frac{i_e}{V_{ce}} = \frac{-h_{fe} h_{re} + h_{oe} h_{ie}}{h_{ie}}$$

$$\boxed{Z_o = \frac{h_{ie}}{h_{oe} h_{ie} - h_{fe} h_{re}}}$$

Input effective Impedence $Z_{in}' = R_B \| Z_{in}$

Effective output impedence $Z_o' = R_E \| R_L \| Z_o$

Input impedence with source $Z_{is} = R_s + Z_i$

A_{Is} = current gain including source

$$A_{Is} = A_I \times \frac{R_s'}{R_s' + Z_i}$$

A_{vs} = voltage gain including source

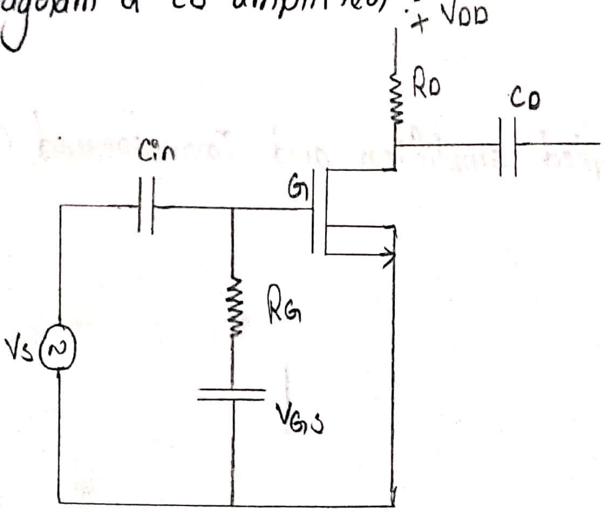
$$A_{vs} = A_v \times \frac{R_i'}{R_i' + R_s} \quad \boxed{R_i' = z_i'}$$

Z_o'' = output impedence with load

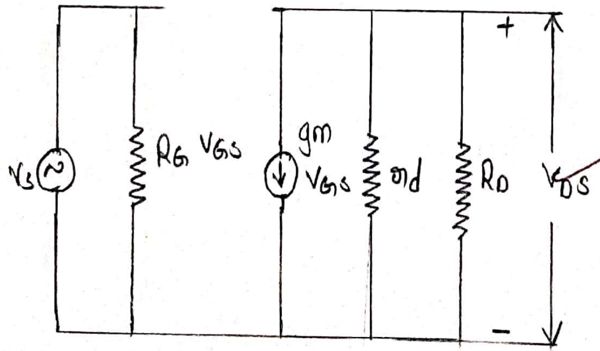
$Z_o'' = Z_o' \,//\, R_L$

2) Analysis of FET CS Amplifier

circuit Diagram of cs amplifier :-



Hybrid Model



current gain :-

$$\frac{i_d}{i_g} = i_d/0 = \infty$$

Input impedence :-

$i_g = 0$

$$Z_i = \frac{V_{gs}}{i_g} = \infty$$

Effective input impedence

$$Z_i' = z_i || R_g$$
$$= \infty || R_g$$
$$Z_i' = R_g$$

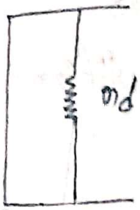
Voltage gain :

$$A_V = \frac{V_{DS}}{V_{GS}}$$
$$A_V = -g_m(r_d || R_D)$$
$$V_{DS} = -g_m V_{GS}[r_d || R_D]$$
$$A_V = -g_m(r_d || R_D)$$
$$g_m = i_d / V_{GS}$$
g_m = Transconductance

Output impedence :

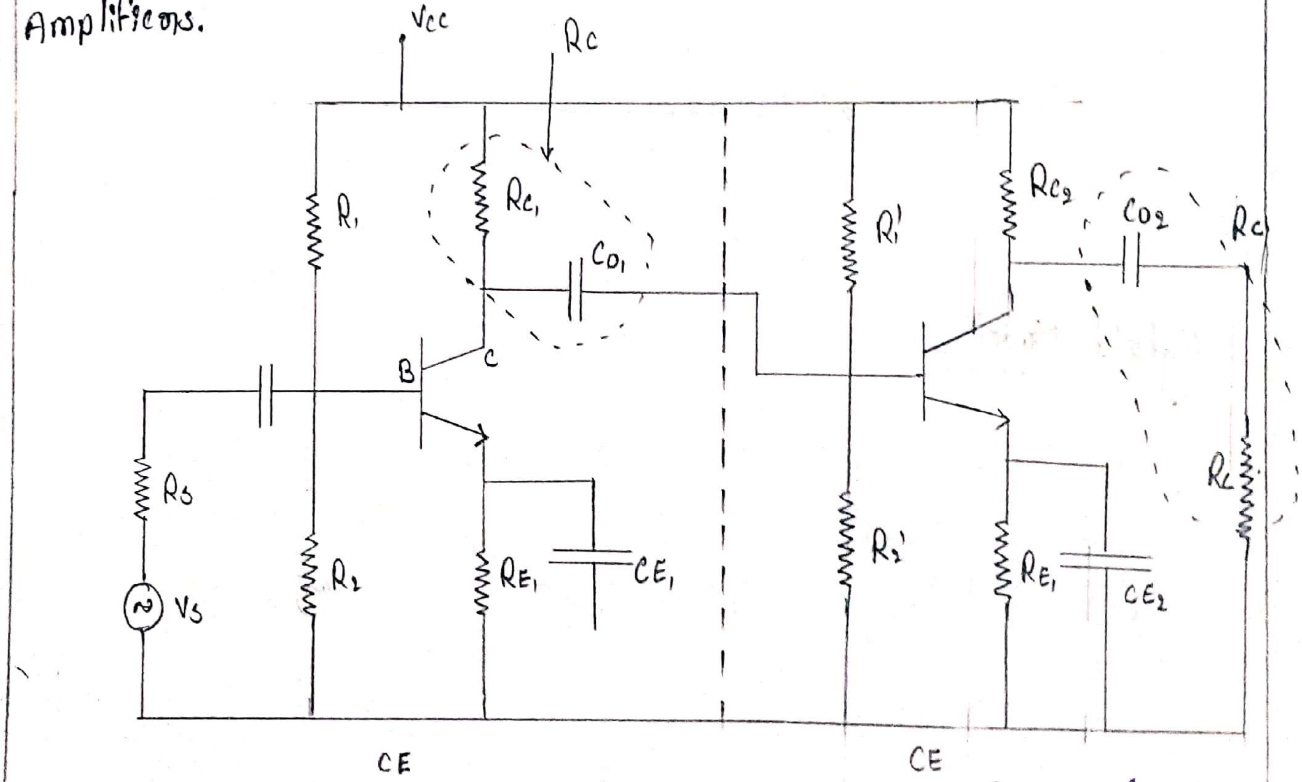
$$Z_o = \frac{V_{DS}}{i_d} \Big|_{V_{GS}=0,\ R_d = \text{disconnected}}$$
$$Z_o = r_d$$

Effective output impedence :-



$$Z_o' = Z_o || R_D$$

3) Explain Two stage R.C coupled amplifier and Transformed Coupled Amplifiers.



* this is the most popular type of Coupling because of amplification and this is cheap and provide excellent amplification.

* In the above fig we consider CE-CE amplifier 1st stage is CE and

2nd stage is also CE amplifier is called cascading.

- * Coupling capacitor is used to Transfer output signal from one stage is cc and to next stage.
- * output is taken first coupling capacitor, this o/p is given to next CE amplifier as input.

Disadvantages

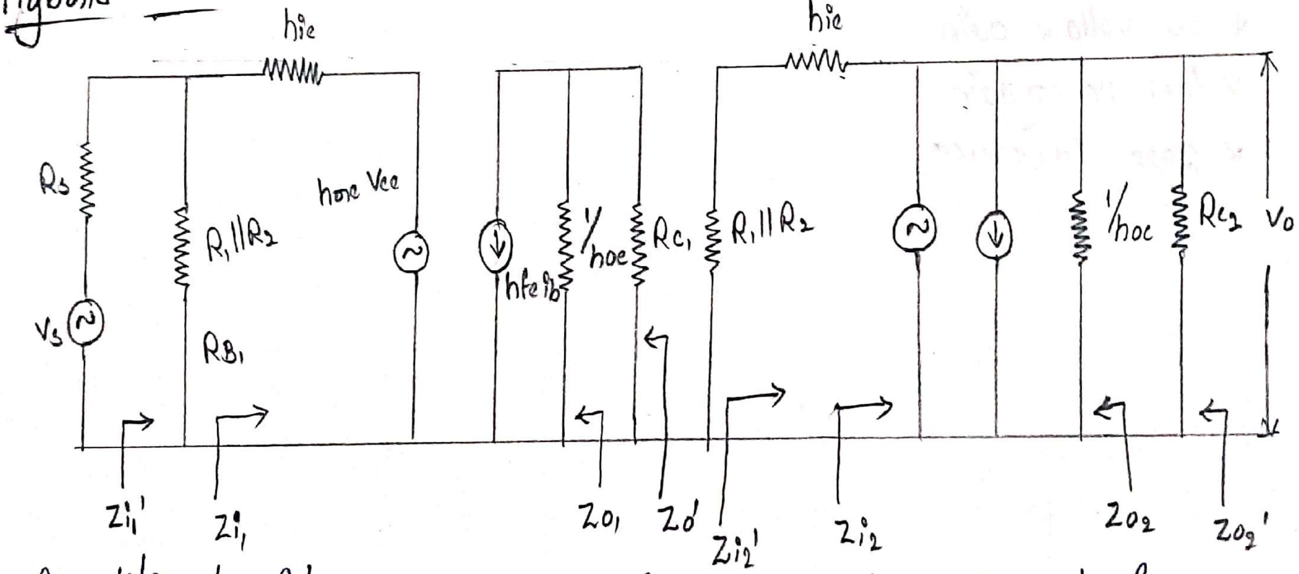
- * It has low voltage and power gain

Advantages :-

- * Easy to construct
- * less cost

Applications:- used in voltage amplifier

Hybrid Model :-



If condition hoe $R_L' \leq 0.1$ satisfies below formulas

1) $AI_2 = -h_{fe} = AI_1$

2) $Zin_2 = h_{ie} = Zin_1$

3) $Zi_2' = Zi_2 \,||\, R_B = Zi_1'$

4) $AV_2 = \dfrac{-h_{fe} R_L'}{Zi_2} = AV_1$

If condition does not satisfies we use below formulas

1) $Zi_1 = h_{ie} - \dfrac{h_{fe} h_{re}}{1/R_L + h_{oe}} = Zi_2$

2) $AI_1 = \dfrac{-h_{fe}}{1 + h_{oe} R_L'} = AI_2$

3) $AV_1 = \dfrac{-h_{fe}}{1/R_L + h_{oe}} \times \dfrac{1}{Zin} = AV_2$

4) $Zo_1 = \dfrac{h_{ie}}{h_{oe} h_{ie} - h_{fe} h_{re}} = Zo_2$

5) $Z_{o_2} = \infty = Z_{o_2}$ 5) $Z_{o_1}' = Z_{o_1} \| R_L = Z_{o_2}'$

6) $Z_{o_2}' = Z_{o_2} \| R_C = Z_{o_2}'$

over all :

$A_I = A_{I_1} * A_{I_2}$

$A_V = A_{V_1} * A_{V_2}$

$Z_I = Z_{i_1}'$

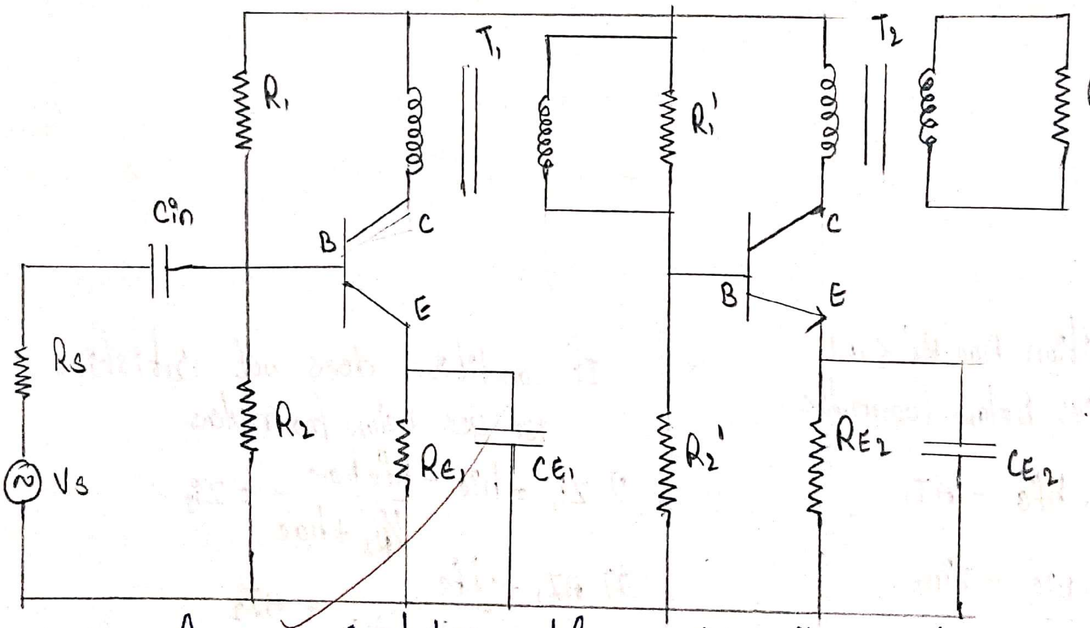
$Z_{o_2} = Z_{o_2}'$

Transformer Coupled Amplifier

The drawback of Rc coupled amplifier is overcome by using Transformer coupled Amplifier.

⇒ Drawbacks of Rc Coupled Amplifier

- * low voltage gain
- * low power gain
- * poor impedance



* In Transformer Coupled amplifier when the collector resistor Rc replaced by Transformer.

Operation:-

* when AC signal is applied to the base of 1st Transformer it

appears amplifier from across the primary of the coupling transformer.

- * The amplified signal is transformed to input to the next stage by Secondary Transformer.
- * In 2nd stage it is further amplified and appears across primary of 2nd Transformer.
- * From Secondary Transformer the output is Transformed.
- * In this Amplifier frequency response is poor because Transformer losses and gain is also unstable.

Advantages:-

- * High Voltage gain and high power gain
- * It has good impedence match
- * No Signal losses in collector or base resistor

Disadvantages:-

- * poor frequency response
- * Because of that RC coupled resistor Transformer is expansive and bulky.

Applications:-

- * Used in impedence matching.
- * It is used in Radio and TV receives to amplify RF signal.

4) Explain differentia modes in Mos Differential Amplifier.

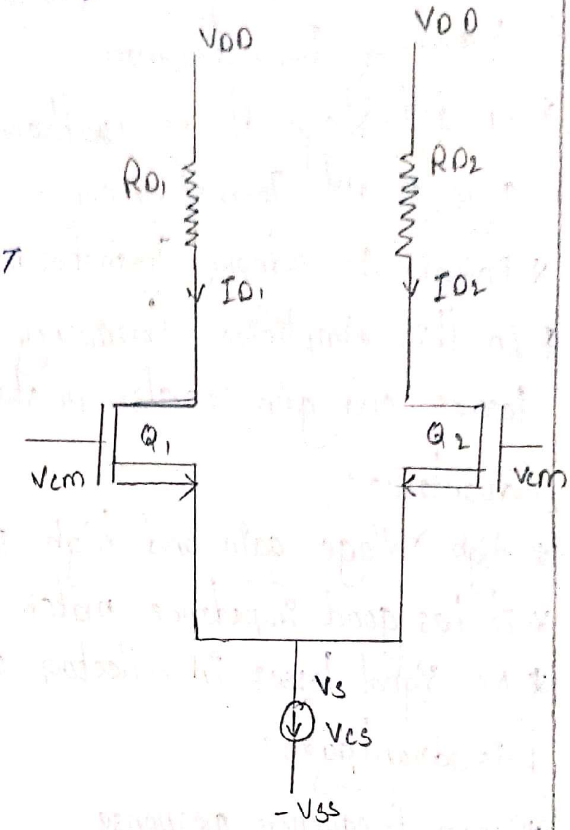
There are four modes in Mos differential Amplifier.

1. common i/p mode
2. Differential i/p mode
3. large signal i/p mode
4. small signal i/p mode

1. Common i/p mode:-

when same i/p voltage is applied to two transistors Q_1, Q_2 the differantial amplifier is operates in common mode

⇒ when the two transistors operate in saturation region the total current Equally distribute into $I_{D1} = I_{D2} = I/2$



$$I = I_{D1} + I_{D2}$$

$$V_S = V_{cm} - V_{gs}$$

$$I_{D1} = I/2 = \frac{k_n'}{2}\frac{W}{L}(V_{GS} - V_t)^2$$

WKT drain current Equation of MOSFET

$$V_{GS} - V_t = V_{ov}$$

V_{ov} = overdrive voltage

$$I_{D1} = I = \frac{k_n' W}{L}(V_{ov})^2$$

$$V_{ov} = \sqrt{\frac{I}{\frac{k_n' W}{L}}}$$

$V_S = V_t$

$V_S = -V_t$

From Drain side

$V_{D1} = V_{DD} - I/2\, R_{D1}$ $\quad V_{D1} = V_{D2}$

$V_{D2} = V_{DD} - I/2\, R_{D2}$ $\quad V_o = 0$

⇒ Because of same voltage output voltage becomes '0'

⇒ common mode voltage range $\begin{cases} V_{cm}(max) = V_D + V_t \\ V_{cm}(min) = -V_{SS} + V_{CS} + V_{GS} \end{cases}$

$$V_{cm}(min) \le V_{cm} \le V_{cm}(max)$$

2) Differential i/p mode

⇒ In differential i/p mode the i/p voltage applied to Q_1 transistor and Q_2 transistor is connected to ground

$$I = I_{D1} + I_{D2}$$

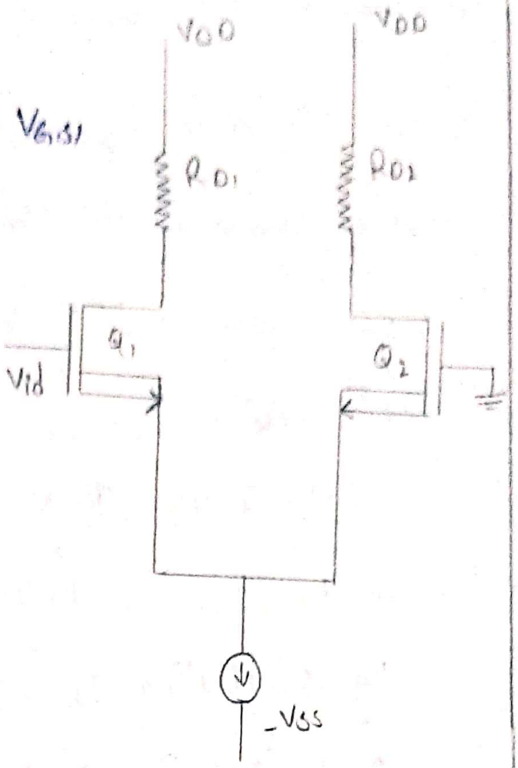
$$I = I_{D1} + I_{D2} = 0$$

$$V_{ov} = \sqrt{\frac{2x}{\frac{k_n' W}{L}}}$$

If vid is +ve $I_{D1} > I_{D2}$ then

$$V_o = V_{GS2} - V_{GS1} \text{ is } +ve$$

⇒ If Vid is -ve then $V_{GS1} < V_{GS2}$ (or) $V_{GS2} > V_{GS1}$



$$I_{D1} = I = \frac{k_n'}{2}\frac{W}{L}\left[V_{GS1} - V_t\right]^2$$

By solving this

$$V_{GS1} = V_t + \sqrt{\frac{2I}{\frac{k_n'W}{L}}}$$

$$\frac{I}{\frac{k_n'W}{L}} = V_{ov} \text{ when } I_{D1} = I/2$$

$$V_{GS1} = V_t + \sqrt{2}\,V_{ov}$$

$$V_{id} = V_{GS1} - V_t$$

$$= \cancel{V_t} + \sqrt{2}\,V_{ov} - \cancel{V_t}$$

$$\boxed{V_{id} = \sqrt{2}\,V_{ov}}$$

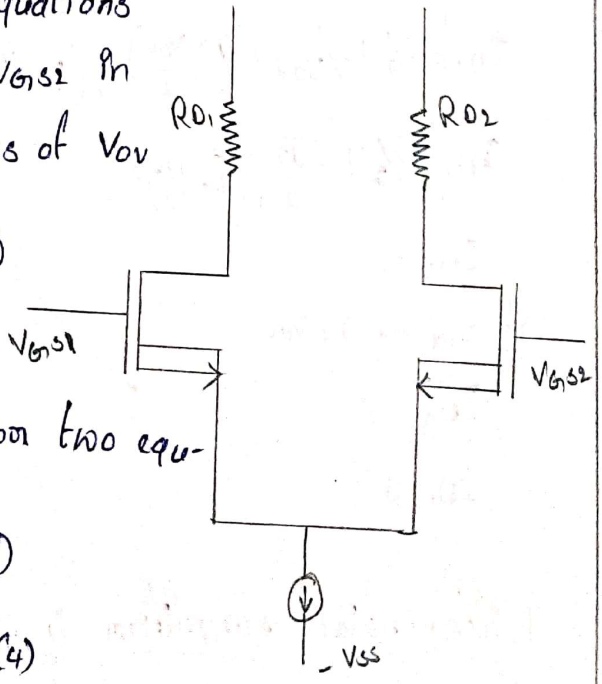
if vid = -ve

$$V_{id} = -\sqrt{2}\,V_{ov}$$

so it is from $-\sqrt{2}\,V_{ov} \leq V_{id} \leq \sqrt{2}\,V_{ov}$

3) Differential Amplifier in large ~~small~~ signal i/p mode:-

In large signal mode the current equations are derived interms of V_{GS1} and V_{GS2} in terms of V_{GS1} and V_{GS2} or interms of V_{ov}



$$I_{D1} = \frac{I}{2} = \frac{k_n'W}{2L}(V_{GS1} - V_t)^2 \longrightarrow ①$$

$$I_{D2} = I/2 = \frac{k_n'W}{2L}(V_{GS2} - V_t)^2 \longrightarrow ②$$

Apply square roots on both sides for two equations

$$\sqrt{I_{D1}} = \sqrt{\frac{k_n'W}{L}}\,(V_{GS1} - V_t) \longrightarrow (3)$$

$$\sqrt{I_{D2}} = \sqrt{\frac{k_n'W}{L}}\,(V_{GS2} - V_t) \longrightarrow (4)$$

$$\sqrt{I_{D1}}-\sqrt{I_{D2}}=\sqrt{\frac{k_n'W}{L}}\left(V_{GS1}-V_t\right)-\sqrt{\frac{k_n'W}{L}}\left(V_{GS2}-V_t\right)$$

$$=\sqrt{\frac{k_n'W}{L}}\left(V_{GS1}-V_{GS2}\right)\longrightarrow(5)$$

Apply square on both sides

$$\left(\sqrt{I_{D1}}-\sqrt{I_{D2}}\right)^2=\frac{k_n'W}{L}\left(V_{GS1}-V_{GS2}\right)^2$$

$$\sqrt{I_{D1}}^2+\sqrt{I_D}^2-2\sqrt{I_{D1}I_{D2}}=\frac{k_n'W}{L}V_{id}^2$$

$$I-2\sqrt{I_{D1}I_{D2}}=\frac{k_n'W}{L}V_{id}^2\longrightarrow(6)$$

By $2\sqrt{I_{D1}I_{D2}}=I-\frac{k_n'W}{L}V_{id}^2\longrightarrow(6)$

By substituting $I_{D2}=I-I_{D1}$

$$2\sqrt{I_{D1}(I-I_{D1})}=I-\frac{k_n'W}{L}V_{id}^2$$

By simplifying this we get

$$I_{D1}=I/2+I/V_{ov}\left(\frac{V_{id}}{2}\right)\sqrt{1-\left(\frac{V_{id}/2}{V_{ov}}\right)^2}$$

$$I_{D2}=I/2-I/V_{ov}\left(\frac{V_{id}}{2}\right)\sqrt{1-\left(\frac{V_{id}/2}{V_{ov}}\right)^2}$$

If $V_{id}=\sqrt{2}\,V_{ov}$

$$I_{D1}=I/2+I/V_{ov}\left(\frac{\sqrt{2}\,V_{ov}}{2}\right)\sqrt{\left(1-\frac{\sqrt{2}\,V_{ov}/2}{V_{ov}}\right)^2}$$

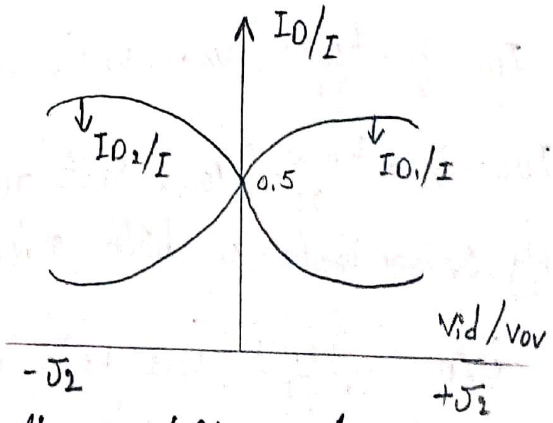
$$I_{D1}=I/2+\frac{I\sqrt{2}}{2}\sqrt{(1-1/2)^2}$$

$$I_{D1}=I$$

if $V_{id}=-\sqrt{2}\,V_{ov}$

$$I_{D2}=I$$

$$I_{D1}=0$$



Differential Amplifier in Small Signal i/p mode:-

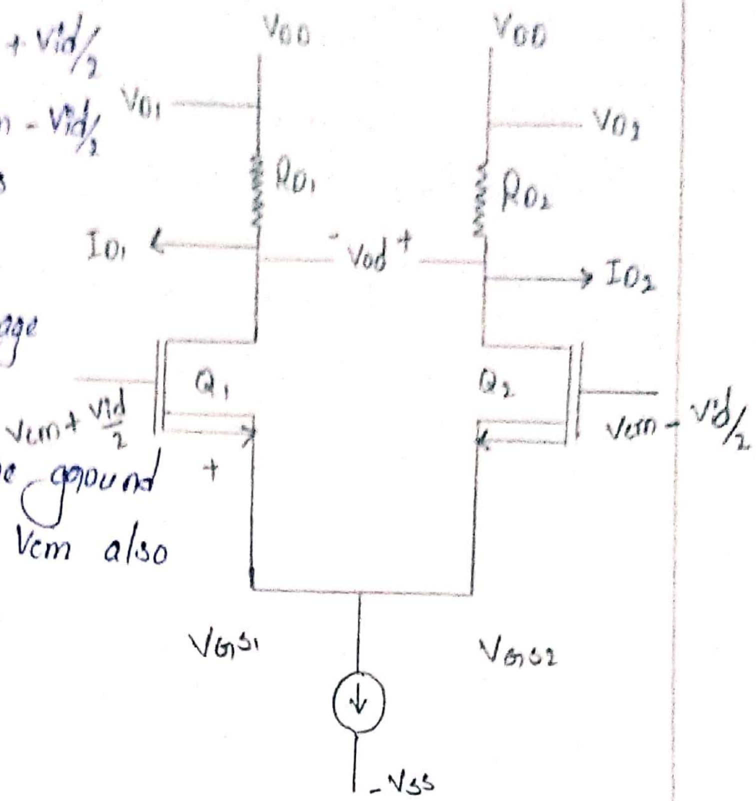
⇒ In this small signal mode we are applying $V_{cm}\pm V_{id}/2$

for Q_1 transistor we applying $V_{cm} + V_{id}/2$
for Q_2 transistor we applying $V_{cm} - V_{id}/2$

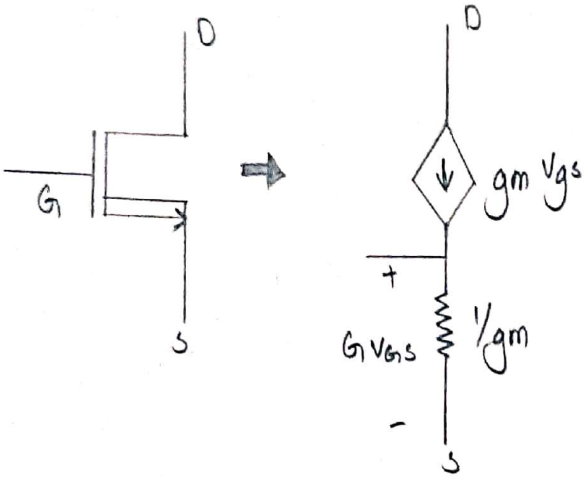
⇒ In this mode the MOS transistors are operated in active region

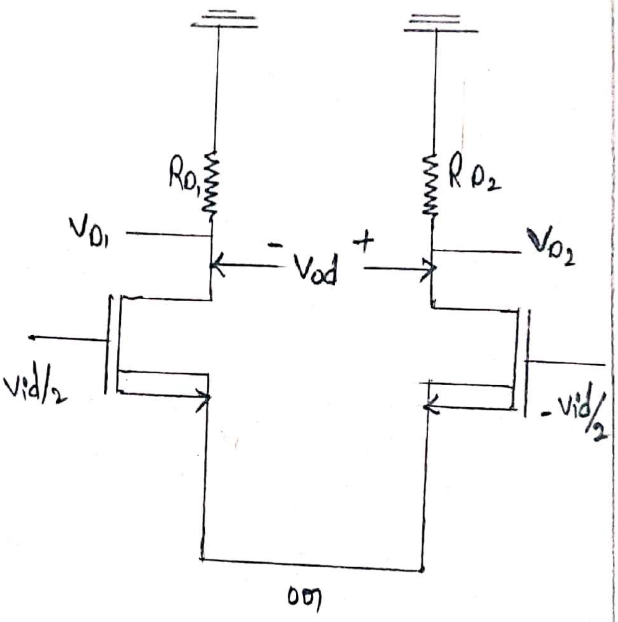
⇒ V_{cm} is required to set DC voltage of MOSFET

& By considering all dc voltages are ground and capacitors are become short, V_{cm} also zero and current source to zero.



Ac Equivalent CKT :-





$$V_{D1} = -gm \frac{V_{id}}{2} R_D$$

$$V_{D2} = gm\ V_{id}/_2\ R_D$$

$$V_0 = V_{D2} - V_{D1}$$

$$= gm \frac{V_{id}}{2} R_D + gm \frac{V_{id}}{2} R_D$$

$$V_0 = 2gm \frac{V_{id}}{2} R_D$$

$$V_0 = gm\ V_{id}\ R_D$$

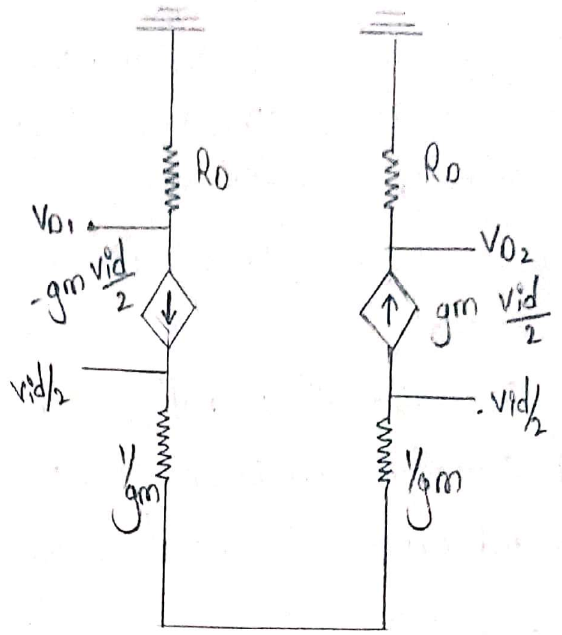
$$\frac{V_0}{V_{id}} = gm\ R_D$$

Ad = differential gain

Ad = $g_m R_D$ by consider 'r_d'

Ad = $g_m (R_D \| r_d)$

$g_m = \frac{2I_D}{V_{ov}}$; $r_d = \frac{2V_A}{I}$



Assignment - I

Name:- P. Hemalatha

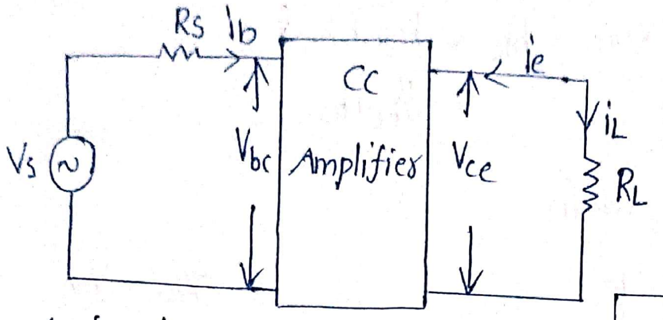
SUBJECT :- ECAKD

Reg No:- 22095A0414

Branch:- ECE (CC) Year:- II year

10

1) Analysis of CC Amplifier in exact Model.



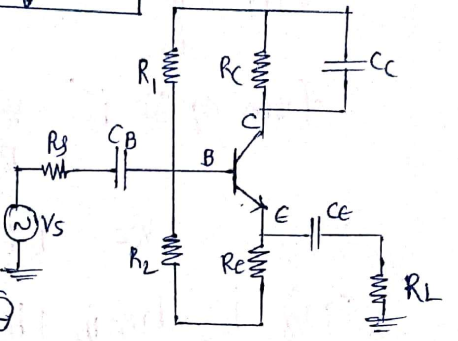
$$V_1 = h_{11} i_1 + h_{12} V_2$$

$$i_2 = h_{21} i_1 + h_{22} V_2$$

$$V_{bc} = h_{ic} i_b + h_{rc} V_{ce} \rightarrow ①$$

$$i_e = h_{fc} i_b + h_{oc} V_{ce} \rightarrow ②$$

$$i_L \text{ (or) } i_2 = \frac{-V_{ce}}{R_L} \rightarrow ③$$



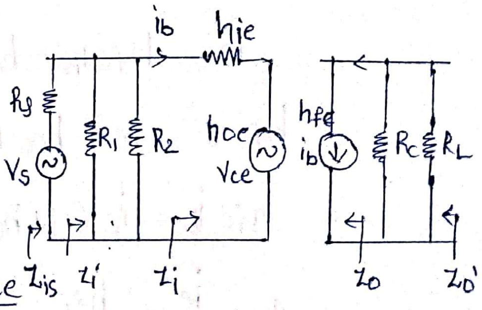
ckt diagram

Input impedance :-

$$Z_{in} = \frac{V_{bc}}{i_b} \rightarrow ④$$

sub eq ③ in eq ④

$$Z_{in} = \frac{h_{ic} i_b + h_{rc} V_{ce}}{i_b}$$



Hybrid model

$$Z_{in} = h_{ic} + \frac{h_{rc} V_{ce}}{i_b} \rightarrow ⑤$$

from eq ② & ③

$$\frac{-V_{ce}}{R_L} = h_{fc} i_b + h_{oc} V_{ce}$$

$$h_{fc} i_b = \frac{-V_{ce}}{R_L} - h_{oc} V_{ce}$$

$$h_{fc} i_b = -V_{ce}\left(\frac{1}{R_L} + h_{oc}\right)$$

$$\frac{V_{ce}}{i_b} = \frac{-h_{fc}}{1/R_L + h_{oc}} \rightarrow ⑥$$

Voltage gain :-

$$A_v = \frac{V_{ce}}{V_{bc}}$$

from eq ④ $Z_{in} = \frac{V_{bc}}{i_b}$

$$V_{bc} = i_b Z_{in}$$

$$A_v = \frac{V_{ce}}{i_b Z_{in}}$$

eq ⑥ in eq ⑤

$$Z_{in} = h_{ic} + h_{rc}\left(\frac{-h_{fc}}{1/R_L + h_{oc}}\right)$$

$$Z_{in} = h_{ic} - \frac{h_{fc} h_{rc}}{1/R_L + h_{oc}}$$

$$\boxed{Z_{in} = h_{ic} - \frac{h_{fc} h_{rc}}{1/R_L + h_{oc}}}$$

Current Gain :-

$$A_I = \frac{i_e}{i_b}$$

from eq ③ $i_e = \frac{-V_{ce}}{R_L}$

$$V_{ce} = -i_e R_L$$

eq ② $i_e = h_{fc} i_b + h_{oc} V_{ce}$

$$i_e = h_{fc} i_b + h_{oc}(-i_e R_L)$$

$$i_e = h_{fc} i_b - h_{oc} i_e R_L$$

$$h_{fc} i_b = i_e + h_{oc} i_e R_L$$

$$h_{fc} i_b = i_e(1 + h_{oc} R_L)$$

$$A_I = \frac{i_e}{i_b} = \frac{h_{fc}}{1 + h_{oc} R_L}$$

$$\boxed{A_I = \frac{h_{fc}}{1 + h_{oc} R_L}}$$

$$A_V = \frac{-h_{fc}}{1/R_L + h_{oc}} \times \frac{1}{Z_{in}}$$

$$\boxed{A_V = \frac{-h_{fc}}{1/R_L + h_{oc}} \times \frac{1}{h_{ic} - \frac{h_{fc} h_{rc}}{1/R_L + h_{oc}}}}$$

$$Z_o = \frac{V_{ce}}{i_e}$$

from eq ②

$$i_e = h_{fc} i_b + h_{oc} V_{ce}$$

divide by V_{ce}

$$\frac{i_e}{V_{ce}} = \frac{h_{fc} i_b}{V_{ce}} + h_{oc} \rightarrow ⑦$$

from eq ①

$$V_{bc} = h_{ic} i_b + h_{rc} V_{ce}$$

$$V_{be} = 0$$

$$h_{ic} i_b = -h_{rc} V_{ce}$$

$$\frac{i_b}{V_{ce}} = \frac{-h_{rc}}{h_{ic}} \rightarrow ⑧$$

from ⑦ & ⑧

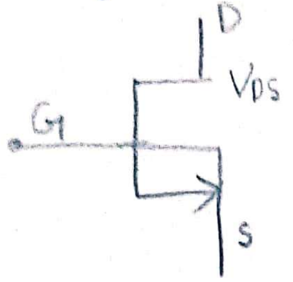
$$\frac{i_e}{V_{ce}} = h_{fc}\left(\frac{-h_{rc}}{h_{ic}}\right) + h_{oc}$$

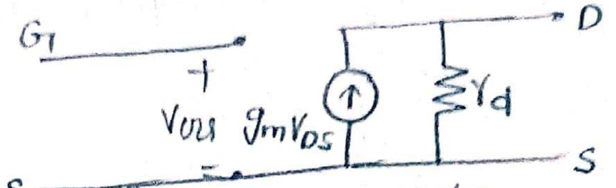
$$\frac{i_e}{V_{ce}} = \frac{-h_{fc} h_{rc} + h_{oc} h_{fc}}{h_{ic}}$$

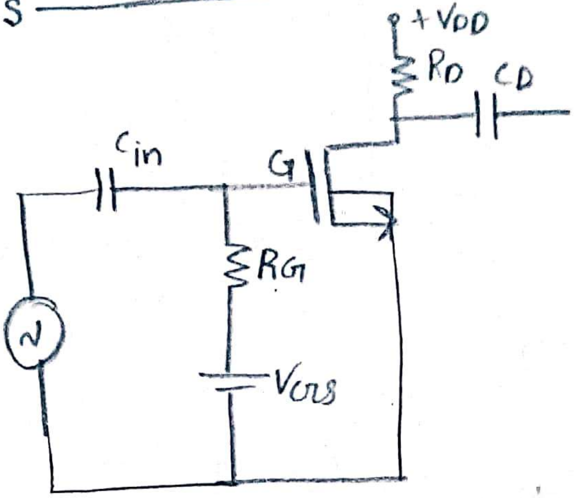
$$\boxed{Z_o = \frac{V_{ce}}{i_e} = \frac{h_{ic}}{h_{oc} h_{ic} - h_{fc} h_{rc}}}$$

2) Analysis of FET CS ~~cc~~ Amplifier in exact Model.

Analysis of CS Amplifier:-





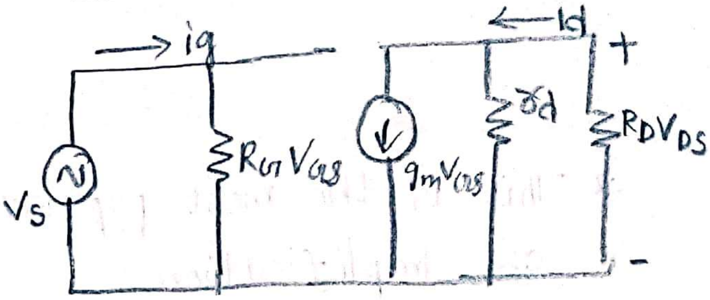


current gain :-

$$\frac{i_d}{i_g} = \frac{i_d}{0} = \infty$$

i/p impedance :-

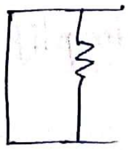
$$Z_i = \frac{V_{gs}}{i_g} = \infty$$



$$Z_i' = Z_i \| R_g = R_g$$

O/p impedance :-

$$Z_0 = \frac{V_{DS}}{i_d}\Big|_{V_S = 0,\ R_d \text{ disconnected}}$$



$$Z_0 = r_d$$

$$Z_0' = Z_0 \| R_D$$

Voltage Gain :-

$$A_V = \frac{V_{DS}}{V_{GS}}$$

$$A_V = \frac{V_{DS}}{V_{GS}} = -g_m (r_d \| R_D)$$

$$V_{DS} = -g_m V_{GS} [r_d \| R_D]$$

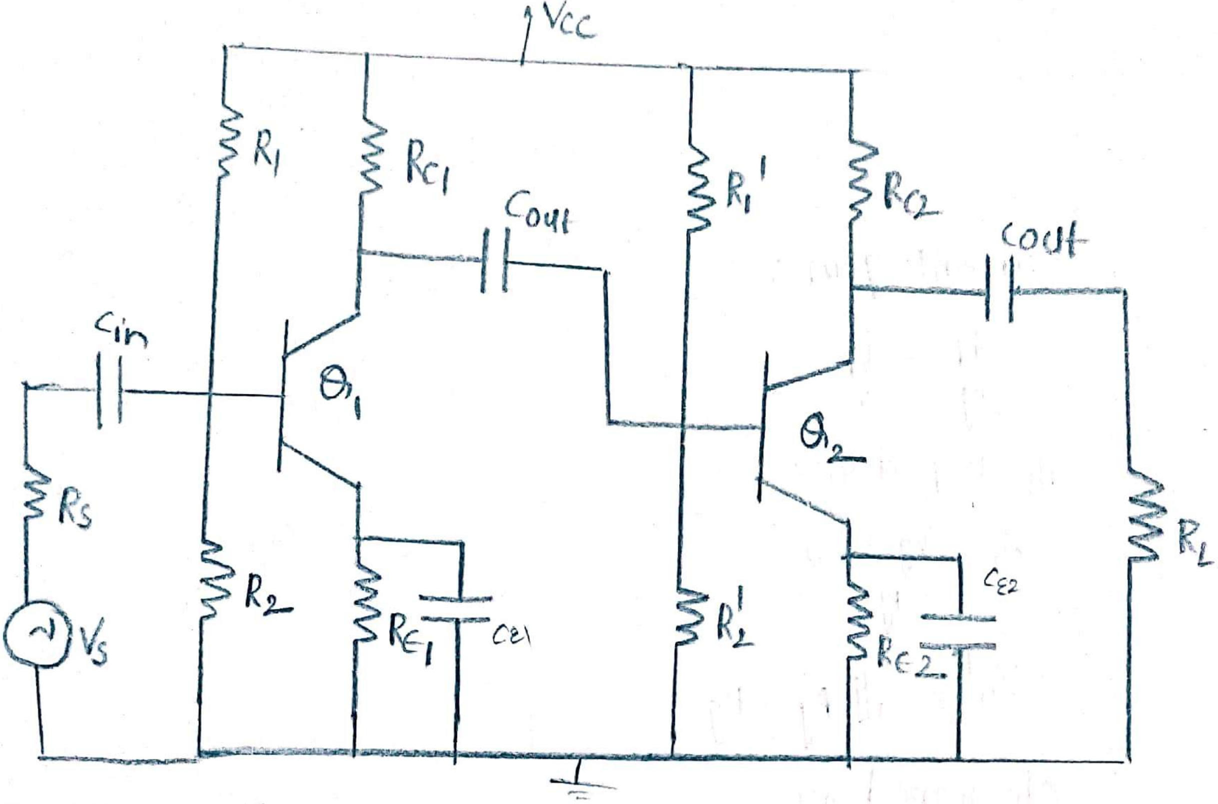
$$A_V = -g_m (r_d \| R_D)$$

$$g_m = i_d / V_{GS}$$

g_m = transconductance

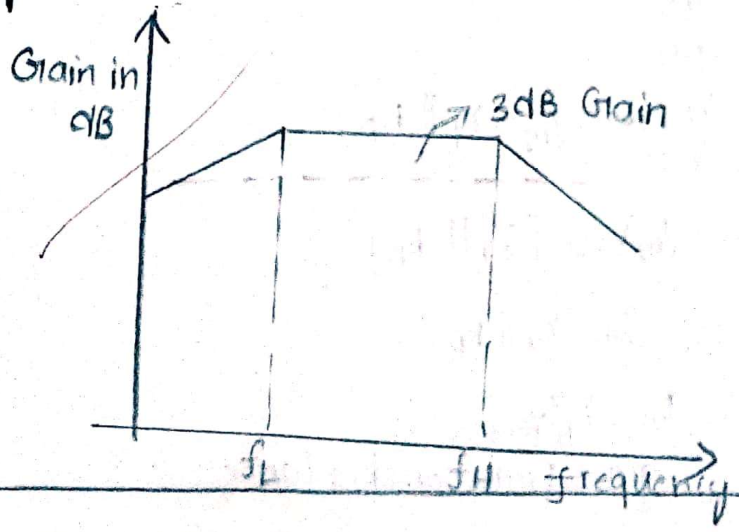
3) Explain two stage RC coupled Amplifier & transformed coupled Amplifier.

Two stage RC coupled Amplifier:-



* This is the most popular type of coupling because of Amplification
* cheap and provides excellent Amplifications
* Used in Voltage Amplification
* coupling capacitor is used to transfer o/p from one stage to next stage.

Frequency response:-



Analysis of CE Amplifier in exact & Simplified Model:-

In Exact Model:-

i/p impedance = $Z_{in} = h_{ie} - \frac{h_{re} h_{fe}}{\frac{1}{R_L} + h_{oe}}$

current gain = $A_I = \frac{-h_{fe}}{1 + h_{oe} R_L'}$

Voltage gain = $A_v = \frac{-h_{fe}}{\frac{1}{R_L} + h_{oe}} \times \frac{1}{h_{ie} - \frac{h_{re} h_{fe}}{\frac{1}{R_L} + h_{oe}}}$

o/p impedance = $Z_o = \frac{h_{ie}}{h_{ie} h_{oe} - h_{fe} h_{re}}$

In simplified Model :-

1) current Gain :- $A_I = -h_{fe}$

2) i/p impedance :- $Z_{in} = h_{ie}$

3) effective i/p impedance :- $Z_{in}' = R_B / Z_{in}$

4) i/p impedance with R_s :- $Z_{is} = R_s + Z_{in}$

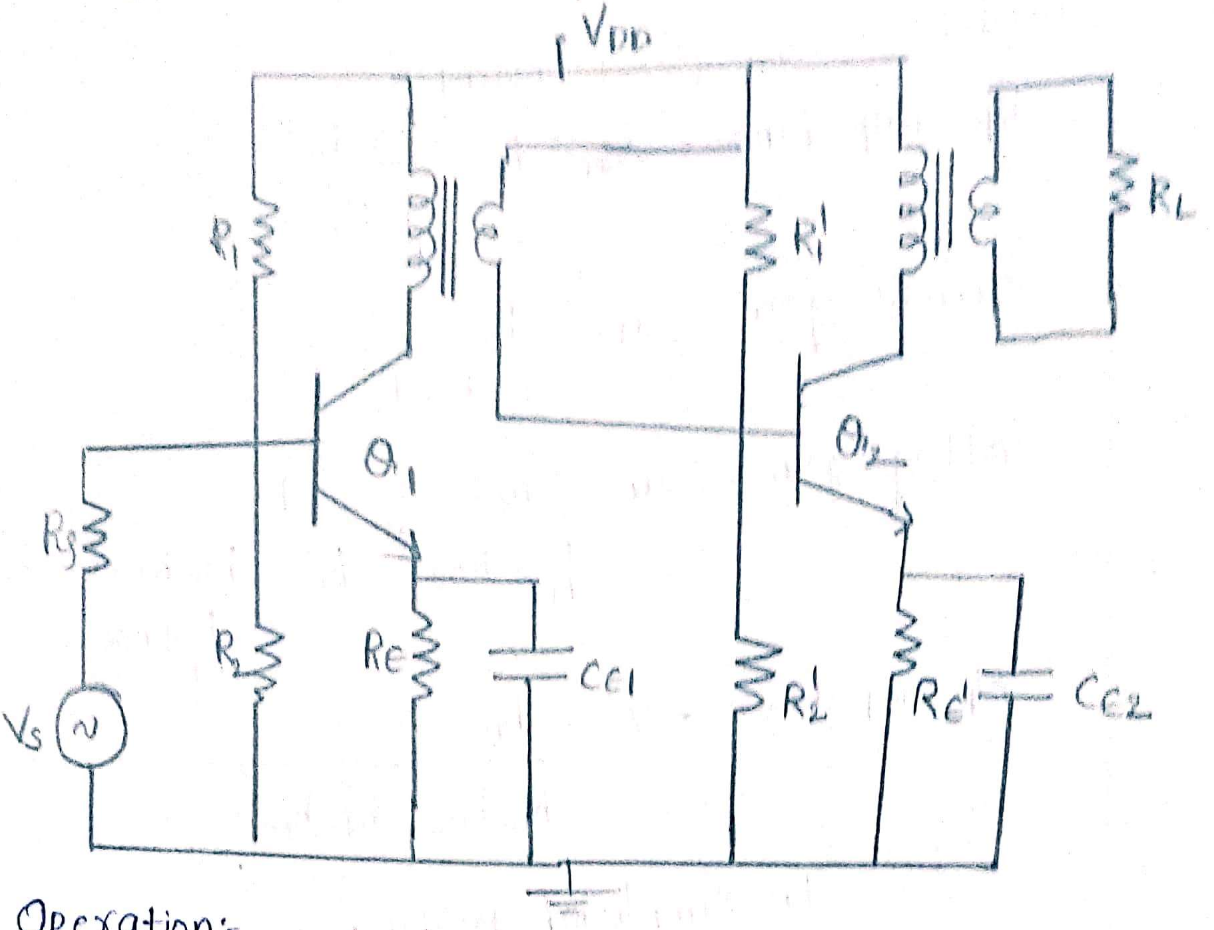
5) Voltage Gain (A_v) :- $A_I \frac{R_L'}{Z_{in}}$

6) Voltage Gain with ~~source~~ :- $A_{vs} = A_v \frac{Z_i'}{Z_i' + R_s}$

7) current Gain with source :- $A_{Is} = A_I \cdot \frac{R_s'}{R_s' + Z_i}$

8) o/p impedance :- $Z_o = \infty$, $Z_o' = R_C$, $Z_o'' = R_L'$

Transformed Coupled Amplifies:-



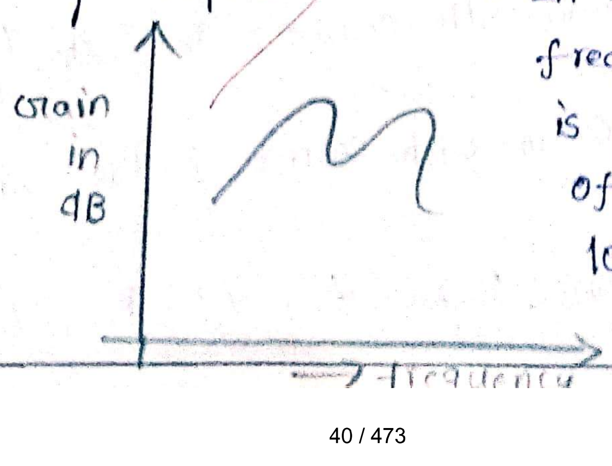
Operation:-

1) When an Ac signal is applied to base of 1st amplifier it appears as amplified across the primary of coupling Amplifier

2) The Amplified signal is transfered to the i/p of next stage by using Secondary transformer.

3) In 2nd stage further Amplification from secondary transformer the o/p is transffered to RL.

Frequency response:-



* In this Amplifier frequency response is poor because of transformer losses & gain is also unstable.

Advantages :

1) It has high Voltage Gain
2) High power Gain
3) Good i/p impedance matching
4) No signal loss in collector / base resistors.

Disadvantages :-

1) Gain is not stable
2) transformer are expensive
3) poor frequency response
4) provides frequency disortion.

Applications :-

1) used in impedance matching
2) it is used in Radio frequencies (20KHz - 200 KHz) & TV receivers to amplify RF signals.

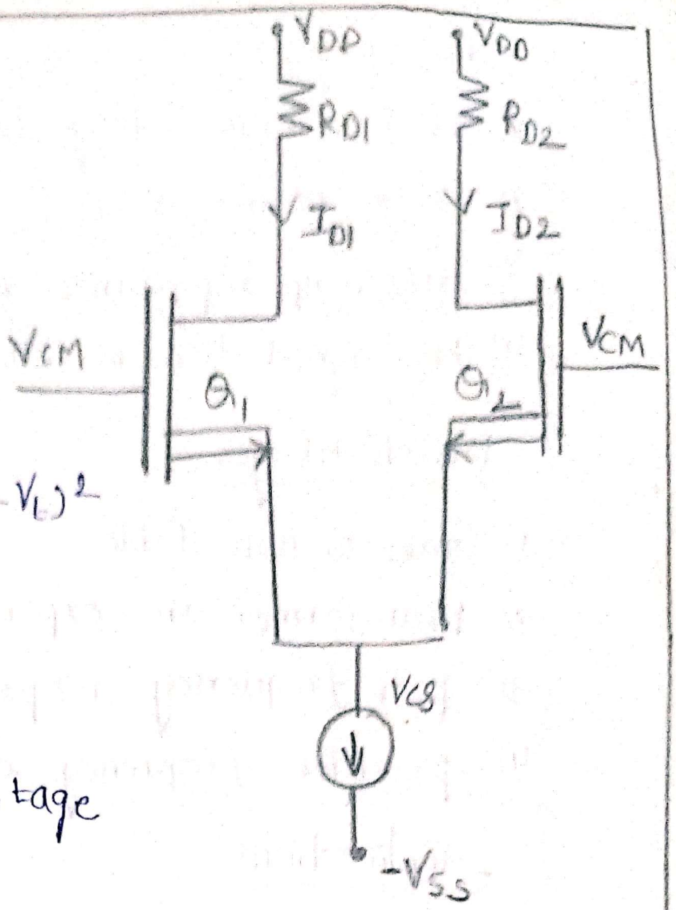
4) Explain different modes in MOS differential amplifier.

MOS differential Amplifiers are operated in 4 modes

1) common i/p mode
2) differential i/p mode
3) large signal i/p mode
4) small signal i/p mode.

1) Common i/p Mode :-

1) When same i/p voltage is applied to 2 transistors Q_1 & Q_2 the differential amplifier operators in common mode.
2) When two transistors are switch on operating saturated region total current is distributed equally.



$I_{D1} = I_{D2} = I/2$

$I = I_{D1} + I_{D2}$

$V_S = V_{CM} - V_{GS}$

We know the drain current of MOSFET is

$$I_{D1} = \frac{I}{2} = \frac{k_n'}{2}\frac{W}{L}(V_{GS} - V_t)^2$$

$$I_{D1} = I = \frac{k_n'W}{L}(V_{ov})^2$$

∴ $V_{GS} - V_t = V_{OV}$

V_{OV} - over drive voltage

$$V_{OV} = \sqrt{\frac{I}{k_n'\frac{W}{L}}}$$

from drain side

$$V_{D1} = V_{DD} - \frac{I}{2}R_{D1}$$

$$V_{D2} = V_{DD} - \frac{I}{2}R_{D2}$$

under this condition the difference btw two voltages is zero

so the o/p voltage is zero

$$V_{D1} = V_{D2}$$

$$V_0 = 0$$

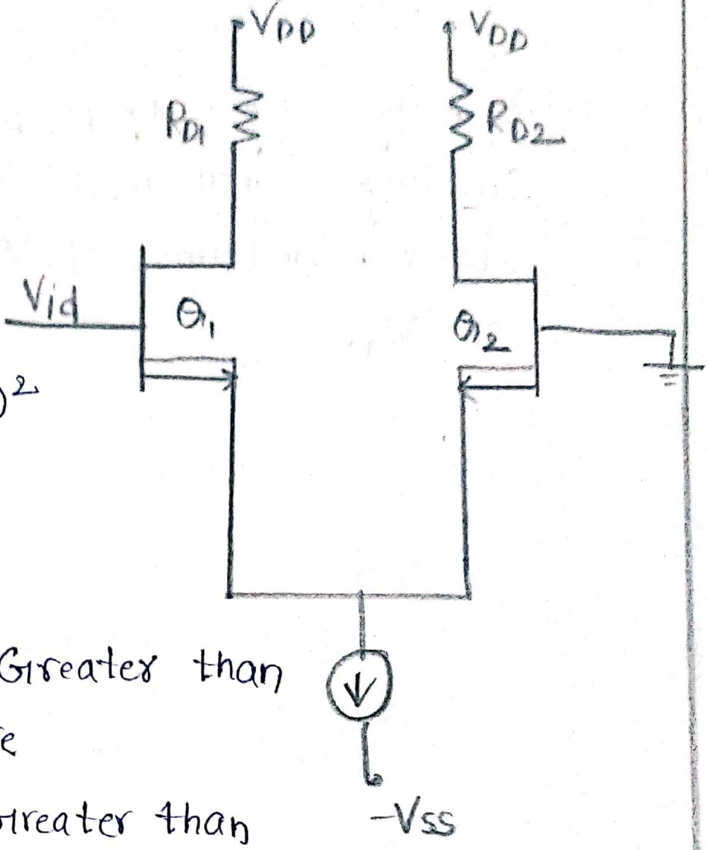
Common mode voltage range is

$$V_{cm}(max) = V_D + V_S$$

$$V_{cm}(min) = -V_{SS} + V_{CS} + V_{GS}.$$

8) 2) Differential i/p Mode:-

In differential i/p mode the i/p voltage is given to Q_1 transistor & Q_2 transistor is connected to ground (0).



$$I_{D1} + I_{D2} = I$$

$$I_{D1} + 0 = I$$

$$I = I_{D1}$$

$$I_{D1} = I = \frac{k_n'}{2}\frac{W}{L}(V_{OV})^2$$

$$V_{OV} = \sqrt{\frac{2I}{k_n'\frac{W}{L}}}$$

⇒ When V_{ID} is +ve I_{D1} is Greater than I_{D2} & also $V_{O2} - V_{O1} = +ve$

⇒ When Vid is −ve I_{D1} is Greater than I_{D2} & also $V_{O1} - V_{O2} = +ve$

⇒ When Vid is −ve, then $V_{GS1} - V_{GS2}$ is −Ve $(V_{GS1} < V_{GS2})$

$$I_{D1} = I = \frac{k_n'}{2}\frac{W}{L}[V_{GS} - V_t]^2$$

$$V_{GS1} = V_t + \sqrt{\frac{2I}{k_n'\frac{W}{L}}} = V_t + \sqrt{2}V_{OV}$$

$\{ I/k_n'\frac{W}{L} = V_{OV}$ when $I_{D1} = I/2 \}$

⇒ if Vid is +ve

$$V_{id} = V_{GS1} - V_t$$

$$V_{id} = V_t + \sqrt{2}V_{OV} - V_t$$

$$V_{id} = \sqrt{2}V_{OV}$$

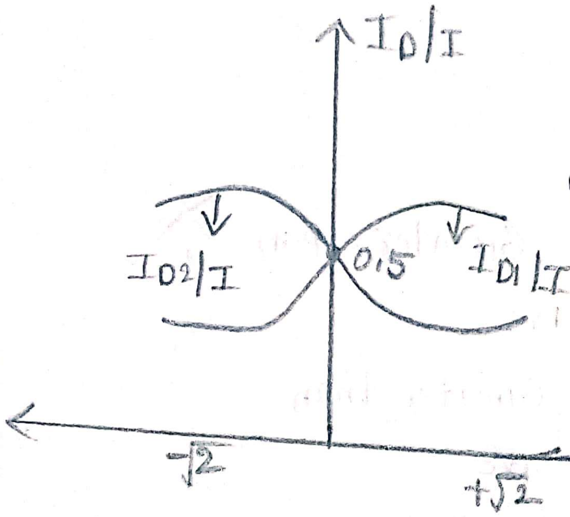
⇒ if $V_{id} \overset{is}{=} -V_c$

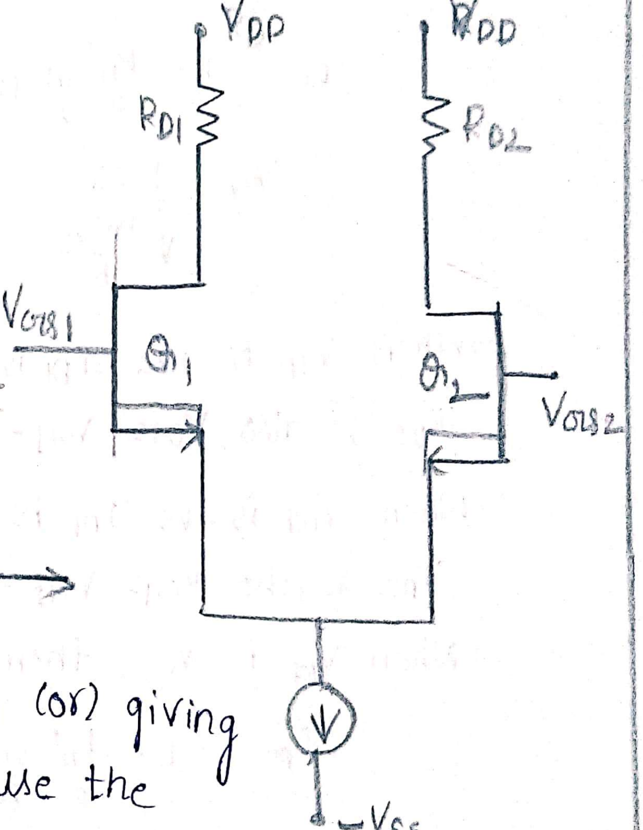
$$V_{id} = -\sqrt{2}\, V_{OV}$$

$$\therefore \; -\sqrt{2}\, V_{OV} \leq V_{id} \leq \sqrt{2}\, V_{OV}$$

3) Large Signal i/p Mode :-

In large signal mode the current equations are derived interms of V_{GS1} & V_{GS2} (or) interms of V_{id}.





Here we are not writing (or) giving any supply i.e (V_{DD}) because the current equations is derived from V_{S1} & V_{GS2}

$$I_{D1} = \frac{I}{2} = \frac{k_n'}{2}\frac{W}{L}(V_{GS1} - V_t)^2 \longrightarrow ①$$

$$I_{D2} = \frac{I}{2} = \frac{1}{2}k_n'\frac{W}{L}(V_{GS2} - V_t)^2 \rightarrow ②$$

Apply square root on both sides for eq②, eq①

$$\sqrt{I_{D1}} = \sqrt{k_n'\frac{W}{L}}\,(V_{GS1} - V_t) \longrightarrow ③$$

$$\sqrt{I_{D2}} = \sqrt{k_n'\frac{W}{L}}\,(V_{GS2} - V_t) \longrightarrow ④$$

Subtracting ③ & ④ equations

$$\sqrt{I_{D1}} - \sqrt{I_{D2}} = \sqrt{k_n' \frac{W}{L}} (V_{GS1} - V_t) - \sqrt{k_n' \frac{W}{L}} (V_{GS2} - V_t)$$

$$\sqrt{I_{D1}} - \sqrt{I_{D2}} = \sqrt{k_n' \frac{W}{L}} (V_{GS1} - \cancel{V_t} - V_{GS2} + \cancel{V_t})$$

$$\sqrt{I_{D1}} - \sqrt{I_{D2}} = \sqrt{k_n' \frac{W}{L}} (V_{GS1} - V_{GS2})$$

squaring on both sides

$$(\sqrt{I_{D1}} - \sqrt{I_{D2}})^2 = k_n' \frac{W}{L} (V_{GS1} - V_{GS2})^2$$

$$(\sqrt{I_{D1}})^2 + (\sqrt{I_{D2}})^2 - 2\sqrt{I_{D1}}\sqrt{I_{D2}} = k_n' \frac{W}{L} (V_{GS1} - V_{GS2})^2$$

$$\boxed{\cancel{(\sqrt{I_{D1}})^2}} \; I_{D1} + I_{D2} - 2\sqrt{I_{D1} I_{D2}} = k_n' \frac{W}{L} (V_{GS1} - V_{GS2})^2$$

$$I_{D1} + I_{D2} - 2\sqrt{I_{D1} I_{D2}} = k_n' \frac{W}{L} (V_{id})^2$$

$$I - 2\sqrt{I_{D1} I_{D2}} = k_n' \frac{W}{L} (V_{id})^2 \; [\because I_{D1} + I_{D2} = I]$$

$$I - k_n' \frac{W}{L} (V_{id})^2 = 2\sqrt{I_{D1} I_{D2}} \longrightarrow ⑥$$

substitude $I_{D2} = I - I_D$ & apply squares on b/s we get

$$I_{D1} = I/2 + I/V_{OV} \left(\frac{V_{id}}{2}\right) \sqrt{1 - \frac{V_{id}2}{V_{OV}}}$$

$$I_{D2} = I/2 - I/V_{OV} \left(\frac{V_{id}}{2}\right) \sqrt{1 - \frac{V_{id}2}{V_{OV}}}$$

if $V_{id} = \sqrt{2} V_{OV}$

$$\frac{I}{2} + \frac{I}{V_{OV}} \cdot \frac{\sqrt{2} V_{OV}}{2} \sqrt{1 - \left(\frac{\frac{\sqrt{2} V_{OV}}{2}}{V_{OV}}\right)^2}$$

$$\frac{I}{2} + \frac{I\sqrt{2}}{2} \sqrt{1 - 2/4}$$

$$\frac{I}{2} + \frac{I\sqrt{2}}{2} \sqrt{1 - 1/2}$$

$$\frac{I}{2} + \frac{I\sqrt{2}}{2} \sqrt{1/2}$$

$$I/2 + I/2 = I$$

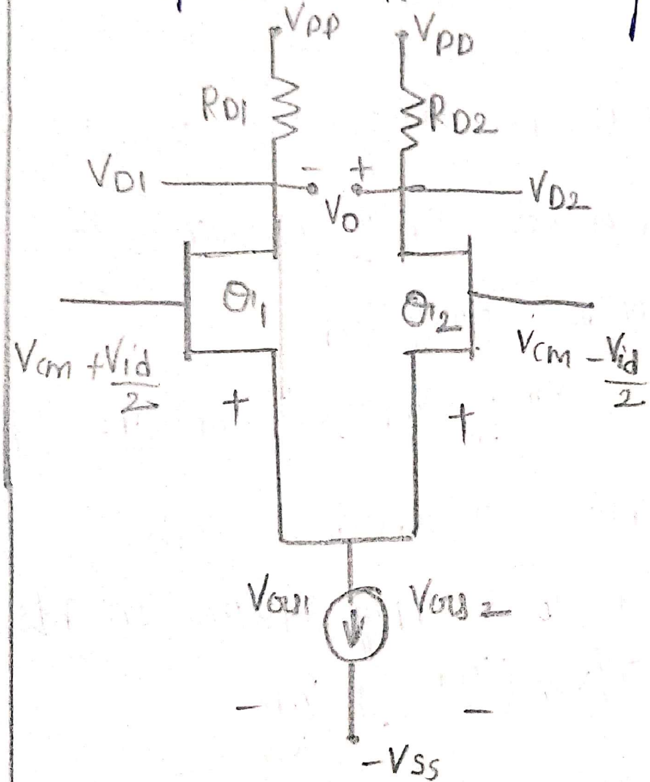
$I_{D1} = I$, $I_{D2} = 0$

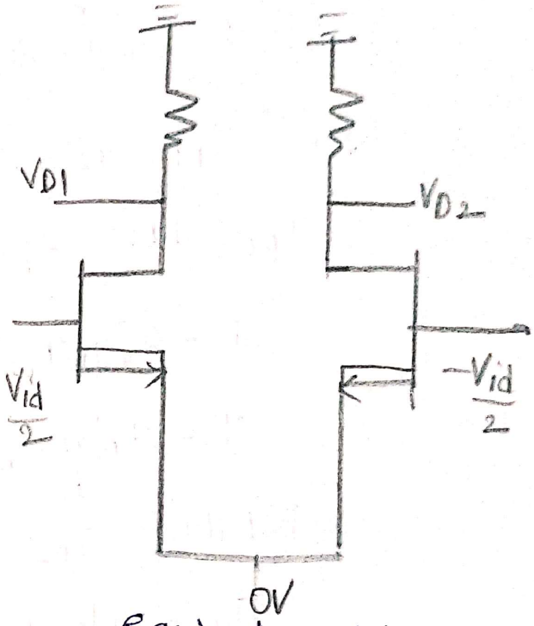
range:- $-\sqrt{2} V_{ov} < V_{id} < \sqrt{2} V_{ov}$

4) Small singal i/p Mode;-

In this small signal mode we are applying $V_{cm} + \frac{V_{id}}{2}$ (Q_1) $V_{cm} - \frac{V_{id}}{2}$ (Q_2)

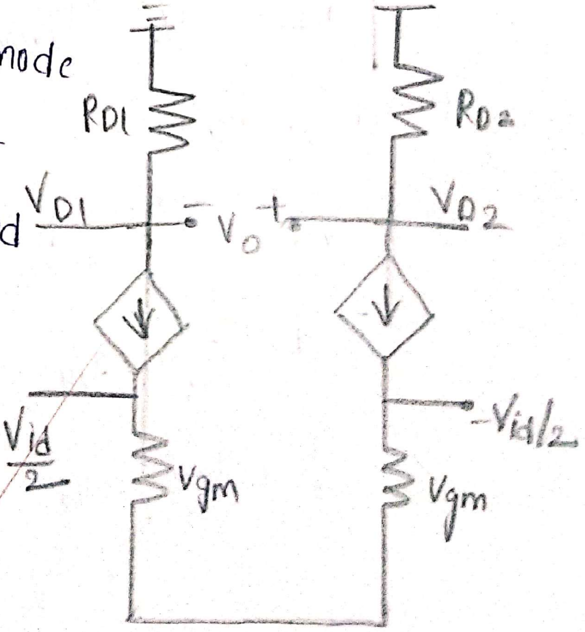
* In this mode the mos transistors Q_1 & Q_2 are operated in active region.





Equivalent ckt

Vcm is the common mode dc Voltage within the mosfet Vcm is required to set dc voltage of MOSFET by considering the dc circuit.



Hybrid model

$$V_{D1} = -g_m \frac{V_{id}}{2} R_D$$

$$V_{D2} = g_m \frac{V_{id}}{2} R_D$$

$$V_0 = V_{D2} - V_{D1}$$

$$V_0 = g_m \frac{V_{id}}{2} R_D + g_m \frac{V_{id}}{2} R_D$$

$$V_0 = g_m V_{id} R_D$$

$$\frac{V_0}{V_{id}} = g_m R_D$$

A_d = differential gain

$$A_d = g_m R_D \Rightarrow \text{without } r_d$$

With r_d

$$A_d = g_m (r_d \parallel R_D)$$

$$g_m = \frac{2I_D}{V_{OV}}$$

$$r_d = \frac{2V_A}{I}$$

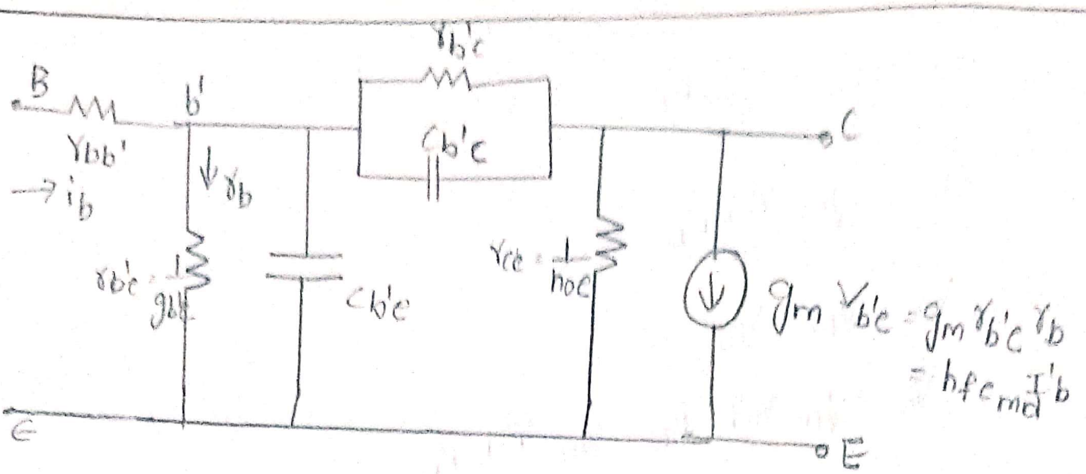
5) Explain about high frequency model of BJT?

* At low frequencies we analyse the transistor using h parameters. But for high frequencies analysis the h-parameter model is not suitable for the following reasons.

1) The values of h-parameters are not constant at high frequencies

2) The h-parameter model is simple & inaccurate because it neglects the early effect.

* Due to above reasons hybrid-π model is used for the analyse of transistors at high frequencies.



1) $C_{b'e}$:- The capacitive effect of normally forward biased base emitter junction of the transistor is represented by $C_{b'e}$ or C_e in the hybrid π model. it is due to the diffusion capacitance of forward bias emitter diode. its typical value is 100 pF.

2) $C_{b'c}$:- The capacitive effect of normally reverse biased base collector junction of the transistor is represented by $C_{b'c}$ or C_c in the hybrid π model. It is due to the transistion capacitance of reverse bias collecter diode. Its typical value is 3pF.

3) $r_{b'e}$:- The resistive effect of normally forward biased base emitter junction of the transistor is represented by $r_{b'e}$ in the hybrid π Model. The resistance is the portion of the base emitter which may be thought of as being "in series with" the collector junction.

4) $r_{b'c}$:- The resistive effect of normally reverse biased base collector junction of the transistor is represented by $r_{b'c}$ in the hybrid π model. The resistance is due to early effect which is the varying voltage across the collector to emitter junction results in base width modulation.

A change in the effective base width causes the emitter current to change. The feedback effect btw o/p & i/p is taken by connecting $r_{b'c}$.

5) $r_{bb'}$:- The resistance effect of bulk of resistances btw the external node B & internal base node b'. This resistance is called the base spreading resistance. Its typical value is 100Ω

6) r_{ce} :- The resistance effect of o/p terminal is represented by r_{ce} in hybrid π model. It is also due to early effect.

7) $g_m V_{b'e}$:- Due to small changes in voltage $V_{b'e}$ across the emitter junction, there is excess minority carrier concentration injected into the base which is propotional to the $V_{b'e}$. Therefore resulting small signal current is propotional to $V_{b'e}$.

Assignment - II

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Reg No :- 21091A04E2　　Subject :- ECA4D

1. The loudspeaker of 8Ω is connected to the secondary of the o/p transformer of class A power amplifier. The Q-point collector current is 140mA. The turns ratio of transformer is 3:1. The collector supply voltage is 10V if AC power delivers to the loud speaker is 0.48watt calculate DC power i/p, Efficiency, and power dissipation.

Given $I_{CEQ} = 140mA$

$V_C = 10V$

$P_{ac} = 0.48$ watt

$N_1/N_2 = 3:1$

$R_L = 8\Omega$

DC i/p power - $V_{CC} \times I_{CEQ}$

$= 10 \times 140 \times 10^{-3}$

$P(DC) = 14 \times 10^{-1}$

$$\boxed{P(DC) = 1.4 \text{ watts}}$$

Efficiency $\eta\% = \frac{\text{AC power o/p}}{\text{DC power i/p}} \times 100$

$\eta\% = \frac{0.48}{1.4} \times 100$

$$\boxed{\eta\% = 34.28\%}$$

power dissipation :- $P_{dc} - P_{ac} = 1.4 - 0.48$

$$\boxed{P(D) = 0.92 \text{ watts}}$$

2. A class B push pull amplifier supplies power to a resistive load of 12Ω. The o/p transformer as a turn ratio 3:1 and Efficiency of 78.5%. calculate i) max o/p (pac) power (ii) max power dessipation in each transistor

Given $N_1 : N_2 = 3:1$

$$P_{ac} = \frac{V_m I_m}{2}$$

$\eta\% = 78.5\%$

Let us assume $V_m = V_{cc} = 20V$, $I_m = V_m$

$$P_{ac} = \frac{V_m^2}{2R_L'}$$

$$R_L' = (N_1/N_2)^2 \times R_L = (3/1)^2 \times 12 = 108\Omega$$

Max power dissipation $(P_{ac}) = \frac{V_m^2}{2R_L'} = \frac{(20)^2}{2\times108} = 1.85$ watts

we know that

$$\eta\% = \frac{P_{ac}}{P_{dc}} \times 100$$

$$P_{dc} = \frac{P_{ac}}{\eta\%} \times 100 = \frac{1.85}{7.85\%} = \frac{1.85}{0.0785}$$

$P_{dc} = 2.356$ watts

∴ power dissipation $= P_{dc} - P_{ac}$

$P(d) = 2.356 - 1.85$

$= 0.506$ watts

∴ for each transistor $= P_d/2 = 0.506/2$

$= 0.25$ watts

3. class-B push pull delivers ac load of 16Ω, connected to the secondary of coil ideal transformer ($N_1 : N_2 = 1:1$). Supply voltage is 25V, If the no. of turns on secondary is 50. calculate Efficiency

Given $R_L = 16\Omega$

$V_{cc} = 25V$

$N_2 = 50$

$R_L' = 16\Omega$

~~$V_m = V_{cc}$~~

$$I_m = \frac{V_{cc}}{R_L'}$$

$$P_{ac} = \frac{V_m I_m}{2}$$

$$P_{dc} = \frac{2V_m(I_m)}{\pi} = \frac{2\times 25(I_m)}{\pi}$$

$$P_{dc} = \frac{2\times 25(V_m)}{\pi R_L'} = \frac{2\times 25\times 25}{\pi\times 16}$$

$$P_{dc} = 24.88 \text{ watts}$$

$$P_{ac} = \frac{V_m I_m}{2} = \frac{V_m(V_{cc})}{2R_L'} = \frac{25\times 25}{2\times 16} = 19.53 \text{ watts}$$

$$\text{Efficiency } \eta\% = \frac{P_{ac}}{P_{dc}}\times 100$$

$$= \frac{19.53}{24.88}\times 100$$

$$\boxed{\eta\% = 78.496}$$

4. A class-B push pull amplifier supplies power to a load speaker of 10Ω, The o/p transformer turn ratio of $N_1:N_2 = 4:1$ and efficiency of 95%. calculate the (i) max power o/p p(ac) ii) Max power dissipation (iii) Max Base current of each transistor

Given $N_1 : N_2 = 4:1$

$\eta\% = 95\%$

$R_L = R_L' = 10\Omega$

$$P_{ac} = \frac{V_m I_m}{2}$$

Let us assume $V_m = V_{cc} = 20V$ $\left(\because I_m = \frac{V_m}{R_L'} \quad V_m = V_{cc}\right)$

$$P_{ac} = \frac{V_m^2}{2R_L'}$$

(i) $P_{ac} = \frac{400}{2\times 160} = 40/32$ $\boxed{P_{ac} = 1.25 \text{watts}}$

$R_L' = (N_1/N_2)^2 \times R_L = (4/1)^2 \times 10 = 160\Omega$

$$P_{dc} = \frac{P_{ac}}{\eta\%} \times 100$$

$$= \frac{1.25}{0.95} \times 100$$

$P_{dc} = 1.315$ watts

ii) power dissipation $(P_d) = P_{dc} - P_{ac}$

$= 1.315 - 1.25$

$= 0.065$ watt

For each transistor

$P_d/2 = 0.065/2$

$= 0.0325$ watts

(iii) for max Base current

$$P_{dc} = \frac{2V_{cc} I_m}{\pi}$$

$$I_m = \frac{\pi \times P_{dc}}{2V_{cc}} = \frac{\pi \times 1.315}{2 \times 20}$$

$$\boxed{I_m = 0.1032}$$

Assume $h_{fe} = 25$

$$\text{for } I_{m\,max} = I_m / h_{fe} = \frac{0.1032}{25} = 4.128 \times 10^{-3}$$

$$\boxed{I_{max} = 4.12\text{mA}}$$

5. For the Rc phase shift oscillator, the feedback Network uses $R = 6k\Omega$, $C = 1500pf$, The transistorized amplifier uses a collector resistance of $18k\Omega$ calculate the frequency of oscillations & minimum value of h_{fe} of transistor

we know that in Rc phase shift oscillator,

$$f = \frac{1}{2\pi RC\sqrt{10}}$$

Given that $R = 6k\Omega$, $C = 1500pf$, $R_c = 18k\Omega$

$$f = \frac{1}{2\pi RC\sqrt{6+4k}}$$

$$k = R_c/R = \frac{18\times10^{3}}{6\times10^{3}} = 3$$

$$f = \frac{1}{2\times3.14\times6\times10^{3}\times1500\times10^{-12}\sqrt{6+4(3)}}$$

$$\boxed{f = 4.17\,kHz}$$

$$h_{fe} = 23+4k+29/k = 4(3)+23+29/3$$

$$= 44.66$$

$$h_{fe} \geq 45$$

6. The frequency sensitive aums of woein bridge oscillator uses $C_1=C_2=0.0010F$ & $R_1=10k\Omega$, R_2 is kepf vauiable and the frequency is vaued from 10kHz to 50kHz. Find min and max value of R_2?

Given that

$C_1=C_2=0.001F$

we know that $f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$

At f= 10kHz

$$10\times10^{3} = \frac{1}{2\pi\sqrt{10\times10^{3}\times0.001\times10^{-6}\times0.001\times10^{-6}\times R_2}}$$

$$10\times10^{3} = \frac{1}{2\pi\sqrt{10^{-7}\times R_2}}$$ S.O.B.S

$$(10^{4})^{2} = \frac{1}{4\pi^2\times10^{-7}R_2}$$

$$R_2 = \frac{1}{4\pi^2\times10^{-7}\times10^{8}}$$

$$R_2 = 2.533\times10^{-17}$$

At f= 50kHz

$$50\times10^{3} = \frac{1}{2\pi\sqrt{10\times10^{3}\times0.001\times10^{-6}\times0.001\times10^{-6}\times R_2}}$$

S.O.B.S

$$50\times10^{3} = \frac{1}{2\pi\sqrt{10^{-7}\times R^2}}$$

$$(50\times10^{3})^{2} = \frac{1}{4\pi^2\times10^{-7}\times R_2}$$

$$R_2 = \frac{1}{4\pi^2\times10^{-7}\times(50\times10^{3})^{2}}$$

$$R_2 = 1.0132\times10^{-18}$$

7. Find the frequency of a transistor hartly oscillator if $L_1 = 100\mu H$, $L_2 = 1mH$, mutual inductance (M) - $20\mu H$ and $c = 20pf$. Find the frequency

we know that

$L_{eq} = L_1 + L_2 + 2M$

$L_{eq} = 100\times10^{-6} + 1\times10^{-3} + 2(20\times10^{-6})$

$c = 20\times10^{-12}$

$$f = \frac{1}{2\pi\sqrt{L_{eq}C}} = \frac{1}{2\pi\sqrt{100\times10^{-6} + 1\times10^{-3} + 40\times10^{-6}\times20\times10^{-12}}}$$

$f = 1054029.36Hz$

$f = 1054.02\times10^{6}\,Hz$

$\boxed{f = 1054.02\,MHz}$

8. Find the frequencies of transistor of colpitts oscillator $C_1 = 0.001\mu F$ $C_2 = 0.01\mu F$, $L = 15\mu H$

Given that

$C_1 = 0.001\mu F$ $C_2 = 0.01\mu F$ $L = 15\mu H$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC_1} + \frac{1}{LC_2}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{15\times10^{-6}\times0.001\times10^{-6}} + \frac{1}{15\times10^{-6}\times0.01\times10^{-6}}}$$

$f = 1362921.5$

$\boxed{f = 1362.92\,kHz}$

9. In a transistorized hartly oscillator, two inductances are 2mH & $20\mu H$, while frequency is to be varied from 950kHz to 2050kHz. calculate the range over which the capacitor is to be varied

Given that

$M = 0$

$L_{eq} = L_1 + L_2 = 2\times10^{-3} + 20\times10^{-6}$

$L_{eq} = 0.00202.$

$$f = \frac{1}{2\pi\sqrt{L_{eq}C_1}}$$

$$950kHz = \frac{1}{2\pi\sqrt{L_{eq}\,C}}$$

$$\sqrt{L_{eq}C_1} = \frac{1}{2\pi(950k)}$$

$$C_1 = \frac{1}{4\pi^2(950k)^2 \times 0.00202}$$

$$C_1 = 13.894pf$$

$$2050kHz = \frac{1}{2\pi\sqrt{L_{eq}C_2}}$$

$$C_2 = \frac{1}{4\pi^2 \times L_{eq}(2050k)^2}$$

$$C_2 = 2.98 \times 10^{-12} F$$

$C_2 = 2.98pf$ * capacitor range is 2.98pf to 13.8pf

10. In a colpitts oscillator $C_1 = 0.001\mu F$, $C_2 = 0.01\mu F$, $L = 10\mu H$. Find the frequency of oscillators, (β), voltage gain (A_v)?

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC_1} + \frac{1}{LC_2}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{1}{10\times10^{-6}\times0.001\times10^{-6}} + \frac{1}{10\times10^{-6}\times0.01\times10^{-6}}}$$

$$f = 1670.07 kHz$$

$$A_v = \text{Gain}(h_{fe}) = \frac{C_2}{C_1} = \frac{0.01}{0.001} = 10$$

we know that $A\beta = 1$

$$\beta = 1/A = 1/10$$

$$= 0.1$$

$$\boxed{\beta = 0.1}$$

11. A FET RC phase shift oscillator has $g_m = 5m℧$, $r_d = 50k\Omega$, Feedback resistance is $(R) = 100k\Omega$, and capacitance value is 64.79pf. calculate the frequency of oscillations & $R_D = ?$

we know that $f = \frac{1}{2\pi RC\sqrt{10}}$

$$f = \frac{1}{2\pi \times 100\times10^{3}\times 64.79\times10^{-12}\sqrt{10}}$$

$$f = 7.779kHz$$

$$R_D = ?$$

$$|A| \geq 29 \quad A = g_m R_L$$

$$R_L = r_d \| R_D$$

$$g_m R_L \geq 29 \Rightarrow R_L \geq 29/g_m$$

$$R_L > \frac{29}{5\times10^{-3}}$$

$$R_L > 5.8k\Omega$$

Let $R_L = 6k\Omega$

$$R_L = r_d \| R_D$$

$$R_L = \frac{r_d \times R_D}{r_d + R_D}$$

$$(r_d + R_D) R_L = r_d * R_D$$

$$50\times10^{3}\times6\times10^{3} + R_D\times6\times10^{3} = 50\times10^{3}\times R_D$$

$$50\times10^{3}\times R_D - R_D\times6\times10^{3} = 300\times10^{6}$$

$$44\times10^{3} R_D = 300\times10^{6}$$

$$R_D = \frac{300\times10^{6}}{44\times10^{3}}$$

$$\boxed{R_D = 6.818k\Omega}$$

12. A crystal has L=0.4H, C=0.085pf, Cm=1pf with Series resistance (Rs)= 5kΩ. calculate Series resonant frequency (fs) and parallel resonant frequency (fp), Quality factor (Q) and By what percent that the parallel resonant frequency exceeds the Series resonant frequency

i) $fs = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.4\times0.085\times10^{-12}}}$

$= 863576Hz$

$= 863.57 kHz$

ii) $fp = \frac{1}{2\pi\sqrt{L_{eq}C}} = \frac{1}{2\pi\sqrt{\frac{C C_m}{C+C_m}\times L}} = \frac{1}{2\pi\sqrt{\frac{0.085\times10^{-12}\times1\times10^{-12}}{0.085\times10^{-12}+1\times10^{-12}}\times0.4}}$

$= 899530Hz$

$= 899.53Hz$

iii) $Q = \frac{\omega_s L}{R_s} = \frac{2\pi f_s L}{R_s}$

$= \frac{2\pi\times863.57\times10^{3}\times0.4}{5\times10^{3}} = 434.07$

iv) $\%\,change = \frac{fp-fs}{fp}\times100$

$= \frac{899.53\times10^{3} - 863.57\times10^{3}}{899.53\times10^{3}}\times100$

$\%\,change = 3.99\%$

G. Rakesh

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II-B.tech - IInd-sem - ECE-C

10

ECAD Assignment - II

1. For RC phase shift oscillator the feedback network uses R= 6kΩ & C= 1500 pF. The transisterized amplifier uses a collector resistance of 18 kΩ. calculate the frequency of oscillator & minimum value of h_{fe} of transistor ?

Sol:- We know that in RC phase shift oscillator

$$f = \frac{1}{2\pi RC\sqrt{10}}$$

Given that,

$R = 6k\Omega$; $C = 1500PF$; $R_c = 18k\Omega$

$$f = \frac{1}{2\pi RC\sqrt{6+4k}} \qquad \because k = \frac{R_c}{R} = \frac{18\times10^3}{6\times10^3} = 3$$

$$f = \frac{1}{2\times3.14\times6\times10^3\times1500\times10^{-12}\times\sqrt{6+4(3)}}$$

$$\boxed{f = 4.17\ kHz}$$

$$h_{fe} = 23 + 4k + \frac{29}{k} = 4(3) + 23 + \frac{29}{3} = 44.66$$

$$\boxed{h_{fe} \geq 45}$$

2. The frequency sensitive arms of the wein bridge oscillator $C_1 = C_2 =$ 0.001μF & $R_1 = 10k\Omega$. while R_2 is kept variable. The frequency is to be varied from 10kHz to 50kHz by varying the r_2 find the min & max values of R_2.

Sol:- $$f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} \Rightarrow 10kHz = \frac{1}{2\pi\sqrt{10k\times R_2\times0.001\times10^{-6}\times0.001\times10^{-6}}}$$

$$10\times10^3 = \frac{1}{50329212\sqrt{R_2}}$$

$$10\times10^3 = \frac{15.91\times10^{\cancel{6}3}}{\sqrt{R_2}} \Rightarrow \sqrt{R_2} = \frac{15.91}{1\cancel{0}}\times10^{\cancel{3}2}$$

$$\sqrt{R_2} = 15.91\times10^2$$

3. Find the frequency of transistor calpits oscillator and condition for oscillator if $C_1 = 0.001\,\mu f$, $C_2 = 0.01\,\mu f$, $L = 15\,\mu H$ also calculate gain & feedback factor.

Sol:- $f = \dfrac{1}{2\pi\sqrt{C_{equ}\, L}}$

$$C_{equ} = 9.99 \times 10^{-15}$$

$$f = \frac{1}{2\pi\sqrt{9.9 \times 10^{-15} \times 15 \times 10^{-6}}} = 1361\text{kHz} = f$$

$$A = h_{fe} = \frac{C_2}{C_1} = \frac{0.01 \times 10^{-6}}{0.001 \times 10^{-6}} = 10$$

feedback factor (β)

$$A = \frac{C_2}{C_1} = 10$$

we know that

$$A\beta = 1 \Rightarrow \beta = \frac{1}{A} = \beta = \frac{1}{10} \Rightarrow \boxed{\beta = 0.1}$$

4. In a transistorised hartly oscillator the two inductors are 2mH and 20μH, while frequency is to be varied from 950 kHz to 2050kHz. Calculate the range over which the capacitor is to be varied?

Sol:- $M = 0$

$f = \dfrac{1}{2\pi\sqrt{L_{eq} C}}$; $L_{eq} = L_1 + L_2 + \cancel{2M} \to 0$

$L_{eq} = 0.00202$

$f = 950\text{ kHz}$

$$950\text{k} = \frac{1}{2\pi\sqrt{L_{eq} C}} \Rightarrow \sqrt{L_{eq} C} = \frac{1}{2\pi(950\text{k})}$$

$$C = \frac{1}{4\pi^2 (950\text{k})^2 * 0.00202} = 13.894\text{pF}$$

$f = 2050\text{kHz}$

$$f = \frac{1}{2\pi\sqrt{L_{eq} C}}$$

$$C = \frac{1}{4\pi^2 (2050\text{k})^2 \times 0.00202} = 2.96 \times 10^{-12}\text{F} = 2.98\text{ pF}$$

∴ Capacitor range is (2.98 pF to 13.89 pF)

5. Find the frequency of a transistor hartly oscillator if $L_1 = 100\mu H$, $L_2 = 1mH$, mutual inductance $(M) = 20\mu H$ and $C = 20pF$. find the freq.

Sol:- $L_{eq} = L_1 + L_2 + 2M = 100 \times 10^{-6} + 1 \times 10^{-3} + 2(20 \times 10^{-6})$

$C = 20 \times 10^{-12}$

$$f = \frac{1}{2\pi\sqrt{L_{eq}C}} = \frac{1}{2\pi\sqrt{(100 \times 10^{-6} + 10^{-3} + 40 \times 10^{-6})\, 20 \times 10^{-12}}}$$

$$\boxed{f = 1054.029\ kHz}$$

6. Find the frequency of transistor colpits oscillators, $C_1 = 0.001\mu F$, $C_2 = 0.01\mu F$, $L = 15\mu H$

Sol:-
$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC_1} + \frac{1}{LC_2}} = \frac{1}{2\pi}\sqrt{\frac{1}{15 \times 10^{-6} \times 0.001 \times 10^{-6}} + \frac{1}{15 \times 10^{-6} \times 0.01 \times 10^{-6}}}$$

$$\boxed{f = 1363.612\ kHz}$$

7. A FET RC phase shift oscillator has $g_m = 5m\mho$, $r_d = 50k\Omega$ Feedback resistance is $(R) = 100k\Omega$ and capacitance value is $64.79pF$. Calculate the frequency of oscillations & $R_D = ?$

Sol:-
$$f = \frac{1}{2\pi RC\sqrt{10}} = \frac{1}{2\pi \times 64.79 \times 10^{-12} \times 100 \times 10^3 \sqrt{10}} = 7.779\ kHz$$

$|A| \geq 29$ $\quad A = g_m R_L$

$R_L = r_d \parallel R_D$

$$g_m R_L \geq 29 \Rightarrow R_L > \frac{29}{g_m}$$

$R_L > 5.8k\Omega$

let $R_L = 6k\Omega$

$$R_L = r_d \parallel R_D = \cancel{\frac{r_d \times R_D}{r_d + R_D}} \Rightarrow (r_d + R_D) 6k\Omega = r_d * R_D$$

$$50 \times 10^3 \times 6 \times 10^3 + R_D \times 6k\Omega = 50 \times 10^3 \times R_D$$

$$300 \times 10^3 + 6 \times 10^3 R_D = 50 \times 10^3 R_D$$

$$44 \times 10^3 R_D = 300 \times 10^3$$

$$R_D = \frac{300}{44}$$

$$\boxed{R_D = 6.818\ k\Omega}$$

8. A crystal, as $L=0.4H$, $C=0.085PF$ and $C_m = 2PF$ $R_s = 5k\Omega$ find

i. Series resonance freq^n (f_s)

ii. Parallel resonance freq^n (f_p)

iii. quality factor of a crystal.

iv. By what % does the parallel resonance freqn with series resonance freq.

Sol: i. $f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.4\times0.085\times10^{-12}}}$

$= 0.863MHz$

ii. $f_p = \frac{1}{2\pi\sqrt{LC_{eq}}}$ $\quad \because C_{eq} = \frac{CC_m}{C+C_m}$

$= \frac{1}{2\pi\sqrt{0.4\times0.765\times10^{-12}}} = .$

$f_p = 0.952MHz$

iii. Quality factor $= \frac{\omega_s L}{R} = \frac{2\pi f_s L}{R} = \frac{2\pi\times0.863\times10^{6}\times0.4}{5\times10^3}$

$= 430$

iv. % change $= \frac{f_p - f_s}{f_p}\times100$

$= \frac{0.951\times10^6 - 0.863\times10^6}{0.95\times10^6} - 100$

$= 9.25\%$

9. The loudspeaker of 8Ω is connected to the secondary of the o/p transformer of class A power amplifier the Q point collector current is 140mA. The turns ratio of the transistor is 3:1. The collector supply voltage is 10V. If AC power delivered to the loudspeaker the 0.48 watt. Calculate DC power i/p efficiency, power description.

Sol: Given $P_{dc} = V_{cc} I_{CQ}$ $\qquad P_{ac} = 0.48W$

$= 10V * 140mA = 1.4W$

$\%\eta = \frac{P_{ac}}{P_{dc}}\times100 = \frac{0.48}{1.4}\times100 = 34.82\%$

$P_d = P_{dc} - P_{ac} = 1.4W - 0.48W$

$P_d = 0.92W$

10. A class B pushpull amplifier supply power to a R_L of 12Ω. The o/p transformer as a trans ratio of 3:1 and efficiency of 78.5%. Calculate ⓐ max. power out ⓑ max power distipation in each transistor.

Sol: $R_L = 12\Omega$

$N_1 : N_2 = 3:1$

$$R_L' = \left(\frac{N_1}{N_2}\right)^2 R_L = \left(\frac{3}{1}\right)^2 \times 12\Omega = 108\Omega$$

ⓐ $$P_{ac\,max} = \frac{V_m I_m}{2} = \frac{V_m}{2} \cdot \frac{V_m}{R_L'} = \frac{V_m^2}{2R_L'} = \frac{(V_{cc})^2}{2R_L'} = \frac{(20)^2}{2 \times 108}$$

$$P_{ac\,max} = 1.85\,W$$

$$P_d = P_{dc} - P_{ac} \quad * \Rightarrow P_d = 2.35\,W - 1.85\,W = 0.5\,W$$

$$\%\eta = \frac{P_{ac}}{P_{dc}} \times 100$$

$$78.5\% = \frac{1.85}{P_{dc}} \times 100 \Rightarrow P_{dc} = \frac{1.85}{78.5} \times 100$$

$$\boxed{P_{dc} = 2.35\,W}$$

$$(P_d) \text{ per transistor} = \frac{P_d}{2} = \frac{0.5\,W}{2} = \boxed{0.25\,W}$$

11. A class B push pull amplifier drives a load of 16Ω connected to the secondary of the ideal transistor the power supply voltage is 25V. The no.of turns on secondary is 50. calculate the efficiency.

Sol: $R_L = 16\Omega$

$N_1 : N_2 = 50 : 50 = 1:1$

$$R_L' = \left(\frac{N_1}{N_2}\right)^2 R_L = \left(\frac{1}{1}\right)^2 \times 16 \Rightarrow R_L' = 16\Omega$$

$$P_{ac} = \frac{V_m I_m}{2} = \frac{V_m}{2} \frac{V_m}{R_L} = \frac{V_m^2}{2R_L}$$

$$V_m = V_{cc} = 20V$$

$$P_{ac} = \frac{(20)^2}{2 \times 16} = 19.53\,W$$

$$P_{dc} = \frac{2V_{cc} I_m}{\pi} = \frac{2V_{cc}^2}{\pi R_L} = \frac{2 \times (25)^2}{\pi(16)} = 24.88\,W$$

$$\%\eta = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{19.53}{24.88} \times 100 = 78.49\%$$

12. A class B push pull amplifier supplies power to a load speaker of 10Ω the o/p transformer has a turn ratio of $n_1:n_2 = 4:1$ and $\eta = 95\%$. Assume $V_{cc} = 20V$. calculate the following (a) max power o/p (b) max power dissipation in each transisted. (c) max base current for each transistor.

Sol: $R_L = 10\Omega$

$N_1 : N_2 = 4:1$

$$R_L' = \left(\frac{N_1}{N_2}\right)^2 R_L = \left(\frac{4}{1}\right)^2 \times 10 = 16 \times 10 = 160\Omega$$

$$P_{ac} = \frac{V_m I_m}{2} = \frac{V_m^2}{2R_L'} = \frac{(20)^2}{2 \times 160} = 1.25W$$

$$\%\eta = \frac{P_{ac}}{P_{dc}} \times 100$$

$$95\% = \frac{1.25}{P_{dc}} \times 100$$

$$P_{dc} = 1.31W$$

$$P_d = P_{dc} - P_{ac}$$

$$= 1.31 - 1.25$$

$$P_d = 0.06W$$

$$(P_d) \text{ per transistor} = \frac{0.06}{2} = 0.03$$

$$P_{ac} = \frac{V_m I_m}{2}$$

$$I_m = \frac{2P_{ac}}{V_m}$$

$$= \frac{2 \times 1.25}{20}$$

$$\boxed{I_m = 0.125A}$$

$\because I_{CQ} = I_m = 0.125A$

$$\text{then } I_{BQ} = \frac{I_{CQ}}{\beta} = \frac{0.125}{25} \quad \left[\text{assume } \beta = h_{fe} = 25\right]$$

$$= \boxed{5mA}$$

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)
16th May 2023
II B.Tech. II Sem. (R20) Mid-I Examinations
ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN
ECE

Time: 2 Hrs **Total Marks: 20**

Note 1:Answer first question compulsorily. *(5 x 1 : 5 Marks)*
2:Answer Any THREE from 2 to 5 questions. (3 x 5 : 15 Marks)

1a Draw the high-frequency hybrid- Π model of BJT.
b Give the typical h-parameter values for a transistor at I_E = 1.3 mA.
c Define common mode rejection ratio (CMRR) of BJT differential Amplifier.
d Compare the three BJT configurations interms of A_i, A_V, R_i and R_o
e What is differential amplifier?

2 a) Draw the block diagram of the basic amplifier circuit [Two-port active network (BJT)] and draw its h-parameter model.
b) Explain the analysis of above BJT amplifier circuit to derive the equations for A_I, Z_i, Av, Y_0 in terms of h-parameters.

3 a) Draw and explain the small-signal model of the differential amplifier.
b) Draw the differential form of the cascode amplifier.

4 For a two stage CE-CC amplifier with R_S = 1KΩ, R_{C1} = 10KΩ and R_{E2} = 5KΩ. Assume the typical values of h-parameters. Calculate
a) Overall Current Gain
b) Overall Input Impedance
c) Overall Voltage Gain
d) Overall Output Impedance.

5 a) How to select the values for coupling capacitor C_{c1} and C_{c2} and bypass capacitor C_E for the common-emitter amplifier
b) Select the values for coupling capacitors C_{c1} , C_{c2} and bypass capacitor C_E for the common-emitter amplifier, which has R_s=100KΩ, R_c=8KΩ, R_L=5KΩ, R_{Sig}=5KΩ, β=100 and g_m=40mA/V, and r_Π=2.5KΩ. It is frequency to have f_l=100H_z

- xxx -

S.No. 86865

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY

AUTONOMOUS

Accredited by NAAC of UGC, New Delhi with 'A' Grade:: Accredited by NBA
Affiliated to JNT University Anantapur
Nandyal - 518 501, Kurnool Dist, A.P.
(ESTD-1995)

INTERNAL EXAMINATIONS ANSWER BOOKLET

NAME OF THE STUDENT: P. MuniTeja Reg. No. 2 2 0 9 5 A 0 4 2 2

Principal
Autonomous

	1	2	3	4	5
A		2	2	5	
B	1	3	1		
C	1				
D	1				
E	1				
Total	4	5	3	5	

Grand Total :(In Figures) 17

(in Words): one seven

NAME OF THE SUBJECT: Electronic circuits analysis&design

INTERNAL EXAM : [✓ I] / II

Date of Exam: 16/05/23 (FN/[✓ AN])

Course : [✓ B.Tech.] / M.Tech./ MBA / MCA

Year : IInd Sem.: IInd

Branch: Electronics communication engineering

Signature of the Invigilator

(Start Writing From Here)

C. Common mode Rejection ratio:-

CMMR means Common mode rejection ratio.

It is the ratio of Ad to Adcm

$$CMRR = \frac{Ad}{Acm}$$

$$CMRR = \frac{-2gmRss}{\frac{\Delta rd}{rd}}$$

$$CMRR = \frac{-2gmRss}{\frac{\Delta gm}{gm}}$$

CMRR in dB is,

$$CMRR_{dB} = 20\log\left(\frac{Ad}{Acm}\right)$$

$$CMRR \text{ in } dB = 20\log(CMRR)$$

d. Compare the three BJT Configurations in terms of Ai, Av, Ri, and Ro.

Parameters	CB	CE	CC
Voltage gain(Ai)	High	medium	Low.
Curren gain (Av)	Low	High	High(
input resistance	Low	High.	high
output resistance	high	High	high.

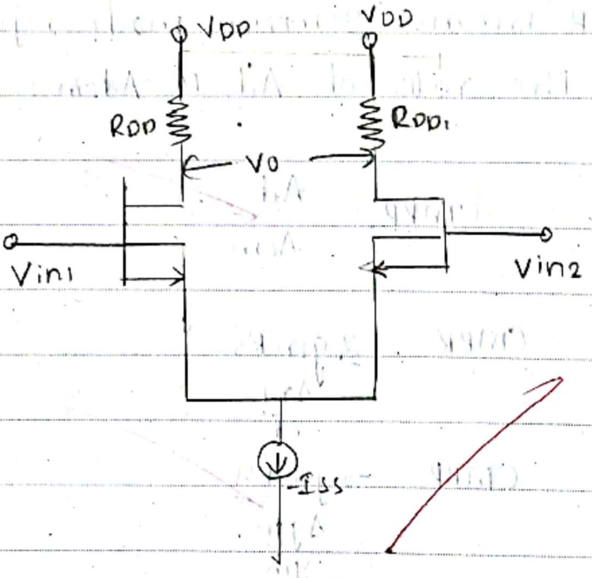
e. Differential Amplifier:-

It is defined as the output is difference between the two i/p signals.

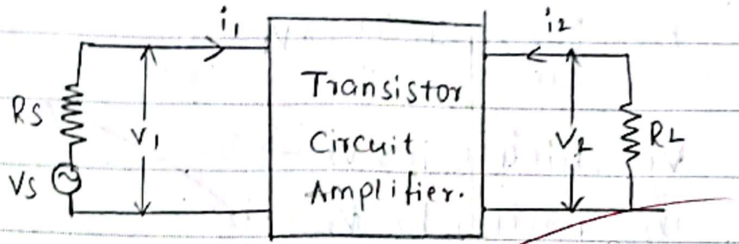
$$V_o = V_{in1} - V_{in2}$$

(or)

$$V_{in2} - V_{in1}$$



2. a) Block diagram of basic amplifier ckt:-

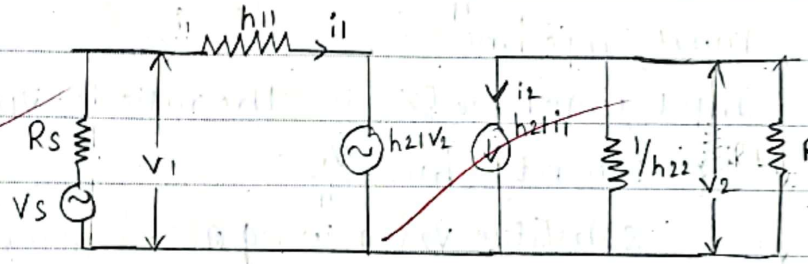


Amplifier means to given the strength to the weak signal is called amplifier

H-parameter model:-

$$V_1 = h_{11} i_1 + h_{12} V_2$$

$$I_2 = h_{21} i_1 + h_{22} V_2$$



b) The Analysis of above BJT Amplifier, is here, the current passing through NPN transistor is positive and PNP transistor is Negative, The Voltages are currents I_1, V_1, I_2, V_2 ~~some of them~~ all are are independent. Here by this Voltages and Currents the H parameters are derived.

Z parameters - Both are dependent.

Here V_1 Voltage is function of i_1, V_2

I_2 ~~Voltage~~ Current is function of i_2, V_2

$$V_1 = f(i_1, V_2)$$

$$I_2 = f(i_1, V_2)$$

By differentiating this equations we get.

$$V_1 = \frac{\partial V_1}{\partial I_1} dI_1 + \frac{\partial V_1}{\partial V_2} dV_2$$

$$I_2 = \frac{\partial I_2}{\partial I_1} \partial I_1 + \frac{\partial I_2}{\partial I_1} \partial V_2$$

$$V_1 = h_{11} i_1 + h_{12} V_2 \rightarrow ①$$

$$i_2 = h_{21} i_1 + h_{21} V_2 \rightarrow ②$$

Here, from the above H-parameter diagram we Short circuit then, $V_2 = 0$

Substitute $V_2 = 0$ in eq ①

$$V_1 = h_{11} i_1 + h_{12}(0)$$

$$h_{11} = \frac{V_1}{i_1}$$

Input impedance:-

Input impedance (Z_i) is the ratio of i/p voltage to i/p current $h_{11} = \frac{V_1}{i_1}$

Substitue $V_2 = 0$ in eq ②

$$i_2 = h_{21} i_1 + h_{21}(0)$$

$$h_{21} = \frac{i_2}{i_1}$$

Curren gain:-

The ratio of ~~input~~ output current to input curren it is called forward current gain (A_I)

$$h_{21} = \frac{i_2}{i_1}$$

Voltage gain:

We open circuit the above H-parameter diagram then, $i_1 = 0$

substitute $i_1 = 0$ in eq ①

$$V_1 = h_{11}(0) + h_{12} V_2$$

$$h_{12} = \frac{V_1}{V_2}.$$

It is ratio of i/p Voltage to the output current it is called reverse voltage gain.

Output admittance (y_o):-

Put $i_1 = 0$ in eq②

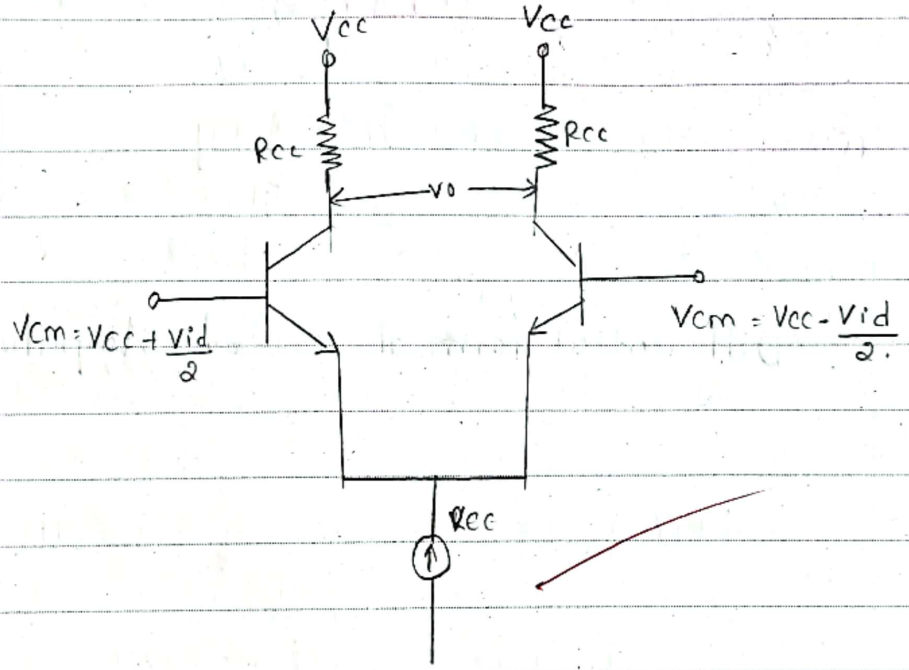
$i_2 = h_{21}(0) + h_{22}V_2$

$$h_{22} = \frac{i_2}{V_2}$$

It is the ratio of output current to output voltage it is called output admittance.

2

3. a. Small signal model of the differential amplifier:-



$V_i = V_{cm} = V_{cc} + \frac{vid}{2}$ & $V_{cm} = V_{cc} - \frac{vid}{2}$.

For MOSFET Amplifier

In BJT small signal model A

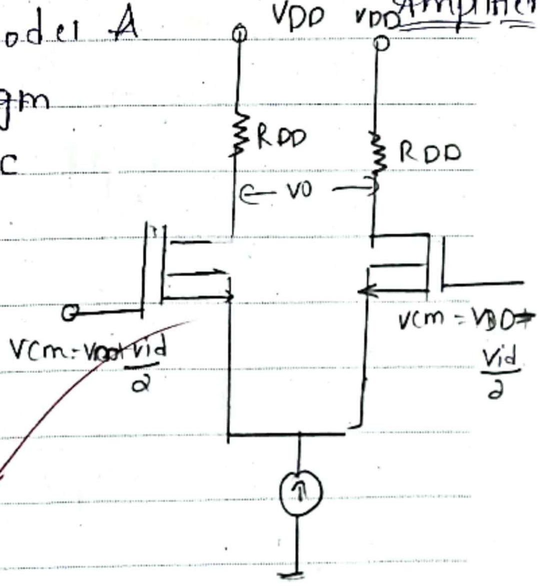
~~Ad = gm~~

~~Ad = Rc~~

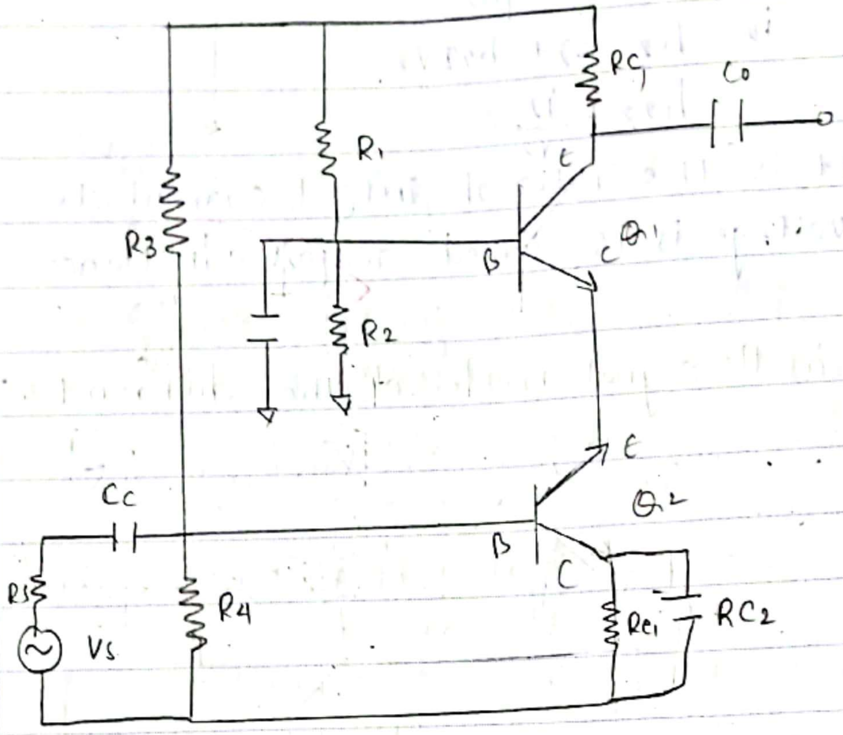
~~Ad = Rcα1~~

$\boxed{Ad = R_cI_E}$

2



6. Draw the differential form of cascode Amplifier.

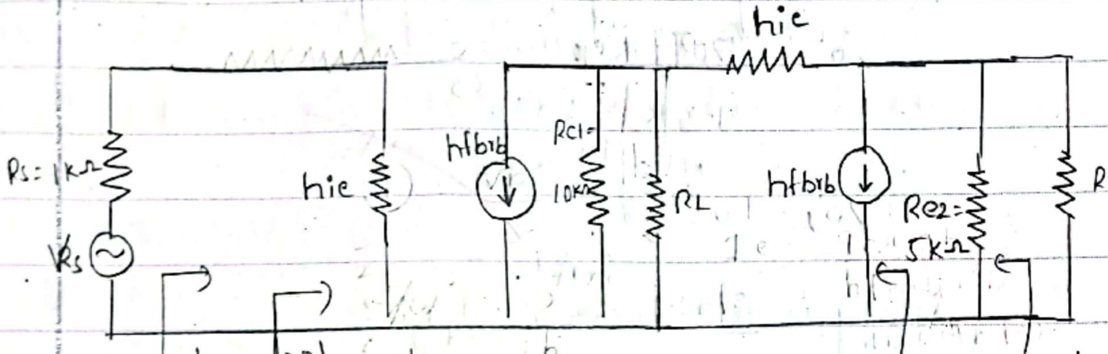


Differential form of Cascode Amplifier

4. Given that,

i) CE-CC amplifier

$R_S = 1K\Omega$, $R_{C_1} = 10K\Omega$, $R_{E_2} = 5K\Omega$



Analysis of Second Stage:-

$R_L' = R_{e2} = 5K\Omega$

$h_{oe} \cdot R_L' = 20\times10^{-6} \times 5\times10^3$ Here, take $h_{oe} = 20\mu A/V$

$= 0.1$

Hence we use simplified model

$A_{I_2} = 1 + h_{fe}$

$A_{I_2} = 1 + 50$

$\boxed{A_{I_2} = 51}$

~~AV =~~ $Z_{in_1}' = h_{ie} + h_{fe} R_L$

$= 1.3\times10^3 + 50(5\times10^3)$

$\boxed{Z_{in} = 251.3K\Omega}$

$A_{V_2} = \frac{-A_I R_L'}{Z_{in}}$

$= \frac{-51\times5\times10^3}{251.3\times10^3}$

$\boxed{A_{V_2} = -1.014}$

$$Zo_2 = \frac{hie + (1+hfe)}{1+hfe}$$

$$Zo_2 = \frac{1.3\times10^3\,(1+50)}{1+50}$$

$Zo_1 = 1300\,\Omega = 1.3K$

$Zo'_1 = Zo \,||\, Re_2$

$= 1.3K \,||\, 5\times10^3$

$\boxed{Zo'_2 = 1031.7.}$

Analysis of ~~second~~ first stage:-

$Zin_1 = hie$ — Here $RL' = RC1 = 10K$

$\boxed{Zin_1 = 1.3K}$ — $hoe\,RL' = 25\times10^{-6}\times10\times10^3$

$AI = hfe$

$\boxed{AI_1 = 50}$

$$AV_1 = \frac{-AI\,RL'}{Zin}$$

$$= \frac{-50\times10\times10^3}{1.3K}$$

$\boxed{AV_1 = -384.61}$

$Zo = \infty$

$Zo' = \infty \,||\, Rc'$

$Zo' = \infty \,||\, 10K$

$Zo'_1 = 10K.$

$Zin'_1 = Zin_1 \,||\, Rs$

$= 1.3K \,||\, 1K$

$\boxed{Zin'_1 = 565.2\,\Omega}$

a) overall current gain $A_I = A_{I_1} \times A_{I_2}$

$= 51 \times 50$

$= 2550$

b) over all voltage gain $A_V = A_{V_1} \times A_{V_2}$

$= -1.014 \times 384.61$

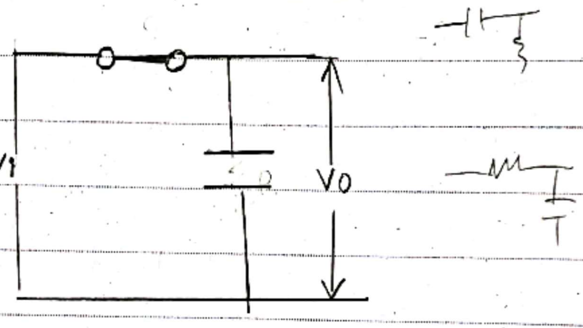
$= 389.99$

2

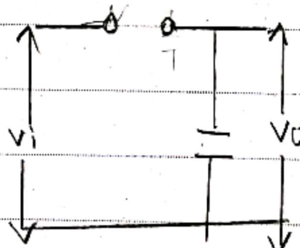
c) over all Input impedance $Z_{in_1}' = 565.2\,\Omega$

d) over all output impedance $Z_{o_2}' = 1031.7\,\Omega$

1. a. High frequency hybrid-π model of BJT.



High frequency hybrid-π model



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Low frequency hybrid-π- model

b) Typical h-parameter values for a trasistor

IC = 1.3 mA.

$hie = 1.3 \times 10^3 = 1.3K$

hoe = 25 uA/V

$hre = 2.3 \times 104$

hfe = 50

hoe = ~~2.5 × 10~~ 25×10^{-6} A/V

hfe = 51.

hre = 1

hie = 1.1K

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

11th July 2023

II B.Tech. II Sem. (R20) Mid-II Examinations

ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN

ECE

Time: 2 Hrs **Total Marks: 20**

Note 1:Answer first question compulsorily. (5 x 1 : 5 Marks)

2:Answer Any THREE from 2 to 5 questions. (3 x 5 : 15 Marks)

1a List the applications of LC oscillators.

b In a wein-bridge oscillator, if the value of R=100kΩ and the frequency of oscillation is 10KHz. Find the value of capacitance.

c Classify the basic amplifiers based on the comparison between Rs and Ri and between Ro and R_L.

d Draw the circuit diagram of class A output stage.

e What is feedback process?

2 a) Draw the circuit diagram of transistorized wein-bridge oscillator.
b) Explain the operation of above circuit and derive the expression for frequency of oscillations.

3 a) With the help of neat sketches explain the different topologies of a negative feedback amplifier.
b) Prove that change in transfer gain with feedback is less than the change in gain without feedback by a factor 1+Aβ.Also define sensitivity and desentivity of transfer gain.

4 a) Draw the circuit diagram of Wien bridge oscillator using FET and explain its operation.
b) Mention the comparison between RC phase shift and Wien bridge oscillators.
c) The frequency sensitive arms of the Wien bridge oscillator use C_1=C_2= 0.001μF and R_1 =10KΩ while R_2 is kept variable. The frequency is to be varied from 10KHz to 50KHz by varying R_2. Find the minimum and maximum values of R_2.

5 a) Show that the maximum efficiency of push pull class B power amplifier is 78.5%.

b) A loud speaker of 8Ω is connected to the secondary of the output transformer of a class A amplifier circuit. The quiescent collector current is 140mA.The turns ratio of the transformer is 3:1. The collector supply voltage is 10V.If the A.C power delivered to the loud speaker is 0.48W. Calculate
i) DC power input.
ii) Maximum Efficiency
iii) Maximum power dissipation.

- xxx -

S.No. 55745

RAJEEV GANDHI MEMORIAL COLLEGE OF ENGINEERING & TECHNOLOGY
AUTONOMOUS

Accredited by NAAC of UGC, New Delhi with 'A' Grade:: Accredited by NBA
Affiliated to JNT University Anantapur
Nandyal - 518 501, Kurnool Dist, A.P.

(ESTD-1995)

INTERNAL EXAMINATIONS ANSWER BOOKLET

NAME OF THE STUDENT: B. Jahnavi

Reg. No. 2 1 0 9 1 A 0 4 6 1

	1	2	3	4	5
A	1	1½	1½	2	1½
B	1	3	3	1½	2
C	½			1	
D	1				
E	1				
Total	4½	4½	4½	4	3½
Grand Total :(In Figures)	18				
(in Words):	One Eight				

NAME OF THE SUBJECT: ECA&D

INTERNAL EXAM : I / [✓ II]

Date of Exam: 11/07/23 (FN/AN)

Course : [✓ B.Tech.] / M.Tech./ MBA / MCA

Year : II Sem.: II

Branch: ECE

Signature of the Invigilator 2/11/7/23

(Start Writing From Here)

Q 1) Applications of LC oscillators.

a) 1) LC oscillators are used to get the sustained frequency oscillations.

2) If we use two inductors and one capacitors it is called Heartly oscillator. Two capacitors and one Inductor uses then it is called colpits oscillators.

1

3) These LC oscillators are used in feedback Amplifiers with +ve feedback.

1 b) Given, R=100kΩ, f=10kHz.

$\therefore \omega = 2\pi f$

$\omega = 2\times\pi\times 10\times 10^3 = 62831.8$ rad

For wein bridge oscillation.

1

$f = \frac{1}{2\pi\sqrt{\ }}$

$f = \frac{1}{2\pi RC}$.

$$10\times10^3 = \frac{1}{2\pi\times100\times10^3\times C}$$

$$\therefore C = \frac{1}{2\pi\times100\times10^3\times10\times10^3}$$

$$= \frac{1}{2\pi\times10^9}$$

$$C = 1.59\times10^{-10}\ F$$

1c) Based on basic amplifiers. these can be classified into 4types.

2

1) Voltage Series Feedback Amplifier
2) Current Series Feedback Amplifier
3) Voltage Shunt Feedback Amplifier
4) Current shunt Feedback Amplifiers.

1d).

1

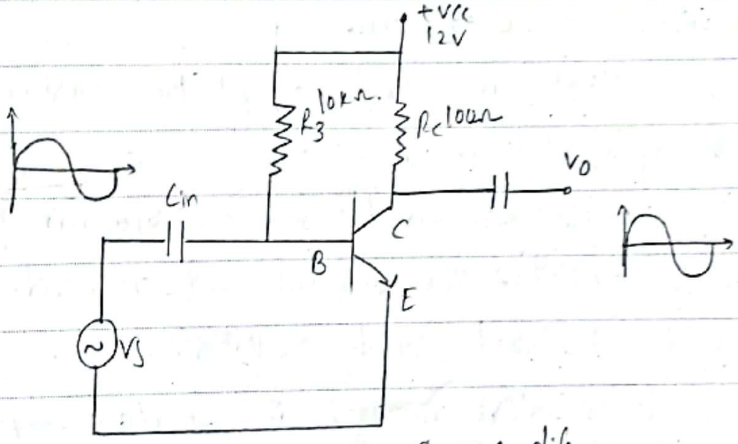


figure: class A Power Amplifier

1e)

1e) The process of magnitude of o/p Signal increases or decreases with respect to i/p Signal is called feedback process.

1

These are of two types.

1) Positive feedback.
2) Negative feedback.

Q. 2a)

A).

12

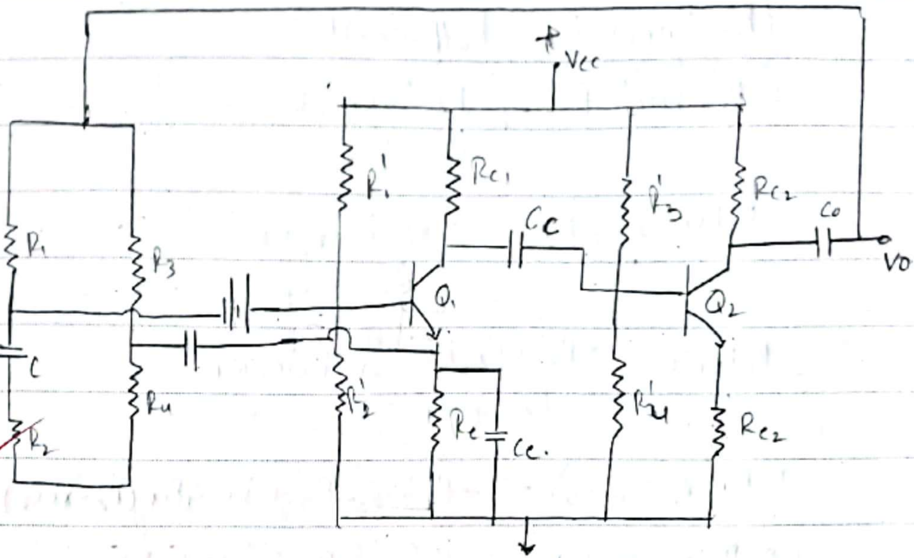


Fig:- Wein bridge Oscillator.

2b) 1) The above fig shows the wein bridge oscillator. $R_1, R_2, R_3,$ R_4 are the bridge resiston.

2) R_1, R_4 are oppositive arms to the bridge. R_2 contains one capacitor $||^{le}$ to it.

3) These wein bridge oscillator consist of two Transistors with Re resistor followed by it.

4) R_1', R_2', R_3', R_4' are the opposite resitive term arms to the circuit.

5) The Output followed to the bridge network.

6) wein bridge oscillators contain two CE amplifiers Transistor.

7) R_3 / R_g are opposite to each other. The impedances of Product of opposite is eqlato the other side opposite Resistors.

$$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}.$$

Here. $\cancel{R_1} = R_1 - j\omega c_1$

$Z_2 = \cancel{R_2} = R_2 || j\omega c_2$

$$\frac{\cancel{Z_4}}{\cancel{Z_2}} \quad Z_1 Z_4 = Z_3 Z_2.$$

$Z_3 = \cancel{R_3} = R_3$

$Z_4 = R_4 = R_4$.

$$(R_1 - j\omega c_1)\ R_4 = (R_2 \parallel j\omega c_1) R_3$$

$$(R_1 - j\omega c_1)\ R_4 = \left(\frac{-R_2 j\omega c_1}{R_2 - j\omega c_1}\right) R_3$$

$$R_1 R_4 - j\omega c_1 R_4 = \frac{-R_2 j\omega C_2}{R_2 - j\omega C_2} \times R_3.$$

$$R_1 R_4 = \frac{-R_2 j\omega C_2 R_3}{R_2 - j\omega C_2} + j\omega c_1 R_4.$$

$$R_1 R_4 (R_2 - j\omega c_2) = -R_2 j\omega c_2 R_3 + j\omega c_1 R_4 (R_2 - j\omega C_2)$$

$$R_1 R_4 R_2 - j\omega C_2 R_1 R_4 = -R j\omega c_2 R_3 + j\omega C_1 R_4 R_2$$
$$+ j^2 \omega^2 C_1 C_2 R_4.$$

$$R_1 R_4 R_2 - j\omega C_2 R_1 R_4 = -R_2 j\omega c_2 R_3 + j\omega C_1 R_4 R_2$$
$$+ \omega^2 C_1 C_2 R_4.$$

$$R_1 R_4 R_2 - \omega^2 \overset{C_1}{\cancel{C}} C_2 R_{4} = -R_2 j\omega C_2 R_3 + j\omega C_2 R_1 R_4$$
$$+ j\omega c_1 R_4 R_2$$

$$R_4 [R_1 R_2 - \omega^2 \overset{C_1}{\cancel{C}} C_2] =$$
$$j[-R_2 \omega C_2 R_3 + \omega C_2 R_1 R_4 + \omega C_1 R_4 R_3]$$

$$\Rightarrow R_4 [R_1 R_2 - \omega^2 C_1 C_2] - j[-R_2 \omega C_2 R_3 + \omega C_2 R_1 R_4 + \omega C_1 R_4 R_3] = 0 \rightarrow ①$$

From eq ①, Imaginary part $= 0$.

$$-R_2 \omega C_2 R_3 + \omega C_2 R_1 R_4 + \omega C_1 R_4 R_3 = 0.$$

If ~~imaginary~~ Real part $= 0$.

$$R_4 (R_1 R_2 - \omega^2 C_1 C_2) = 0$$

$$R_1 R_2 = \omega^2 C_1 C_2$$

if $R_1 = R_2 = R$

$C_1 = C_2 = C$

$$\omega^2 = R_1 R_2 \cancel{C_1} C_2. \Rightarrow$$

3

$$\omega^2 = R^2 \overset{C_1}{\cancel{C^2}} C_2$$

$$\cancel{2}\pi f = \frac{1}{R^2 C^2}.$$

$$f = \frac{1}{\cancel{2}\pi^2 R^2 C^2}$$

$$\boxed{f = \frac{1}{2\pi RC}.}$$

$$\therefore \frac{1}{2^2 \pi^2 f^2} = R^2 C^2$$

$$f^2 = \frac{1}{2^2 \pi^2 C^2 R^2}$$

$$f = \frac{1}{2\pi RC}$$

which is frequency of oscillations.

3)
a)

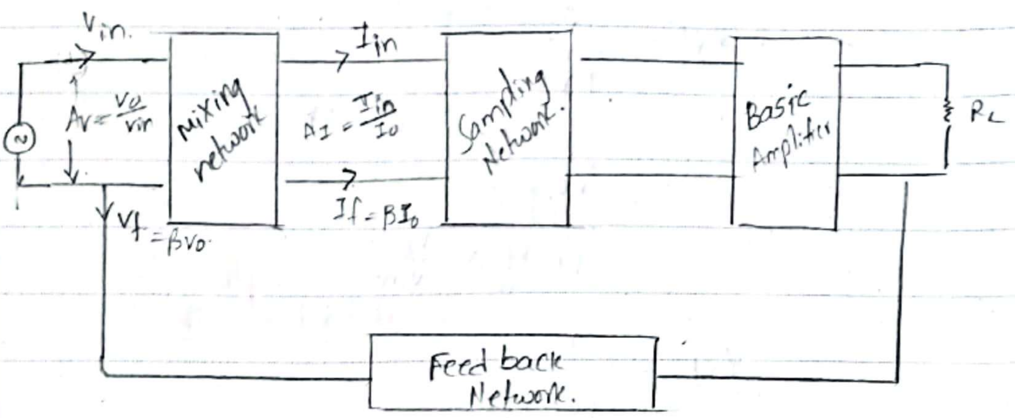


figure : Topologies of a negative Amplifier

1) The above figure shows the Topologies of a negative feedback Amplifier.

2) To become an feedback amplifier the circuit is mixing with o/p Signal and i/p Signal. If any sampling to the voltage and current of a circuit we use Voltage and Current sampling.

3) For the basic Amplifiers the mixing and sampling network give ito it.

4) By these 3 types of Network called feedback Amplifier.

5) If the magnitude of o/p signal of voltage (or) current reduces is called -ve feedback Amplifier.

3 b) Transfer Gain:- It is between the i/P and output Impedances. $A_v = \frac{V_o}{V_{in}} = Z_i$

$V_{in} = V_s - V_f$

$V_s = V_{in} + V_f$

For the -ve feedback Amplifiers ;' $V_f = \beta V_o$.

$$\therefore A_v = \frac{V_o}{V_s - V_f}, \text{ for } A_{vf} = \frac{V_o}{V_s} = \frac{V_o}{V_{in} + V_f} \quad ①$$

For eq ① divide numerator and denominator with Vin

$$A_{vf} = \frac{V_o/V_{in}}{\frac{V_{in}+V_f}{V_{in}}}$$

$$A_{vf} = \frac{\frac{v_o}{v_{in}}}{1+\frac{v_f}{v_{in}}}$$

$$= \frac{\frac{V_o}{v_{in}}}{1+\frac{v_f}{v_o} \times \frac{v_o}{v_{in}}}$$

$$A_{vf} = \frac{A}{1+\beta A}$$

for o/p impedance $Z_{of} = A_{vf} = \frac{A}{1+A\beta}$

$$Z_{of} = \frac{A}{1+A\beta}$$

From the above equation, that change in transfer gain with feedback is less than the change in gain without fb by a factor $1+A\beta$.

Sensitivity, $S = \frac{1}{1+A\beta}$ $D = \frac{1}{1+A\beta}$

Desensitivity, δ $\boxed{D = 1+A\beta}$ $[\frac{1}{S} = D]$

open loop gain is A.

4)
a)

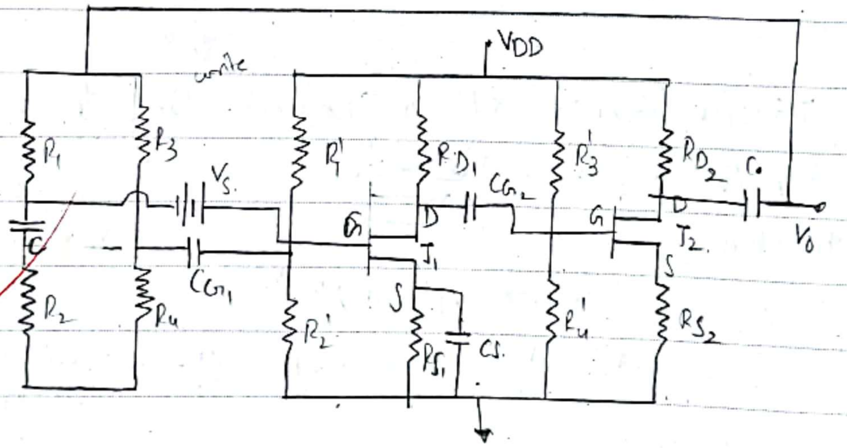


Figure: Wein bridge oscillator using JFET

4 b)

Rc Phase shift	wein bridge oscillator
1) circuit is Simple	1) circuit is complex due to bridge network.
2) It is degenative	2) It is a generative
3) Frequency of oscillations $f = \frac{1}{2\pi\sqrt{RC}}$ $f = \frac{1}{2\pi\sqrt{RC}\sqrt{6}}$.	3) Frequency of oscillations $f = \frac{1}{2\pi RC}$.
4) It is a variable oscillator.	4) It is not variable oscillator.
5) ~~Bandwidth~~ Audio (or) Low frequency Range. (20Hz – 2MHz).	5) Radio(or) High frequency Range (20MHz–20MHz)

2

4c) Given, $C_1 = C_2 = 0.001\,uF$

$R_1 = 10k\Omega$; $f_1 = 10Hz$, $f_2 = 50KHz$.

$k = \frac{R_C}{R_0}$ =

For Rc phase shift oscillator, frequency is

$$f = \frac{1}{2\pi\sqrt{RC}}.$$

$$\therefore f_1^2 = \frac{1}{4\pi^2 R_1 R_2 C_1 C_2} \Rightarrow (10\times10^3)^2 = \frac{1}{4\pi^2\, 10\times10^3 \times R_2 \times 0.001uF \times 0.001uF}$$

$$\therefore R_2 = \frac{1}{(10\times10^3)^2 \times 2\pi \times 10\times10^3 \times 0.001\times10^{-6} \times 0.001\times10^{-6}}$$

$$R_2 = \frac{1}{4\pi^2 \times 100\times10^6 \times 10^3 \times 10 \times 0.001\times10^{-6} \times 0.001\times10^{-6}}$$

$R_2 = 25.33 K\Omega$

If $f_o = 50kHz$

$$(50\times10^3)^2 = \frac{1}{4\pi^2\times10\times10^3\times R_2\times2\times0.001\times10^{-6}}$$

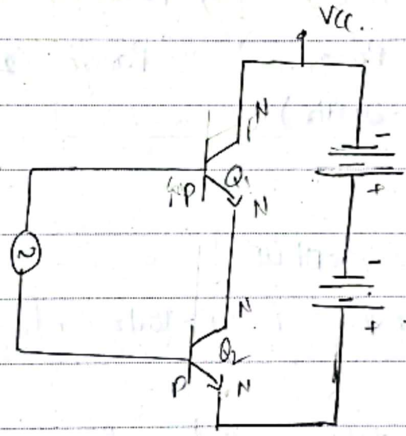
$$R_2 = \frac{1}{4\pi^2\times2500\times10^6\times2\times0.001\times10^{-6}}$$

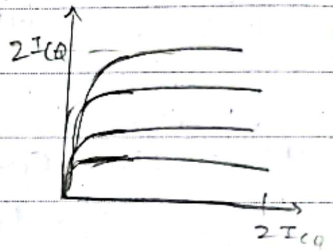
$R_2 = 10.13\, M\Omega$

$\therefore$ R_2 value varies from $25.3k\Omega$ to $10.103\, Mk\Omega$

5a) 1) Push Pull class B Power Amplifier.

2) Push pull class B Power Amplifier consist of two NPN Transistors.





Dc operation

Apply KVL $V_{CC} = V_{CEQ}$ for O/P a/p voltage is zero.

$V_m = \frac{2V_m}{2\pi}$ [For rectifiers]

for peak to peak voltage.

Ac operation.

Apply KVL for input $-V_{BE} + V_S - I_B R_B = 0$

$V_S = V_{BE} - N_{BE}$

$I_m = \frac{2I_m}{\pi}$

[For rectifiers] $\boxed{V_S = V_{CE} - 0.7}$

For (%η) officiency $= \frac{P_{ac}}{P_{dc}} \times 100$

For $P_{dc} = V_{cc_{max}} - V_{min}$

$P_{dc} = 2V_{CCQ} - 0$

$P_{dc} = 2\frac{V_m}{\pi}$

For, $P_{ac} = I_{max} - I_{min}$

$= 2I_{max} - 0$

$= 2\frac{I_m}{\pi}.$

$$\therefore \eta = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{\frac{2I_m}{\pi}}{2\frac{V_m}{\pi}} \times 100$$

$$\eta = \frac{\frac{\pi}{4} I_m V_m}{(V_{CQ}-0)(I_m-0)} \times 100$$

$$\eta = \frac{\pi}{4} \times \frac{\cancel{V_{CQ}}\ \cancel{I_m}}{\cancel{(V_{CQ}-0)(I_m-0)}} \times 100$$

$\% \eta = 78.5\%$

$\therefore$ Maximum efficiency of Push Pull class B is 78.5%.

5b)

Sol: Gived $R_L = 8\Omega$, $I_C = 140mA$, $\frac{N_1}{N_2} = \frac{3}{1}$

$V_S = 10V.$

$P_{ac} = 10V.$

(i) Dc power input $P_{dc} = V_{CC} \times I_{CQ}.$

$R_L' = \left(\frac{N_1}{N_2}\right)^2 \times R_L$

$= \left(\frac{3}{1}\right)^2 \times 8$

$R_L' = 72\Omega$

~~For output KVL~~

~~$V_{CE} - I_C R_L - V_{CE} = 0$~~

100 -

$V_{CE} = I_C R_L + V_{CC}$

$= 140 \times 10^{-3} \times 8 + 10$

$\boxed{V_{CC} = 11.12\,V}$

Dc input Power = 11.12 V × 140 mA
= 1.538 W

(ii) ~~Dc input Power = $\frac{P_{dc}}{P_{dc}} \times 100$~~

Maximum efficiency η ~~0.48~~ = $\frac{11.12 \times 140 \times 10^{-3}}{P_{ac}} \times 100$

η ~~P_{ac}~~ = $\frac{\cancel{11.12 \times 1.55}}{\cancel{0.4}8} \times 100$

η. ~~P_{dc}~~ = $\frac{P_{ac}}{P_{dc}} \times 100$

$\eta = \frac{0.48}{11.12 \times 140 \times 10^{-3}} \times 100$

2

(ii) $\boxed{\eta = 30\%}$

(iii) Maximum Power dissipation = $P_{dc} - P_{dc}$

= 1.538 − 0.48.

= 1.058 watts.

5b) Given, $R_L = 8\Omega$

5b)

$\frac{N_1}{N_2} = \frac{3}{1}$ ∴ $R_L' = \left(\frac{N_1}{N_2}\right)^2 \times R_L$

$= (3)^2 \times 8$

$R_L' = 72\Omega$

(ii) Dc input Power (P_{dc}) = $V_{CEQ} \times I_{CQ}$

Apply KVL

$V_{CE} - I_C R_L - V_{CE} = 0$

$V_{CE} = 140 \times 10^{-3} \times 8 + 10$

$= 11.2V$

∴ $P_{dc} = 11.2 \times 140 \times 10^{-3} = 1.56$ watts

(ii) $\% \eta = \frac{P_{de}}{P_{dc}} \times 100 = \frac{0.48}{1.56} \times 100$

$= 30.7\%$

2

10.05 - 10

0.05

VCC

(ii) Maximum Power dissipation = $P_{dc} - P_{ac}$

$= 1.56 - 0.48$

$= 1.08$ watts

Code: A0409204R0723

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

20th July 2023

II B.Tech. II Sem. (R20) End Examinations (Regular)

ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN

ECE

Time: 3 Hrs **Total Marks: 70**

Note 1:Answer Question No.1 (Compulsory) and 4 from the remaining
2:All Questions Carry Equal Marks

1a Define current-shunt negative feedback.

b Draw the high-frequency hybrid- Π model of BJT.

c Draw the circuit diagram of class A output stage.

d When the differential pair can be used as a linear amplifier?

e Define h_{ic} and h_{re}

f Define growing oscillations.

g Define voltage-series negative feedback.

2 a) Draw the circuit diagram of RC-phase shift oscillator and explain its operation.(7)
b) Draw the approximate hybrid model of RC phase shift oscillator and derive the output frequency of RC phase shift oscillator. (7)

3 a) Draw the circuit diagram of two-stage CE-CB cascode amplifier and its approximate hybrid model. (6)
b) Explain the h-parameter analysis of the above circuit. (8)

4 a) Draw the topology of Current Series feedback amplifier. Derive the expressions for input and output impedances with feedback. (8)
b) For a current series feedback amplifier with R_S=1KΩ, R_E=1.2KΩ and R_L =2.2KΩ. The transistors with parameters are h_{ie}=1.1KΩ and h_{fe}=50. Calculate G_M, β, D, A_{vf},R_{if} and R_{of} . (6)

5 a) Draw a common-source amplifier using the classical biasing arrangement (voltage divider biasing) and draw its equivalent circuit. (6)
b) Analyse the above circuit to find R_{in}, R_o, and Voltage Gain (8)

6 A common source amplifier has C_{C1}=C_{C2}=C_S=1μF, R_G=10MΩ, R_{Sig}=100KΩ, g_m=2mA/V, R_D=R_L=R_S=10KΩ. Find
a) Mid band gain A_M (3)
b) f_{p1} (2)
c) f_{p2} (2)
d) f_{p3} (2)
e) f_z and f_l (5)

7 a) Show that the maximum efficiency of series fed class A power amplifier is 25%. (7)

b) A class B push pull amplifier supplies power to a resistive load of 12Ω. The output transformer has a turns ratio of 3:1 and efficiency of 78.5%. Assume V_{CC} = 20V and h_{fe} = 25. Calculate (7)

i) Maximum power output

ii) Maximum power dissipation in each transistor.

iii) Maximum base and collector currents for each transistor.

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RGM College of Engineering & Technology (Autonomous)

20th July 2023

II B.Tech II-Sem (R20) End Examinations (Regular)

ELECTRONIC CIRCUITS - ANALYSIS AND DESIGN

ECE   Code: A0409204R0723

Total Marks: 70

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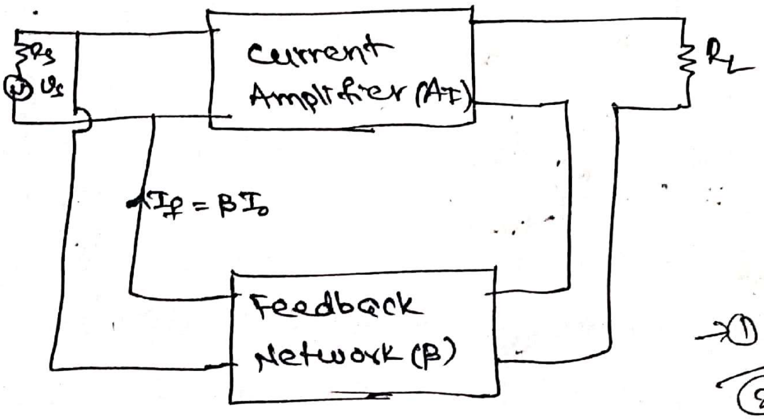
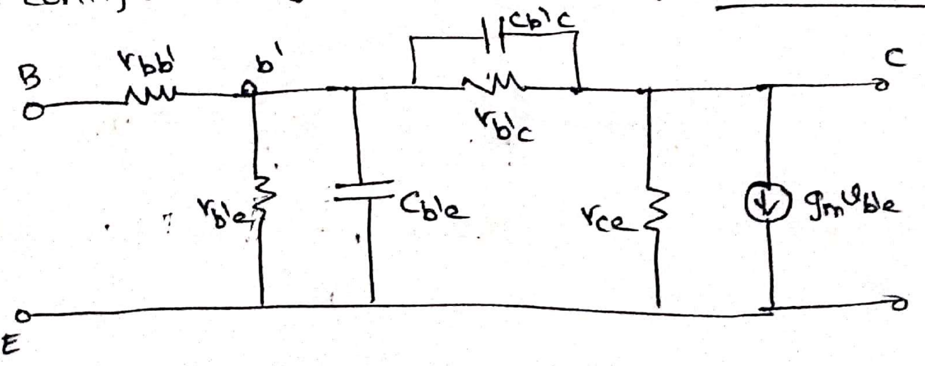
① ⓐ Current shunt feedback amplifier means output current is sampled and the feedback signal is mixed in shunt with input signal. In this the basic amplifier is current amplifier. The below figure shows the topology of the current shunt feedback amplifier. →① M



→① M

② M

① ⓑ The below figure shows the hybrid-π model for a transistor in CE configuration. It is also called "Giacoletto model".



→① M

(2|14)

~~Here $r_{bb'}$ - Base spreading resistance - 100Ω~~

$r_{b'e}$ - Resistance between B' and E - 1KΩ

$r_{b'c}$ - Resistance between B' and C - 4MΩ

r_{ce} - output resistance between C and E - 80kΩ

$C_{b'e}$ - Junction capacitance between B' and E - 100pF

$C_{b'c}$ - Junction capacitance between B' and C - 3pF

g_m - Mutual conductance of transistor - 50 mA/V.

→①M

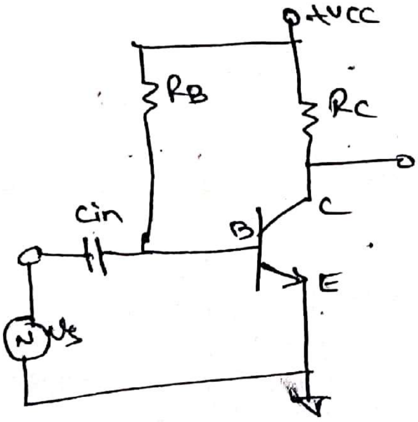
②M

①

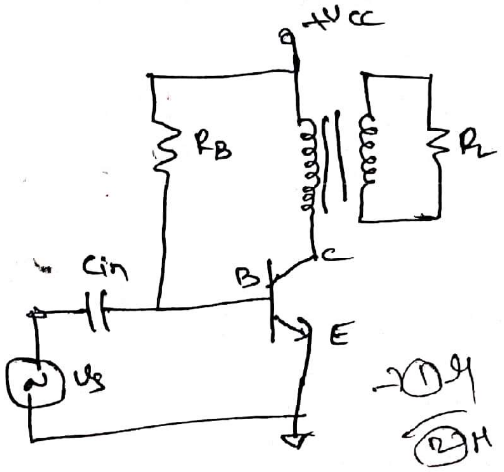
ⓒ The power amplifier is said to be class A amplifier if the Q-point and the input signal are selected such that the output signal is obtained for a full input cycle.

→①M

→ A simple fixed bias circuit can be used as large signal class A power amplifier.



(or)

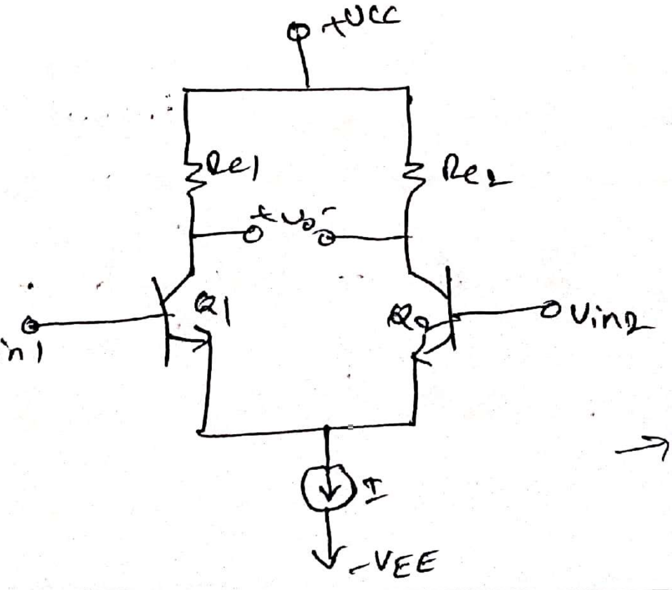


→①M

②M

①

ⓓ



→①M

→ Under BJT differential amplifier, the output voltage is given by $v_0 = (V_{in1} - V_{in2})$

→ If any one of the input voltage is zero and another input varies linearly then the differential amplifier will acts as a linear amplifier.

$v_0 = V_{in1}$ (or) $v_0 = -v_{in2}$ → ① M

② M

① ⓔ **hie :-** It is called input resistance (or) input impedance of CE transistor. It is the ratio of change in base to emitter voltage (V_{BE}) to change in base current (I_B) for a constant collector voltage. It is also defined as the ratio of input voltage to input current of a CE transistor.

i.e $\boxed{hie = \frac{V_{BE}}{I_B}}$ → ① M

It's typical value is 1.1KΩ.

hre :- It is called reverse voltage gain of a CE transistor. It is the ratio of change in base to emitter voltage (V_{BE}) to change in collector to emitter voltage (V_{CE}) at a constant base current.

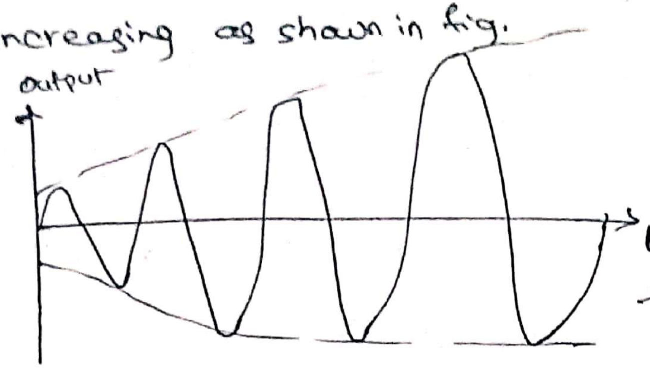
→ It is also defined as the ratio of input voltage to output voltage of a CE transistor.

i.e $\boxed{hre = \frac{V_{BE}}{V_{CE}}}$ → ① M

→ It is unitless and its typical value is 2.5×10^{-4}.

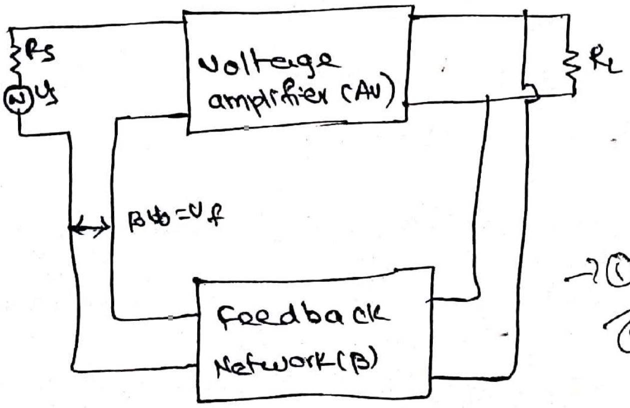
② M

① ⓕ When the total phase shift around a loop is 0° or 360° and $|A\beta|>1$, then the output oscillates but the oscillations are of growing type. The amplitude of oscillations goes on increasing as shown in fig. →①M



→①M
②M

① ⓖ In voltage series feedback amplifier, the output voltage is sampled and the feedback signal is mixed in series with the input signal. In this the basic amplifier should be voltage amplifier. The below fig shows the topology of voltage series feedback amplifier. →①M

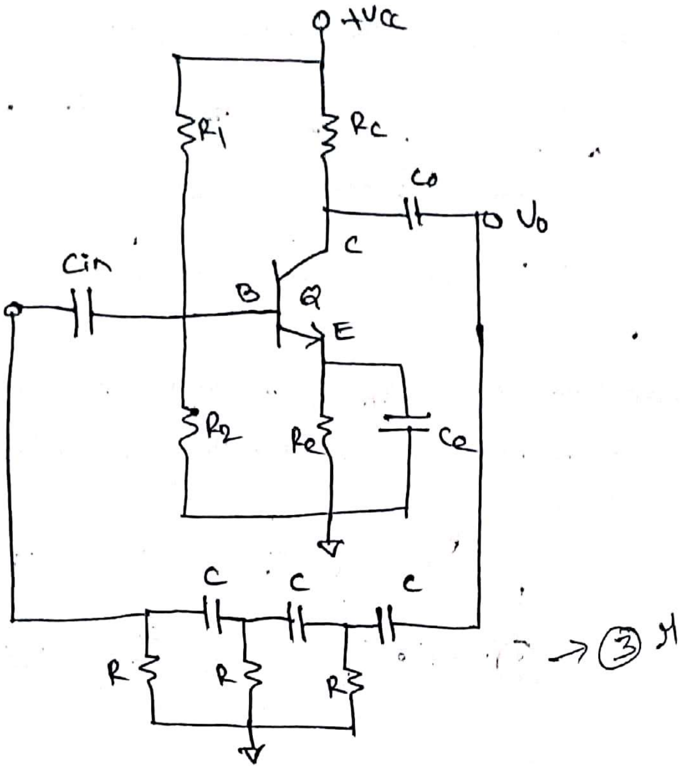


→①M
②M

② ⓐ RC phase shift oscillator is commonly used sinusoidal low frequency oscillator. It basically consists of an amplifier and a feedback network consisting of resistors and capacitors

5/17

arranged in ladder fashion. Hence such an oscillator is also called ladder type RC phase shift oscillator.



→ ③ M

→ The above circuit shows a practical transistorised RC phase shift oscillator which uses a common emitter single stage amplifier and a phase shifting network consisting of three identical RC sections.

→ The output of the feedback network gets loaded due to the low input impedance of a transistor.

→ In the above circuit, CE amplifier provides 180° of phase shift and the feedback network provides another 180° of phase shift. So the total phase shift is 0° or 360°.

→ In feedback network, we can choose a suitable values of R and C to get the phase shift as 60°.

i.e $\theta = Tan^{-1}\left(\frac{X_c}{R}\right)$

where $X_c = \frac{1}{2\pi f C}$

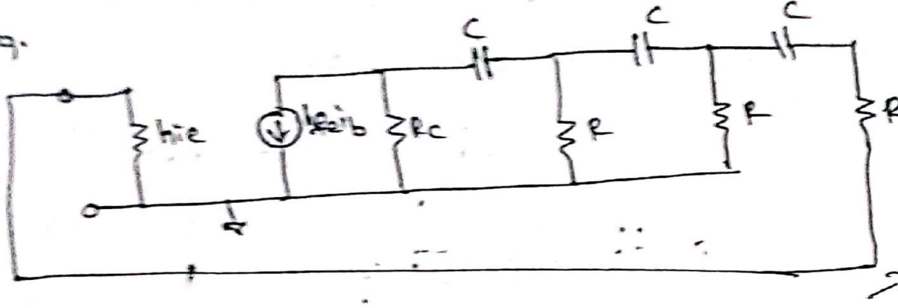
R is resistance.

→ ④ M

⑦ M

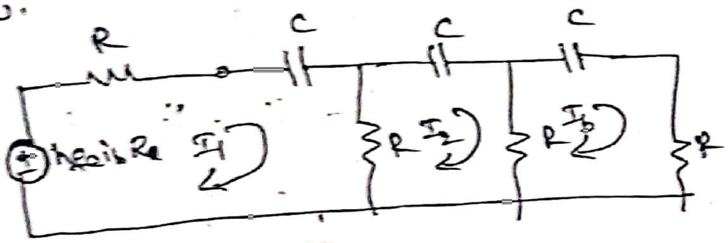
6½

② ⓑ By replacing the transistor by its approximate h-parameter model, we get the equivalent oscillator circuit as shown in below fig.



→①M

By neglecting hre & 1/hoe, make Rc = R and replace current source by voltage source then the modified equivalent circuit is shown below.



→①M

By applying KVL to three loops, we get

For loop ①, $h_{fe} i_b R + R I_1 + \frac{1}{j\omega C} I_1 + R(I_1 - I_2) = 0$

$$\left(2R + \frac{1}{j\omega C}\right) I_1 - R I_2 + h_{fe} i_b = 0 \rightarrow ①$$

for loop ② $(I_2 - I_1) R + \frac{1}{j\omega C} I_2 + (I_2 - I_b) R = 0$

$$-R I_1 + \left(2R + \frac{1}{j\omega C}\right) I_2 - R I_b = 0 \rightarrow ②$$

~~from~~ for loop ③, $(I_b - I_2) R + \frac{1}{j\omega C} I_b + R I_b = 0$

$$0 I_1 - R I_2 + \left(2R + \frac{1}{j\omega C}\right) I_b = 0 \rightarrow ③$$

From eq. ①, ② & ③, the current I_1, I_2 & I_b are non vanishing mean those does not becomes zero. So the determinant of coefficients of I_1, I_2 & I_b must be zero.

$$\begin{vmatrix} 2R - jX_c & -R & h_{fe} R \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{vmatrix} = 0$$

→①M

7(17)

$\Rightarrow (2R - jX_c)[(2R - jX_c)^2 - R^2] + R[-R(2R - jX_c) - 0] + h_{fe}R[R^2 - 0] = 0$

$\Rightarrow (2R - jX_c)[4R^2 - j4RX_c - X_c^2 - R^2] - R^2(2R - jX_c) + h_{fe}R^3 = 0$

$\Rightarrow 8R^3 - j8R^2X_c - 2RX_c^2 - 4R^3 - j4R^2X_c + 4RX_c^2 + jX_c^3 - jR^2X_c$
$- 2R^3 - jR^2X_c + h_{fe}R^3 = 0$

$\Rightarrow 4R^3 - 6RX_c^2 + h_{fe}R^3 + j(X_c^3 - 10R^2X_c) = 0$

By equating imaginary part to zero.

$X_c^3 - 10R^2X_c = 0$

$X_c^3 = 10R^2X_c$

$X_c^2 = 10R^2$

$X_c = \sqrt{10}R$

$\frac{1}{2\pi fC} = \sqrt{10}R$

$$\boxed{f = \frac{1}{2\pi\sqrt{10}RC}}$$

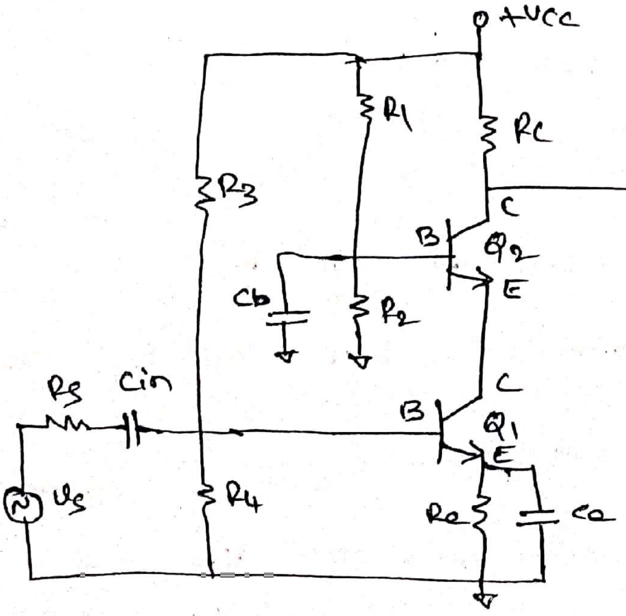
→ ③ M

⑦ M

7+7 = ⑭ M

③

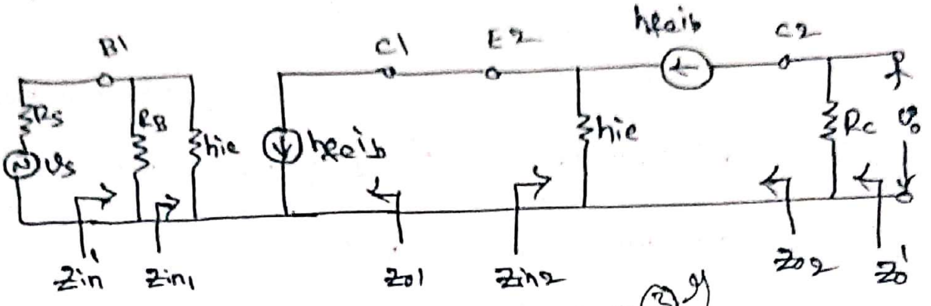
ⓐ The cascode amplifier consists of a common emitter amplifier in series with a common base amplifier. It is one approach to solve the low impedance problem of a common base circuit.



→ ③ M

(21/4)

The simplified h-parameter equivalent circuit for cascode amplifier is drawn by replacing transistors with their simplified equivalent circuits as shown below.



where $R_B = R_3 || R_4$. →③M

⑥M

③ ⓑ Analysis of second stage (CB amplifier).

① Current gain, $A_{I2} = \frac{h_{fe}}{1+h_{fe}}$

② Input impedance, $Z_{in2} = \frac{h_{ie}}{1+h_{fe}}$

③ Voltage gain, $A_{V2} = \frac{A_{I2} R_L}{Z_{in2}}$ →②M

Analysis of first stage (CE amplifier)

① Current gain, $A_{I1} = -h_{fe}$

② Input impedance, $Z_{in1} = h_{ie}$

③ Voltage gain, $A_V = \frac{A_{I1} R_{L1}}{Z_{in1}}$

where $R_{L1} = Z_{in2}$ →②M

overall voltage gain, $A_V = A_{V1} \times A_{V2}$

overall input impedance, $Z_{in} = Z_{in1} || R_B = Z_{in1} || R_3 || R_4$

overall voltage gain, $A_{Vs} = \frac{V_o}{V_s} = A_V \times \frac{Z_{in}}{Z_{in}+R_s}$.

over all current gain, $A_I = A_{I1} \times A_{I2}$

$A_{IS} = A_I \times \frac{R_B}{R_B + Z_{in1}}$ →③M output impedance, (Zo):-

$$Z_{o1} = \infty$$

$$Z_{o2} = \infty$$

$$Z_o = Z_{o2} \| R_C$$

$$\boxed{Z_o = R_C}$$

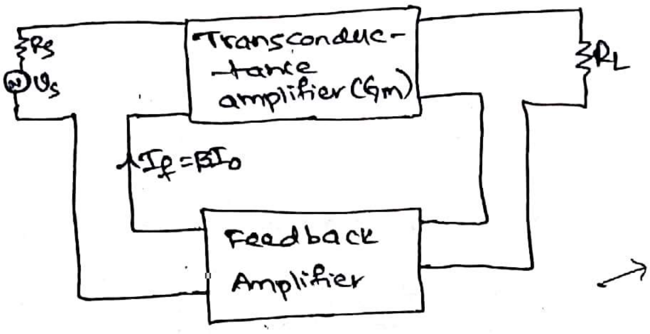
→① M

⑦M

7+7 = ⑭ M

④

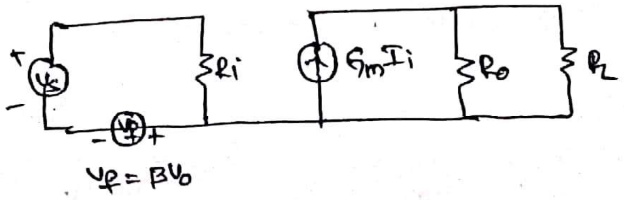
ⓐ Current series feedback amplifier, the output current is sampled and the feedback signal is mixed in series with input. In this, the basic amplifier is transconductance amplifier with gain G_M. The below figure shows the topology of current series feedback amplifier.



→② M

Input Impedance (Zin):-

The current series feedback topology with amplifier input circuit is represented by Thevenin's equivalent circuit and output circuit by Norton's equivalent circuit.



→① M

Let $Z_{in} = \frac{V_{in}}{I_{in}}$ and $Z_{if} = \frac{V_s}{V_{in}}$.

From topology, $V_{in} = V_s - V_f \Rightarrow V_s = V_{in} + V_f$

here $V_f = \cancel{\beta V_o}\ \beta I_o$ and $I_o = G_m V_{in}$

$$V_s = V_{in} + \beta G_m V_{in}$$

$$\frac{V_s}{\cancel{V_{in}}} = V_{in}(1 + G_m\beta)$$

$$Z_{if} = \frac{V_s}{I_{in}} = \frac{V_{in}}{I_{in}}(1+G_m\beta)$$ (10|12)

$$\boxed{Z_{if} = Z_{in}(1+G_m\beta)}$$ → ②M

Output Impedance (Z_o) :- Let Z_o & Z_{of} are the output impedances of without and with feedback.

$$Z_{of} = \frac{V_o}{I_o}\Big|_{V_s=0 \,\&\, R_L\to\infty}$$

By using KCL at output circuit

$$I_o = G_m V_{in} + \frac{V_o}{Z_o}$$

$$\frac{V_o}{Z_o} = I_o - G_m V_{in}$$

with $V_s = 0$, $V_{in} = -V_f = -\beta I_o$

$$\frac{V_o}{Z_o} = I_o - G_m(-\beta I_o)$$

$$= I_o + I_o G_m\beta$$

$$\frac{V_o}{I_o} = Z_o(1+G_m\beta)$$

$$\boxed{Z_{of} = Z_o(1+G_m\beta)}$$ → ③M

⑧M

④ ⓑ Given that $R_s = 1k\Omega$, $R_E = 1.2k\Omega$ & $R_L = 2.2k\Omega$.

The transistors with parameters are $h_{ie} = 1.1k\Omega$

$h_{fe} = 50$.

Open loop gain, $$G_m = \frac{I_o}{V_i} = \frac{-h_{fe} i_b}{V_s}$$

$$= \frac{-h_{fe}\cancel{i_b}}{\cancel{I_b}(R_s + h_{ie} + R_e)}$$

$$= \frac{-h_{fe}}{R_s + h_{ie} + R_e} = \frac{-50}{1K + 1.1K + 1.2K}$$

$$\boxed{G_m = -0.015}$$ → ②M

$\boxed{11/17}$

$$\beta = \frac{V_f}{I_o} = \frac{I_e R_e}{I_o} = -\frac{\cancel{I_o} R_e}{\cancel{I_o}} = -R_e = -1.2K$$

$D = 1 + g_m \beta$

$= 1 + (-1.2k)(-0.015)$

$= 19.18$ →① M

$$g_{mf} = \frac{g_m}{D} = \frac{-0.15}{19.18} = -0.782\times10^{-3}$$

$$A_{vf} = \frac{V_o}{V_s} = \frac{I_o R_L}{V_s} = g_{mf} R_L$$

$= -0.782\times10^{-3}\times2.2\times10^{3}$

$= -1.72$ →① M

$Z_{in} = R_s + h_{ie} + R_e$

$= 1K\Omega + 1.1K\Omega + 1.2K\Omega$

$= 3.3K\Omega$ →① M

$Z_{if} = \cancel{R}\, Z_{in} D = 3.3K(19.18)$

$= 63.294K\Omega$

$Z_o = \infty$

$Z_{of} = R_o D = \infty$

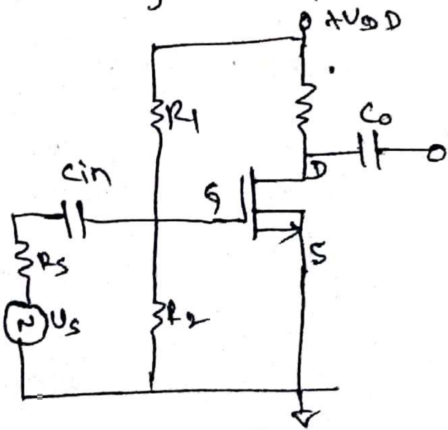
$Z'_{of} = R_{of} \| R_L = R_L = 2.2K\Omega.$ →① M

⑥ M

8+6 = ⑭ M

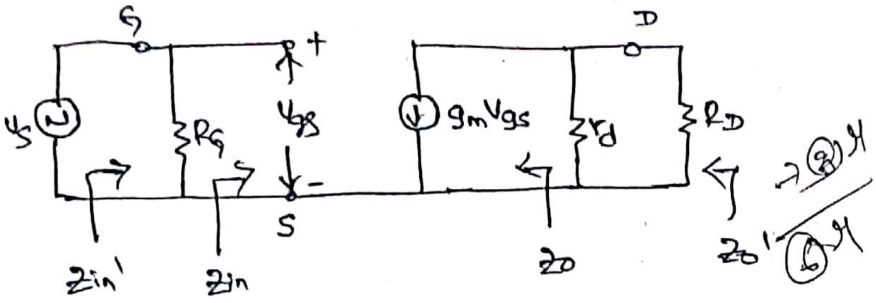
⑤

ⓐ In common source amplifier, the input voltage is applied between gate to source terminal and output is taken across drain to source terminal. The figure shows the CS amplifier with voltage divider bias.



→③ M

→ The AC equivalent circuit of common source amplifier. is shown below.



→ ⑧M / ⑥M

where $R_G = R_1 || R_2$.

ⓑ **Input Impedance (R_{in}):-** It is the ratio of input voltage V_{gs} to input current I_G in CS amplifier.

$$\therefore R_{in} = \frac{V_{gs}}{I_G}.$$

From input circuit, input terminals are open circuited. i.e which indicates $i_G = 0$

$$\therefore R_{in} = \frac{V_{gs}}{0}$$

$$\boxed{R_{in} = \infty}.$$ → ②M

Overall input impedance, $R_{in}' = R_{in} || R_G$

$$= \infty || R_G$$

$$\boxed{R_{in}' = R_1 || R_2}$$ → ①M

Output Impedance (R_o):- It is the ratio of output voltage V_{ds} to output current I_D in CS amplifier with $V_s = 0$.

$$\therefore Z_o = \frac{V_{ds}}{I_D}\bigg|_{V_s=0}$$

From output circuit, as $V_{gs} = 0 \Rightarrow g_m V_{gs} = 0$

$$\therefore \boxed{Z_o = r_d}$$ → ①M

overall output impedance, $z_o' = z_o || R_D$

$$\boxed{z_o' = r_d || R_D}$$ →① M

Voltage Gain (Av) :- It is the ratio of output voltage V_{ds} to input voltage V_{gs} in CS amplifier.

$$A_v = \frac{V_{ds}}{V_{gs}}.$$

from output circuit, ∴ $V_{ds} = -g_m V_{gs} (r_d || R_D)$

$$A_v = \frac{-g_m \cancel{V_{gs}} (r_d || R_D)}{\cancel{V_{gs}}}$$

$$\boxed{A_v = -g_m (r_d || R_D)}$$ →② M

⑧ M

6+8=⑭ M

⑥ Given that, a common source amplifier has

$C_{c1} = C_{c2} = C_s = 1\mu F$

$R_G = 10M\Omega$ $R_D = R_L = R_s = 10K\Omega$

$R_{sig} = 100K\Omega$ $g_m = 2mA/V$.

ⓐ Mid band gain, $A_m = \frac{-R_G}{R_G + R_{sig}} \cdot g_m (R_D || R_L)$

$$= \frac{10M\Omega}{10M\Omega + 100K\Omega} \times 2\times10^{-3} (10K || 10K\Omega)$$

$$= 0.99 \times 2\times10^{-3} \times 5K\Omega$$

$$\boxed{A_m = 9.9}$$ →③ M

14/12

ⓑ $$f_{P1} = \frac{1}{2\pi (C_{C1} (R_{sig} + R_G)}$$

$$= \frac{1}{2\pi \times 1 \times 10^{-6} (100K + 10M)}$$

$$f_{P1} = 0.0157\,Hz$$ → ② M

ⓒ $$f_{P2} = \frac{g_m + 1/R_S}{2\pi\ C_S}$$

$$= \frac{2 \times 10^{-3} + \frac{1}{10K}}{2\pi \times 1 \times 10^{-6}}$$

$$f_{P2} = 334.22\,Hz$$ → ② M

ⓓ $$f_{P3} = \frac{1}{2\pi\ C_{C2} (R_D + R_L)}$$

$$= \frac{1}{2\pi \times 1 \times 10^{-6} (10k\Omega + 10k\Omega)}$$

$$= \frac{1}{2\pi \times 10^{-6} \times 20k}$$

$$= 7.95\,Hz$$ → ② M

ⓔ $$f_Z = \frac{1}{2\pi\ C_S R_S}$$

$$= \frac{1}{2\pi \times 1 \times 10^{-6} \times 10 \times 10^{3}}$$

$$f_Z = 15.915\,Hz$$ → ② M

⑮ 17

$$f_L = \sqrt{f_{P1}^2 + f_{P2}^2 + f_{P3}^2 - 2f_Z^2}$$

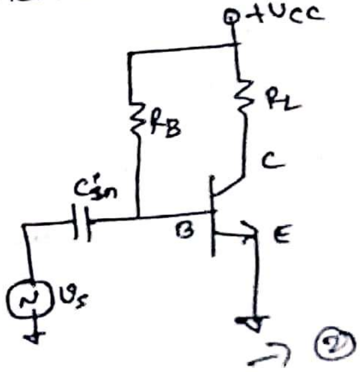
$$= \sqrt{(0.0157)^2 + (334.22)^2 + (7.95)^2 - 2\times(15.915)^2}$$

$$\underline{f_L = 333.55 \text{ Hz.}} \rightarrow ③ M$$

⑭ M

⑦

ⓐ The circuit represents the directly coupled class A power amplifier as the load resistance is directly connected in the collector circuit.



→ ② M

For d.c operation, the collector supply voltage, Vcc and resistance R_B decides the d.c base bias current I_{BQ}.

$$\therefore I_{BQ} = \frac{V_{CC} - 0.7V}{R_B}$$

$$I_{CQ} = \beta I_{BQ}.$$

$$V_{CEQ} = V_{CC} - I_{CQ} R_L.$$

→ The d.c power input is provided by the supply. with no a.c input signal, the d.c current drawn is the collector bias current I_{CQ}. Hence d.c power input is

$$P_{dc} = V_{CC} I_{CQ}. \rightarrow ① M$$

→ When an input a.c signal is applied, the base current varies sinusoidally. The output current i.e I_C varies around its quiescent value while the output voltage i.e V_{CE} varies around its Q value. The varying output voltage and output current deliver an a.c power to the load.

→ The a.c power delivered to the load is

$$P_{ac} = V_{rms} I_{rms}$$

$$= \frac{V_m}{\sqrt{2}} \times \frac{I_m}{\sqrt{2}}$$

$$= \frac{V_m I_m}{2}$$

11(11)

$$P_{ac} = \frac{\left(\frac{V_{pp}}{2}\right)\left(\frac{I_{pp}}{2}\right)}{2}$$

$$= \frac{V_{pp} I_{pp}}{8}$$

$$= \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8} \rightarrow ②M$$

Efficiency (η) :- It represents the amount of a.c power delivered or transferred to the load from the d.c power input.

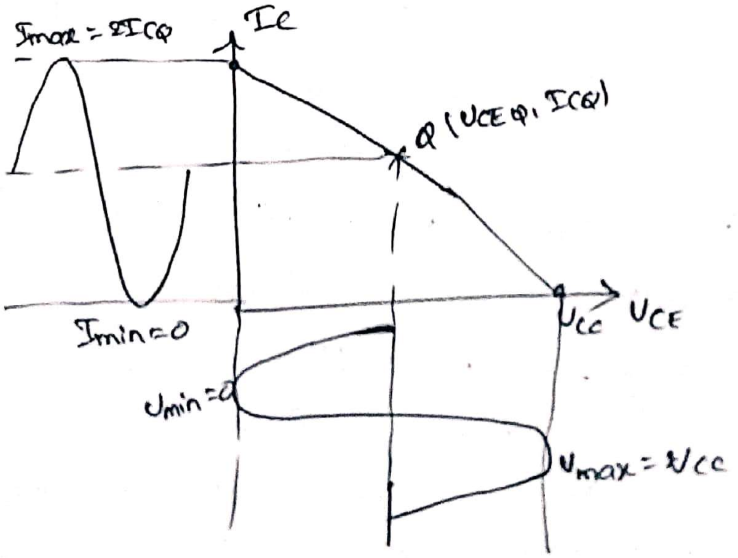
$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100$$

$$\% \eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{cc} I_{cQ}} \times 100$$

For maximum efficiency, assume

$V_{max} = V_{cc}$ and $V_{min} = 0$

$I_{max} = 2 I_{cQ}$ and $I_{min} = 0$



$$\% \eta_{max} = \frac{(V_{cc} - 0)(2 I_{cQ} - 0)}{8 V_{cc} I_{cQ}} \times 100$$

$$= \frac{\cancel{V_{cc}} \cdot \cancel{2} \cancel{I_{cQ}}}{4 \cancel{8} \cancel{V_{cc}} \cancel{I_{cQ}}} \times 100$$

$$= \frac{1}{4} \times 100$$

$$\boxed{\% \eta_{max} = 25\%} \rightarrow ②M$$

③M

(17|17)

⑦

ⓑ Given that, $R_L = 12\Omega$, $n = \frac{N_2}{N_1} = \frac{1}{3} = 0.333$

$\%\eta = 78.5\%$ $h_{fe} = 25$, $V_{CC} = 20$.

$$R_L' = \frac{R_L}{(n)^2} = \frac{12\Omega}{0.333}$$

$$= 108\Omega. \rightarrow ① M$$

ⓘ $$(P_{ac})_{max} = \frac{1}{2}\frac{(V_{CC})^2}{R_L'}$$

$$= \frac{1}{2}\left(\frac{(20)^2}{108}\right.$$

$$= 1.8518W$$

But $\%\eta = 78.5\%$

$$P_L = \%\eta \times (P_{ac})_{max}$$

$$= 0.785 \times 1.8518$$

$$P_L = 1.4537W \rightarrow ② M$$

(ii) $$(P_d)_{max} = \frac{2}{\pi^2}\frac{(V_{CC})^2}{R_L'}$$

$$= \frac{2}{\pi^2} \times \frac{(20)^2}{108}$$

$$= 0.7505W$$

$(P_d)_{max}$ per transistor $= \frac{0.7505}{2} = 0.37524W$.

$\rightarrow ② M$

(iii) $$(P_{ac})_{max} = \frac{V_m I_m}{2}$$

$1.8518 = \frac{20 I_m}{2} \Rightarrow I_m = 0.1851A = I_{c\,max}$

and $$(I_b)_{max} = \frac{(I_c)_{max}}{h_{fe}}$$

$$= \frac{0.1851}{25}$$

$$\boxed{(I_b)_{max} = 7.407mA} \rightarrow ② M$$

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⑦M

Code: A0407194S0723

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

20th July 2023

II B.Tech. II Sem. (R19) End Examinations (Supplementary)

ELECTRONICS CIRCUITS-ANALYSIS AND DESIGN

ECE

Time: 3 Hrs **Total Marks: 70**

Note 1:Answer Question No.1 (Compulsory) and 4 from the remaining

2:All Questions Carry Equal Marks

1a Draw the CB approximated hybrid model.

b Define voltage amplifier.

c Draw the circuit diagram of class A output stage.

d List the demerits of LC oscillators.

e Define input common mode range of a differential amplifier.

f Draw the simplified high-frequency T-model of MOSFET.

g Give the typical h-parameter values for a transistor at I_E = 1.3 mA.

2 a) Draw the circuit of BJT differential amplifier with an active load (4)
b) Explain the operation of above circuit (10)

3 a) Write a short on characteristics of power MOSFETs. (10)
b) List the advantages of power MOSFETs and power BJTs. (4)

4 For a CB transistor amplifier driven by a voltage source of internal resistance Rs=1200Ω, the load Z_L = 1000 Ω. The h- parameters of the transistor are h_{ib} = 22 Ω, $h_{rb} = 3x10^{-4}$, h_{fb} = -0.98 and h_{ob} = 0.5 μA/V. Compute
a) The current gain A_I (4)
b) The input impedance Z_i (3)
c) Voltage gain A_V and (3)
d) The output impedance Z_O (4)

5 a) Explain the effect of negative feedback on frequency response and bandwidth. (6)
b) Explain the analysis of voltage series negative feedback amplifier to find its voltage gain, input resistance and output resistance. (8)

6 a) Draw the circuit of BJT cascode amplifier and its high-frequency equivalent circuit.
(7)
b) Explain the analysis of high-frequency response of BJT cascode amplifier to derive the equation for midband voltage gain.
(7)

7 a) Draw the circuit diagram of tuned base oscillator. (4)
b) Explain the operation of above circuit. (10)

- xxx -

RGM college of Engineering & Technology (Autonomous)
20th July 2023
II B.Tech II-Sem. (R19) End Examinations (Supplementary)
ELECTRONIC CIRCUITS-ANALYSIS AND DESIGN
ECE Code: A0407194507 23
Total Marks: 70

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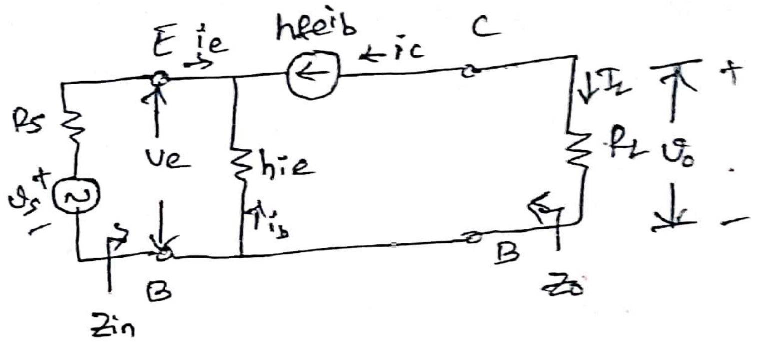
①
ⓐ The approximate CB model can be drawn by giving Input to emitter, taking output at collector and making base common. The below figure shows the approximate CB model.
→①M



→①M

②M

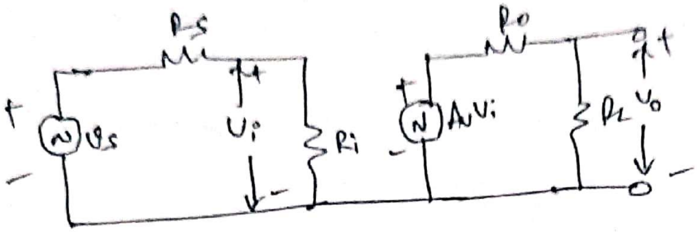
①
ⓑ If the amplifier input resistance R_i is large compared to the source resistance R_s then $V_i \simeq V_s$. If the external load resistance R_L is large compared to the output resistance R_o of the amplifier, then $V_o \simeq A_u V_i \simeq A_u V_s$. Such amplifier circuit provides a voltage output proportional to the voltage input and the proportionality factor does not depends on the magnitudes of the R_s and R_L. Hence this amplifier is called voltage amplifier. →①M

→ An ideal voltage amplifier must have infinite input resistance R_i and zero output resistance R_o.

(2)(b)

→ For practical voltage amplifier, we must have

$R_i >> R_s$ and $R_L >> R_o$.



→①M

②M

①

ⓒ A simple fixedbias circuit can be used as a large signal class A power amplifier as shown below. The circuit represents the directly coupled class A amplifier as the load registance is directey connected in the ~~to~~ collector circuit.

→①M

The circuit is transformer coupled as the load registance is connected to transformer secondary at collector.

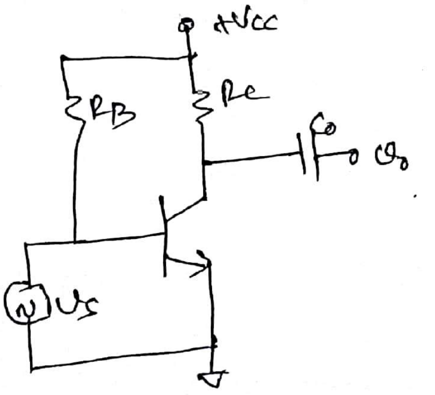
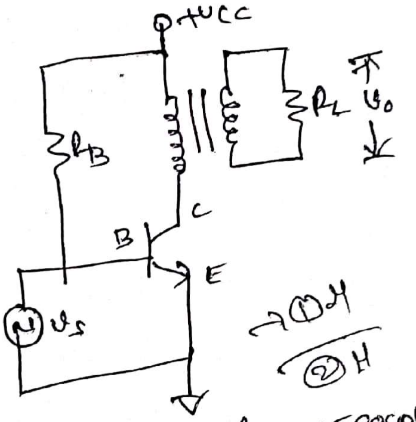


fig:- Direct coupled class A power Amplifier



→①M

②M

fig:- Transformer coupled class A power amplifier

①

ⓓ Demerits of LC oscillators:-

① The circuits becomes bulky and costly due to inductors.

② It provides poor frequency stability.

③ These are not able to generate microwave frequencies in the range of Gigahertz (GHz).

④ These are not able to ~~en~~ generate constant amplitude due to inductor losses.

→ ② M

①

ⓔ An important specification of a differential amplifier is its input common mode range. This is the range of V_{cm} over which the differential pair operates properly. The highest value of V_{cm} is limited by the requirement that Q_1 and Q_2 remains in saturation, thus

$$V_{cmmax} = V_i + V_{DD} - \frac{I}{2} R_D. \quad \rightarrow ① M$$

→ The lowest value of V_{cm} is determined by the need to allow for a sufficient voltage across the current source I for it to operate properly. If a voltage V_{GS} is needed across the current source. Then

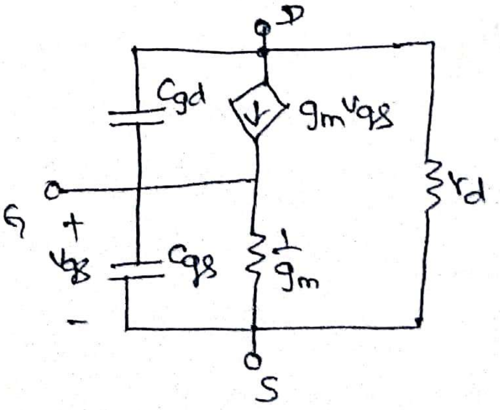
$$V_{cm\,min} = -V_{SS} + V_{GS} + V_t + V_{ov}. \quad \rightarrow ① M$$

② M

①

ⓕ The small signal model of MOSFET, including the four capacitances C_{gs}, C_{gd}, C_{sb} and C_{db} is called high frequency MOSFET model. It is, however, quite complex for manual analysis and its use is limited to computer simulation. So by neglecting C_{sb} and C_{db} then it is called simplified T model shown below.

① M



→ ① M

② M

(4½)

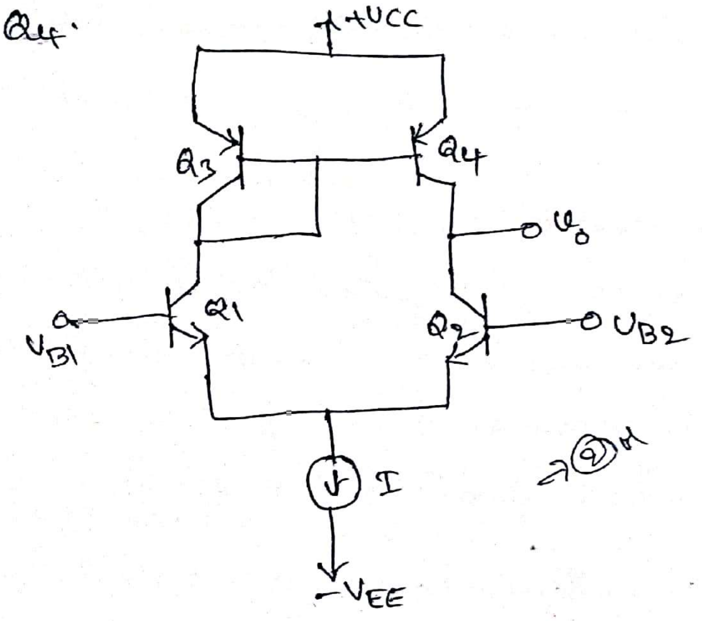
① ⑨ The typical h-parameters values for a transistor at $I_E = 1.3mA$

	CB	CE	CC
h_i	20 Ω	1.1 KΩ	1.2 KΩ
h_f	-0.98	50	-51
h_r	2.9×10^{-4}	2.5×10^{-4}	≃1
h_o	0.49 μA/V	25 μA/V	25 μA/V

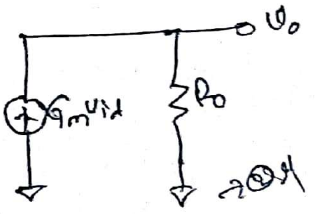
→② M

②

ⓐ The BJT differential amplifier with an active load is shown below. It is formed by transistors Q1 and Q2, loaded by a current mirror formed by transistors Q_3 and Q_4.



→② M



→② M

fig:- Small signal equivalent circuit.

④ M

② ⓑ A simple active load circuit for a differential amplifier is the current mirror active load as shown in fig. The active load comprises of transistors Q_3 and Q_4 with the transistor connected as a diode with its base and collector shorted. The circuit is shown to drive a load R_L.

~~4+8~~ 5|1.6

→ When an a c input voltage is applied to the differential amplifier, the various currents of the circuit are given by

$$I_{c4} = I_{c3} = I_{c1} = g_m \frac{v_{id}}{2} \quad \rightarrow ① M$$

where $I_{c4} = I_{c3}$ due to current mirror action.

$$I_{c2} = -g_m \frac{v_{id}}{2} \quad \rightarrow ① M$$

→ We know that the load current I_L entering the next stage is

$$I_L = I_{c2} - I_{c4} = -g_m \frac{v_{id}}{2} - g_m \frac{v_{id}}{2} = -g_m v_{id}.$$

Then the output voltage from the differential amplifier is given by

$$v_0 = -I_L R_L = g_m v_{id} R_L. \quad \rightarrow ② M$$

The amplifier can amplify the differential input signals and it provides single ended output with a ground reference since the load R_L is connected to only one output terminal. This is made possible by the use of the current mirror active load.

→ The output resistance R_o of the circuit is that offered by the parallel combinations of transistors Q_2 and Q_4. It is given by $R_o = r_{o2} \| r_{o4}$. → ② M

→ The differential amplifier using active load provides high voltage gain to the differential input signal and a single ended output that is referred to the ground is obtained.

→ The differential amplifier which provides conversion for a differential signal to a single ended signal is necessary in differential input signal ended output amplifiers. The changes in the common-mode signal of the bias current source. This includes a change in I_{c2} and an identical change in I_{c1}. The change in I_{c1} will then produce a change in the PNP load devices and thereby a change in I_{c4}, which is the collector current Q_4. The current I_{c4} is in such a direction as to cancel the change in I_{c2}. As a result, any common mode input does not cause a change in output.

→④ M

⑩ M → 4+10=⑭ M

6/1/18

③

ⓐ Power MOSFETs have in the past number of years gained popularity in the design of power electronic circuits. This is a result of the following properties.

① Unlike BJTs, power MOSFETs have threshold voltages in the range of 1V to 4V. In saturation, the drain current is related to V_{GS} by the square law characteristics given by

$$I_D = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2 \rightarrow ② M$$

where I_D is the drain current

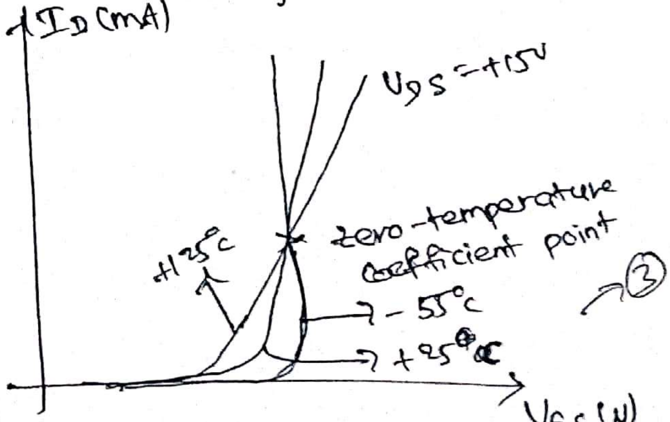
W is the width of the channel

L is the length of the channel

V_t is threghold voltage

V_{GS} is gate to source voltage → ① M

→ However, the $I_D - V_{GS}$ characteristics becomes linear for larger values of V_{GS}. The linear portion of the characteristics occurs as a result of the high electric field along the short channel, causing the velocity of charge carriers to reach an upper limit, a phenomeron known as velocity saturation. The linear $I_D - V_{GS}$ relationship implies a constant g_m in the velocity saturation region.



→ ③ M

→ Of considerable interest in the design of MOS power circuits is the variation of the MOSFET characteristics with temperature. Observe that there is a value of V_{GS} (in the range of 4V to 6V for most power MOSFET) at which the temperature coefficient of I_D is zero. At higher values of V_{GS}, I_D exhibits a negative temperature coefficient.

→ This is a significant property: It implies that a MOSFET operating beyond the zero-temperature-coefficient point does not risk the possibility of thermal runaway. This in not the case, however, at low currents. In that region, the temperature coefficient of I_D is positive and the power MOSFET can easily suffer thermal runaway.

→ ④ M

⑩ M

③

ⓑ Advantages of power MOSFETs and Power BJTs :-

① Power MOSFETs do not require dc gate drive current. This greatly simplifies the design of the driving circuitry.

② MOSFETs can operate at much higher switching speeds than BJTs, a definite advantage of for power circuits employing switching

③ MOSFETs do not suffer from secondary breakdown, thus benefiting from an extension of SOA.

④ The thermal characteristics of the MOSFET as well we shall see shortly, are superior to those of the BJT.

⑤ To support higher voltages without device breakdown, the base is made wider and the collector is made thicker and its doping lighter.

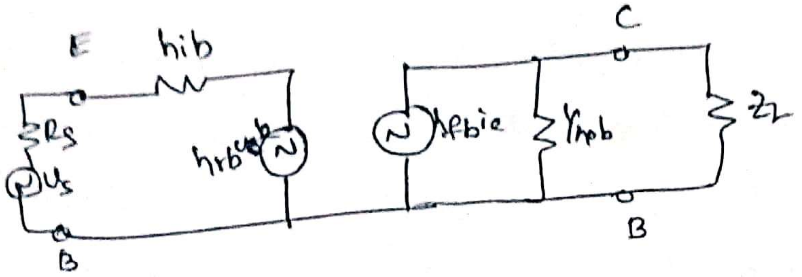
→ ④ M

10 + 4 = ⑭ M

④

For CB transistor amplifier, given that $R_s = 1200\,\Omega$, $Z_L = 1000\,\Omega$. The h-parameters of the transistor are $h_{ib} = 22\,\Omega$, $h_{rb} = 3\times10^{-4}$, $h_{fb} = -0.98$ and $h_{ob} = 0.5\,\mu A/V$.

From given data the h-parameter model of the amplifier is



ⓐ Current Gain, $A_I = \dfrac{-h_{fe}}{1+h_{ob}R_L}$

$$= \frac{-(-0.98)}{1+0.49\times10^{-6}\times1\times10^{3}}$$

$$= \frac{0.98}{1+0.49\times10^{-3}}$$

$$\boxed{A_I = 0.98}$$

→ ④M

ⓑ Input Impedance, $Z_{in} = h_{ib} - \dfrac{h_{fb}h_{rb}}{\frac{1}{R_L}+h_{ob}}$

$$= 22\,\Omega - \frac{(-0.98)(3\times10^{-4})}{\frac{1}{1k}+0.49\times10^{-6}}$$

$$= 22\,\Omega + \frac{0.98\times3\times10^{-4}}{10^{-3}+0.49\times10^{-6}}$$

$$\boxed{Z_{in} = 22.294\,\Omega}$$

→ ③M

④ 8.1

For CB transistor amplifier, given that $R_s = 1200\Omega$, $Z_L = 1000\Omega$. The h-parameters of the transistor are $h_{ib} = 22\Omega$, $h_{rb} = 3\times10^{-4}$, $h_{fb} = -0.98$ and

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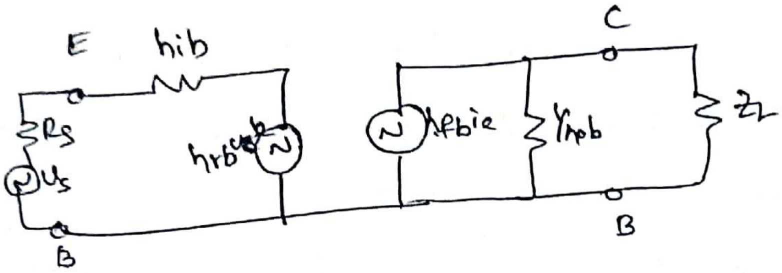

ⓐ Current Gain, $A_I = \frac{-h_{fe}}{1+h_{ob}R_L}$

$$= \frac{-(-0.98)}{1+0.49\times10^{-6}\times1\times10^{3}}$$

$$= \frac{0.98}{1+0.49\times10^{-3}}$$

$$\boxed{A_I = \underline{0.98}}$$

→ ④ M

ⓑ Input Impedance, $Z_{in} = h_{ib} - \frac{h_{fb}h_{rb}}{\frac{1}{R_L}+h_{ob}}$

$$= 22\Omega - \frac{(-0.98)(3\times10^{-4})}{\frac{1}{1k}+0.49\times10^{-6}}$$

$$= 22\Omega + \frac{0.98\times3\times10^{-4}}{10^{-3}+0.49\times10^{-6}}$$

$$\boxed{Z_{in} = 22.294\,\Omega}$$

→ ③ M

9||8

ⓒ Voltage gain, $A_v = \frac{+A_I R_L}{Z_{in}}$

$$= \frac{0.98 \times 1 \times 10^3}{22.294}$$

$$\boxed{A_v = 44}$$

→③M

ⓓ Output Impedance, $Z_o = \frac{1}{h_{ob} - \frac{h_{fb} h_{rb}}{h_{ib} + R_s}}$

$$= \frac{1}{0.49 \times 10^{-6} - \left(\frac{(-0.98)(3 \times 10^{-4})}{22 + 1200}\right)}$$

$$= \frac{1}{0.49 \times 10^{-6} + 0.0023 \times 10^{-4}}$$

$$\boxed{Z_o = 1.388\,M\Omega}$$

→④M

⑭M

⑤

ⓐ Effect of Negative feedback on frequency response and Band-width:-

we know that $A_f = \frac{A}{1+A\beta}$

using this equation, we can write

$$A_{f mid} = \frac{A_{mid}}{1 + A_{mid}\beta}, \quad A_{f low} = \frac{A_{low}}{1 + A_{low}\beta}, \quad A_{f high} = \frac{A_{high}}{1 + A_{high}\beta}$$

Lower cut off frequency:- we know that, the relation between gain at low frequency and gain at mid frequency is given as

$$A_{low} = \frac{A_{mid}}{1 - j\left(\frac{f_L}{f}\right)} \quad \text{then} \quad A_{f low} = \frac{\frac{A_{mid}}{1 - j(f_L/f)}}{1 + \frac{A_{mid}}{1 - j\left(\frac{f_L}{f}\right)} \cdot \beta}$$

→①M

1011

$$= \frac{A_{mid}}{1 - j\left(\frac{f_L}{f}\right) + A_{mid}\beta} = \frac{A_{mid}}{(1 + A_{mid}\beta) - j\left(\frac{f_L}{f}\right)}$$

Dividing numerator and denominator by $(1+A_{mid}\beta)$

$$A_{f\,low} = \frac{\frac{A_{mid}}{1+A_{mid}\beta}}{1 - j\left(\frac{\frac{f_L}{1+A_{mid}\beta}}{f}\right)} = \frac{A_{fmid}}{1 - j\left(\frac{f_{Lf}}{f}\right)}$$

$$\text{where } f_{Lf} = \frac{f_L}{1+A_{mid}\beta}.$$

2024

Upper cutoff frequency :- we know that, the relation between gain at high frequency and gain at mid frequency is given as

$$A_{high} = \frac{A_{mid}}{1 - j\left(\frac{f}{f_H}\right)} \quad \text{then}$$

$$A_{f\,high} = \frac{\frac{A_{mid}}{1-j(f/f_H)}}{1 + \frac{A_{mid}}{1-j\frac{f}{f_H}}\beta} = \frac{A_{mid}}{(1+A_{mid}\beta) - j\left(\frac{f}{f_H}\right)}$$

Dividing numerator and denominator by $(1+A_{mid}\beta)$.

$$A_{f\,high} = \frac{\frac{A_{mid}}{1+A_{mid}\beta}}{1 - j\frac{f}{(1+A_{mid}\beta)f_H}} = \frac{A_{fmid}}{1 - j\frac{f}{f_{Hf}}}$$

$$\text{where } f_{Hf} = (1+A_{mid}\beta) f_H.$$

The bandwidth of the amplifier is given as

$$BW = f_H - f_L$$

The bandwidth with feedback is given as

$$(BW)_f = f_{Hf} - f_{Lf} = (1+A_{mid})\beta) f_H - \frac{f_L}{1+A_{mid}\beta}.$$

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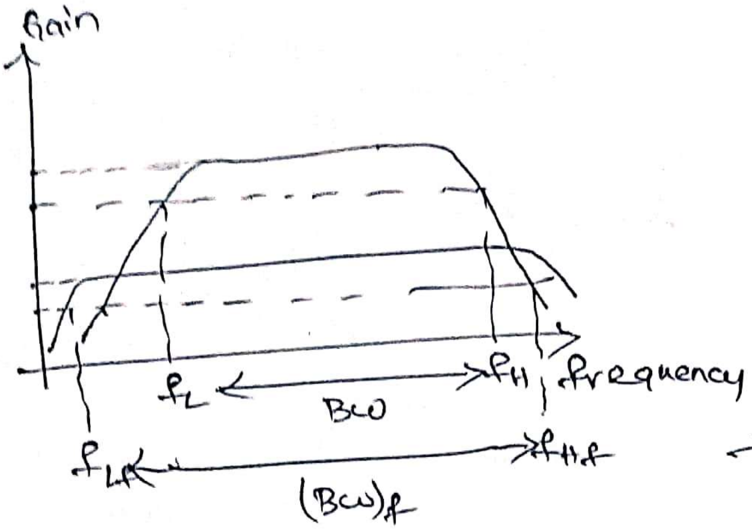
11/16

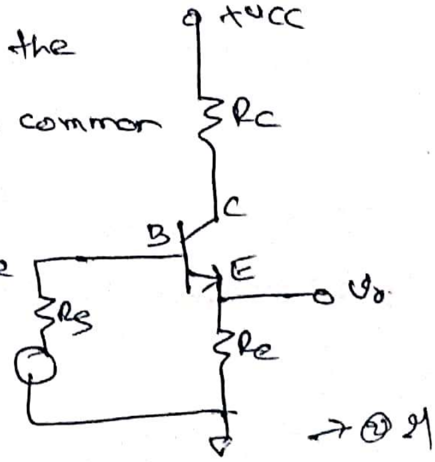
→ It is clear that $(f_{Hf} - f_{Lf}) > (f_H - f_L)$ and hence bandwidth of amplifier with feedback is greater than bandwidth of amplifier without feedback.



→ ① M

⑥ M

⑤ ⓑ The practical example of voltage series feedback amplifier is the emitter follower (or) CC amplifier.



→ In this figure, Re resistor is the feedback resistor because it is common to both i/p & o/p equations.

$V_o = I_e R_e$ and $V_{be} = V_s - I_e R_e$

From this, $V_f = V_o$,

$$\beta = \frac{V_f}{V_o} = 1$$

→ ② M

Voltage gain, $A_v = \frac{V_o}{V_{in}}$

$$= \frac{h_{fe} i_b R_e}{(R_s + h_{ie}) i_b}$$

$$\boxed{A_v = \frac{h_{fe} R_e}{R_s + h_{ie}}}$$

→ ② M

12(1)

$$D = 1 + A_v \beta$$

$$= 1 + \frac{h_{fe} R_e}{R_s + h_{ie}} \cdot 1$$

$$= \frac{R_s + h_{ie} + h_{fe} R_e}{R_s + h_{ie}}$$

$$A_{vf} = \frac{A_v}{D} = \frac{\frac{h_{fe} R_e}{\cancel{R_s + h_{ie}}}}{\frac{R_s + h_{ie} + h_{fe} R_e}{\cancel{R_s + h_{ie}}}}$$

$$\boxed{A_{vf} = \frac{h_{fe} R_e}{R_s + h_{ie} + h_{fe} R_e}} \rightarrow ② M$$

Input Impedance, $Z_{in} = R_s + h_{ie}$.

$$Z_{if} = Z_{in}(1 + A_v \beta) = Z_{in} D.$$

$$= \cancel{(R_s + h_{ie})} \cdot \frac{R_s + h_{fe} + h_{fe} R_e}{\cancel{R_s + h_{ie}}}$$

$$\boxed{Z_{if} = R_s + h_{ie} + h_{fe} R_e} \rightarrow ① M$$

output impedance, $Z_o = \infty$

$$Z_{of} = \frac{Z_o}{D} = \frac{\infty}{D} = \text{undetermined.}$$

To determine Z_{of}, make $R_e \rightarrow \infty$

$$Z_{of} = \lim_{R_e \to \infty} \left(\frac{(R_s + h_{ie}) R_e}{R_s + h_{ie} + h_{fe} R_e} \right)$$

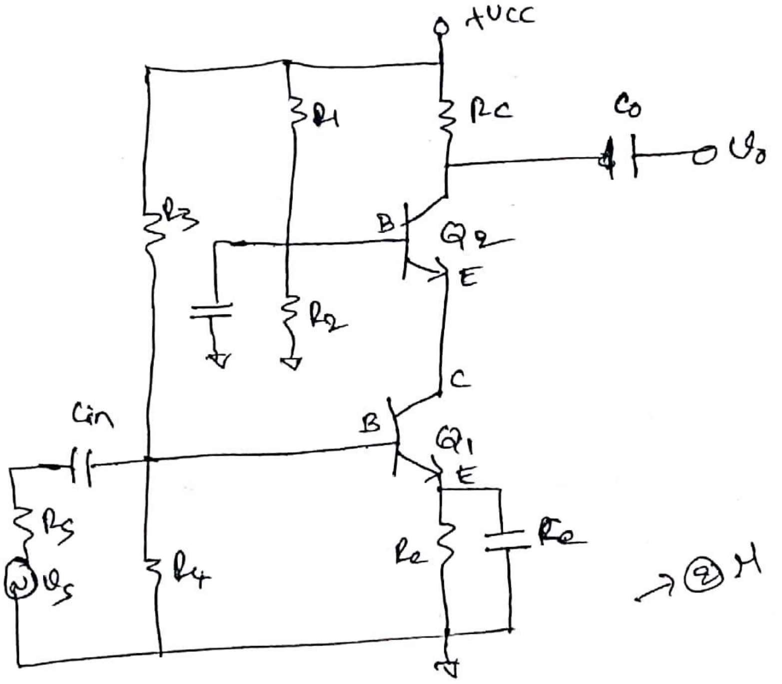
$$= \frac{\cancel{R_e}(R_s + h_{ie})}{\cancel{R_e}\left(h_{fe} + \frac{R_s + h_{ie}}{R_e}\right)}$$

$$\boxed{Z_{of}' = \frac{R_s + h_{ie}}{h_{fe}}} \quad ① M$$

8M

6+8 = ⑭ M

⑥ ⓐ The cascode amplifier consists of a common emitter amplifier stage in series with a common base amplifier. It is one approach to solve the low impedance problem of a common base circuit.

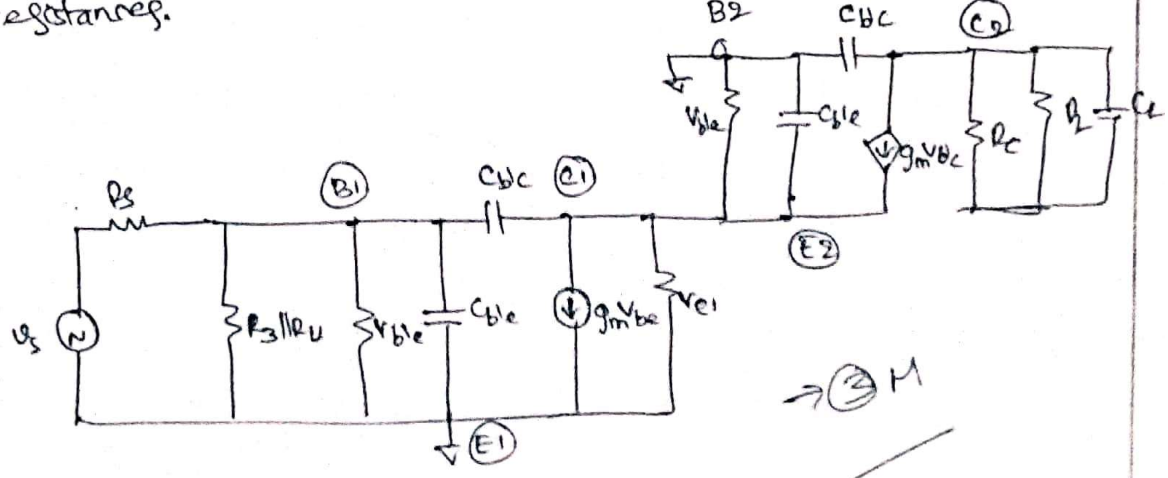


→ ② M

→ Transistor Q1 and its associated components operate as a common emitter amplifier stage, while the circuit of Q2 functions as a common base output stage.

→ ① M

High frequency equivalent circuit consists of hybrid-π model of transistor by considering the junction capacitances and resistances.

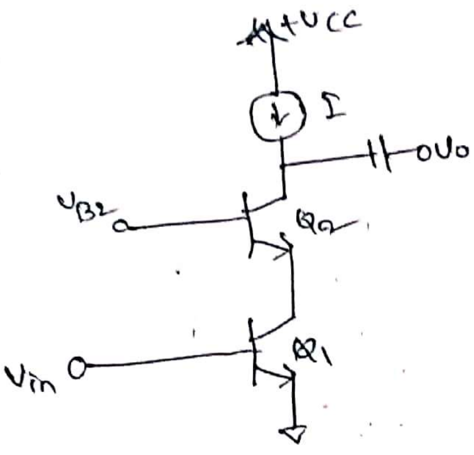


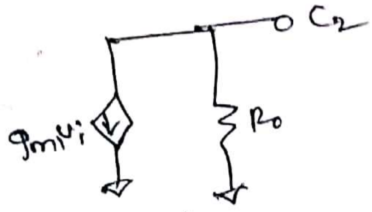
→ ③ M

④ M

[illegible] [illegible]

⑥ ⓑ The BJT cascode amplifier is shaon below.





→② M

→ Voltage V_{B2} is a dc bias voltage for the CB cascode transistor Q_2. The circuit is very similar to the MOS cascode and the small signal analysis will follow in a parallel fashion. First, note that the input resistance of the bipolar cascode amplifier is finite.

$R_{in} = r_{\pi 1}$. →① M

→ Second, recall that the current signal in the collector of Q_2 will be approximately equal to $g_{m1}v_i$. Thus, the equivalent circuit of the cascode amplifier will be that shown in fig. To obtain R_o we use

$$R_o \simeq r_{o2} + (g_{m2}r_{o2})(r_{o1} \| r_{\pi 2}).$$

Since $g_{m2}(r_{o1} \| r_{\pi 2}) >> 1$,

$$R_o \simeq (g_{m2}r_{o2})(r_{o1} \| r_{\pi 2}).$$ →① M

→ The open circuit voltage gain of the ~~bity~~ bipolar cascode can be found using the equivalent circuit as shown above.

$$A_{vo} = \frac{v_o}{v_i}$$

$$= -g_{m1}R_o$$

Thus $$A_{vo} = -g_{m1}(g_{m2}r_{o2})(r_{o1} \| r_{\pi 2})$$

$$= -g_{m1}g_{m2}r_{o2}(r_{o1} \| r_{\pi 2})$$

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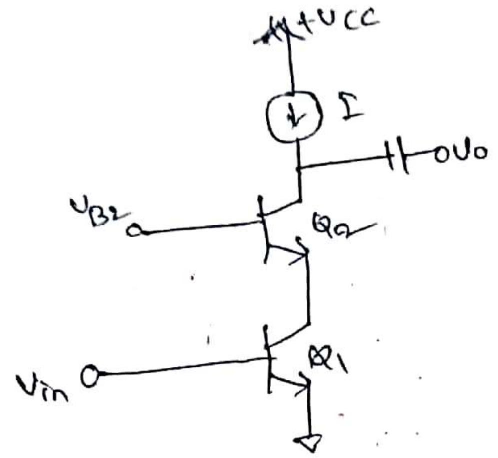

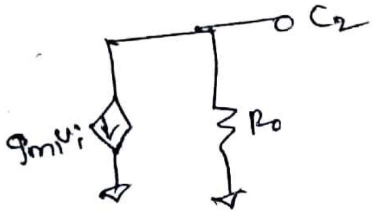

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Since $g_{m2}(r_{o1}\|r_{\pi 2}) \gg 1$,

$$R_o \simeq (g_{m2}r_{o2})(r_{o1}\|r_{\pi 2}).$$ →① M

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$$= -g_{m1}R_o$$

Thus $$A_{vo} = -g_{m1}(g_{m2}r_{o2})(r_{o1}\|r_{\pi 2})$$

$$= -g_{m1}g_{m2}r_{o2}(r_{o1}\|r_{\pi 2})$$

(15/18)

For the case $g_{m1} = g_{m2}$; $r_{o1} = r_{o2}$

$$A_{vo} = -g_m r_o \, g_m (r_o \| r_\pi)$$

which will be less than $(g_m r_o)^2$ in magnitude. Infact, the maximum possible gain magnitude is obtained when $r_o \gg r_\pi$ and is given by

$$|A_{vo}|_{max} = \beta g_m r_o$$

$$= \beta A_o \quad \rightarrow ③ M$$

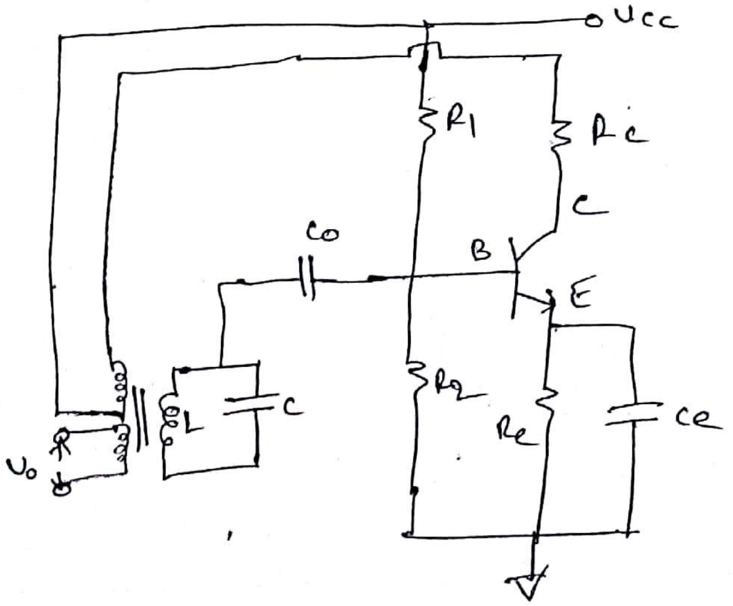
→ Finally, we note that to be able to realize gains approaching this level, the current source load must also be cascoded.

② M

7+7=⑭M

⑦

ⓐ Tuned base oscillators are called so because the tuned circuit is placed in the base of the transistor amplifier. The combination of L and C form the tuned circuit or frequency determining circuit. The below figure shows the tuned base oscillator.



→ ④ M

⑦ⓑ <u>Operation</u>:- The resistors R1, R2 and RE are used to provide d.c bias to the transistor. The parallel combination of Re and Ce in the emitter circuit is the stabilizing circuit. Cc is the

→② M

(15/18)

For the case $g_{m1} = g_{m2}$; $r_{o1} = r_{o2}$

$$A_{vo} = -g_m r_o \, g_m (r_o \| r_\pi)$$

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⑦M

7+7=⑭M

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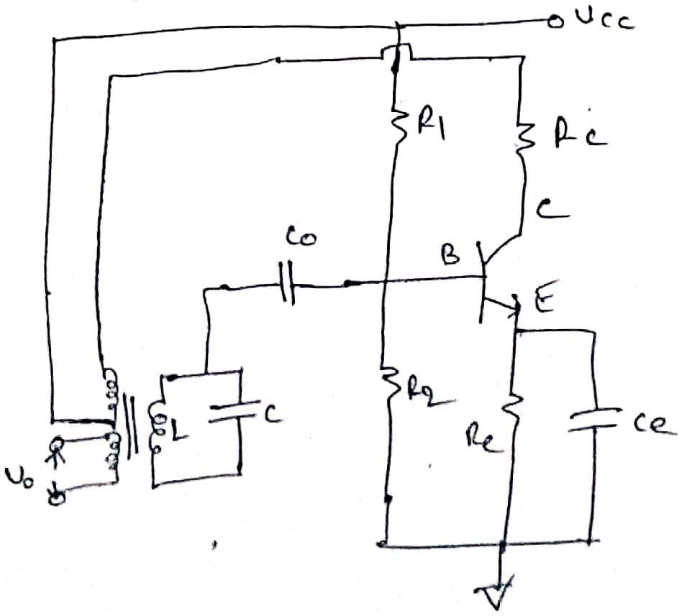

→④M

⑦ⓑ Operation:- The resistors R1, R2 and RE are used to provide d.c bias to the transistor. The parallel combination of Re and Ce in the emitter circuit is the stabilizing circuit. Cc is the

→②M

16.14

the blocking capacitor. The capacitors C_e and C are the by-pass capacitors. The primary coil L and the secondary coil L_1 of RF transformer provides the required feedback to collector and base circuits.
→ ② M

→ As the CE amplifier provides 180° phase shift and another 180° phase shift is provided by the transformer which makes 360° phase shift between the input and output voltages.

→ When the circuit is switched on, the collector current starts rising. As the collector is connected to the coil L_1, that current creates some magnetic field around it. This induces a voltage in the tuned circuit coil L.
→ ② M

→ The feedback voltage produces an increase in V_{BE} and I_B. A further increase in I_C is thus achieved and the cycle continues until the I_C becomes saturated. In the meanwhile, the capacitor is fully charged.

→ When the I_C reaches saturation level, there is no feedback voltage in L. As the C has been charged fully, its starts discharging through 'L', this decreases the V_{BE} and hence I_B and I_C also decreases. By this time the I_C reaches cutoff, the C is full charged with opposite polarity.
→ ② M

→ As the transistor now gets off, the condenser C begins to discharge through L. This increases the emitter base bias. As a result I_C increases.

→ The cycle repeats so long as enough energy is supplied to meet the losses in L.C circuit. The frequency of oscillations is equal to the resonant frequency of LC circuit and give by

$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

→ ⑧ M / ⑩ M = 4 + 10 = ⑭ M

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24/7/23

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RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)

07th July 2022

II B.Tech. II Sem. (R20) End Examinations (Regular)

ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN

ECE

Time: 3 Hrs **Total Marks: 70**

Note 1:Answer Question No.1 (Compulsory) and 4 from the remaining

2:All Questions Carry Equal Marks

1a Define h_{fe} and h_{oe}.

b Define lower 3-DB frequency .

c Define the common mode gain of BJT differential amplifier if the output is single ended output.

d Define positive feedback.

e Define sustained oscillations.

f Why power amplifier is called large signal amplifier?

g Define h_{fb} and h_{ob}.

2 a) A MOS differential amplifier is operated at a total current of 0.8 mA, using transistors with a W/L ratio of 100, $\mu_n.C_{ox}$ = 0.2 mA/V^2, V_A=20 V, and R_D=5 KΩ. Find V_{OV}, g_m, r_O, and A_d. (7)

b) Define and explain the input common-mode resistance of BJT differential amplifier (7)

3 a) With the help of neat diagrams explain in details the basic amplifiers. (6)

b) Draw the block diagram of a single loop feedback connection and explain the function of each block. (8)

4 a) Draw the simplified h-parameter model of a CB amplifier. Derive the expressions for current gain, input impedance, voltage gain and output impedance. (10)

b) Give the comparison between CE, CB and CC amplifiers. (4)

5 a) Draw the capacitive-coupled MOSFET amplifier and its high-frequency equivalent circuit model? (4)

b) Explain the analysis of high-frequency response of common-source amplifier to find its equivalent gain and f_H. (10)

6 a) List the differences between class A and class B power amplifiers. (7)

b) Draw the circuit diagram of series fed class A power amplifier using BJT and explain its operation (7)

7 a) Draw the circuit diagram of transistorized wein-bridge oscillator. (4)

b) Explain the operation of above circuit and derive the expression for frequency of oscillations. (10)

- xxx -

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RGM COLLEGE OF ENGINEERING & TECHNOLOGY (Autonomous)

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ELECTRONIC CIRCUITS- ANALYSIS AND DESIGN.

(ECE)

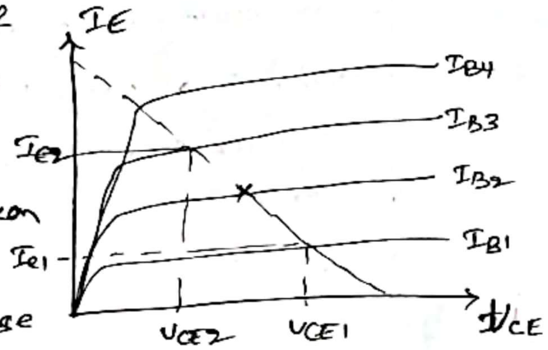
Code: A0409204R0722

Total Marks: 70

①

ⓐ h_{fc} : Forward current gain with output short circuited.

From the output characteristics of common collector configuration, it is defined as the ratio of change in emitter current I_E taken around the quiescent point Q to the corresponding change in the base current I_B for constant value of output voltage V_{CE} at the Q-point.



i.e $$h_{fc} = \frac{\Delta I_E}{\Delta I_B}\Big|_{V_{CE}\text{ constant}} = \frac{I_{e2} - I_{e1}}{I_{B3} - I_{B1}}$$

$\rightarrow$ ① M

→ It's typical value is -51 if β=50 or -101 if β=100.

h_{oc} :- Output admittance with input open circuited.

→ It can be obtained as the change in the emitter current i.e I_E divided by the change in collector to emitter voltage i.e V_{CE} for a constant base current at the quiesent point Q.

i.e $$h_{oc} = \frac{\Delta I_E}{\Delta V_{CE}}\Big|_{I_B\text{ constant}} = \frac{I_{E2} - I_{E1}}{V_{CE2} - V_{CE1}}$$

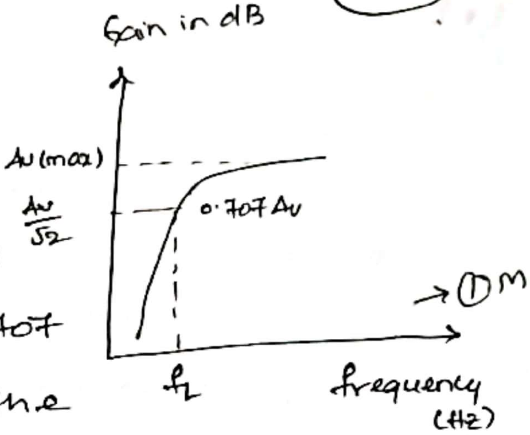
→ It's typical value is 25 μA/V

$\rightarrow$ ① M

② M

2|23

① ⓑ Lower 3-dB frequency, it is the frequency at which the maximum gain of the amplifier falls or decreases to $\frac{1}{\sqrt{2}}$ times (or) 0.707 times of maximum gain of the amplifier at low frequency. It is denoted by f_1 (or) f_L. ↳① M

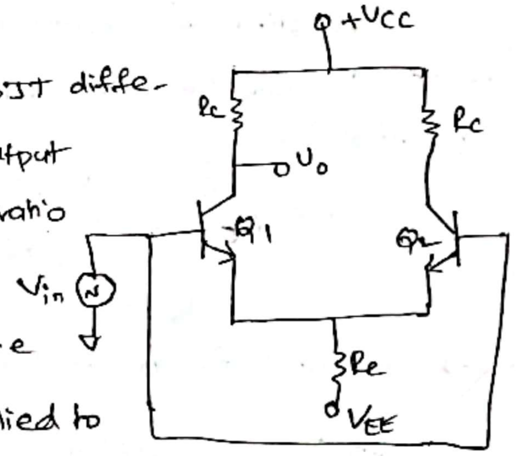


→① M

→ It is also called half power frequency since gain or output voltage drops to 70.7% of maximum value and this represents a power level of one-half the power at the reference frequency in mid frequency range (or) region.

② M

① ⓒ The common mode gain of BJT differential amplifier if the output is single ended output is the ratio of output voltage to the common mode input signal i.e common input signal is applied to both inputs of the transistors Q1 and Q2 and the output is taken either at Q1 or Q2 then it is called single ended output.



→① M

$$A_c = \frac{V_o}{V_{in}} = \frac{V_o}{V_{cm}}$$ and it is given by

→① M

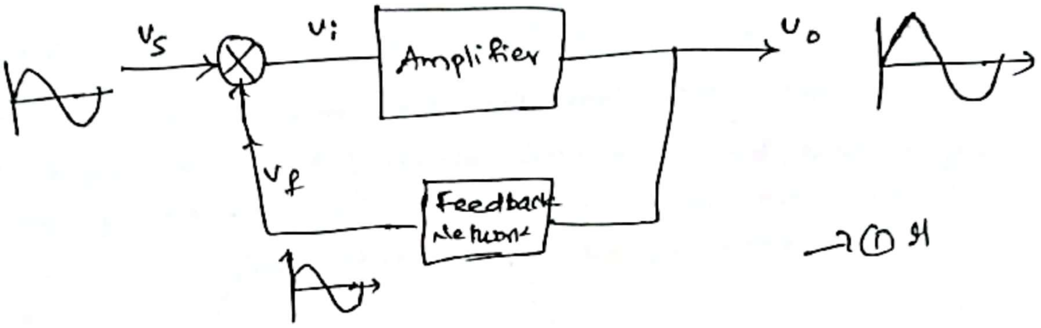
$$A_c = \frac{\beta R_c}{r_i + 2(\beta+1)R_e} \quad (\text{or}) \quad \frac{h_{fe} R_c}{h_{ie} + 2(h_{fe}+1)R_e}.$$

② M

3|23

① The feedback is a property which allows to feedback the part
(d) of the output to the same circuit as its input. Such a feedback is said to be positive ~~whether~~ whenever the part of the output that is fed back to the amplifier as its input is in phase with the original input signal applied to the amplifier.

→①M



→①M

→ If the magnitude of input signal increases due to the feedback signal then it is also called positive feedback.

i.e $\boxed{V_i = V_s + V_f}$.

②M

①
(e) As stated by Barkhausen criterion, when total phase shift around a loop is 0° or 360° ensuring positive feedback and the magnitude of the product of the open loop gain of the amplifier (A) and feedback factor (B) is unity i.e $|AB| = 1$ then the oscillations are with constant frequency and amplitude called sustained oscillations.

→①M

→①M

②M

4|23

①

(f) → Power amplifiers are basically used to increase the power level of the input signal. Power amplifier is also called large signal amplifiers, as in order to get large power at the output input signal voltage required must also be large.

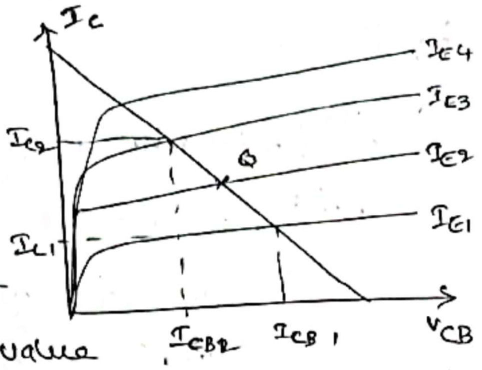
→ Power amplifiers takes the d.c power supply connected to the output circuit and converts it into a.c signal power. Output power is controlled by input signal. →①M

→ The power amplifiers develop an a.c power of the order of few watts. Similarly large power gets dissipated in the form of heat, at the junctions of the transistors used in it. Hence the transistor used in it are of large size, having large power dissipating rate called power transistors. →①M

②M

①

(g) h_{fb}: Forward current gain with output short circuited.



From the output characteristics of CB configuration, it is defined as the ratio of change in collector current I_c taken around Q-point to the corresponding change in the emitter current I_E for constant value of output voltage V_{CB} at the Q-point.

$$h_{fb} = \frac{\Delta I_c}{\Delta I_E}\Big|_{V_{CB}\ \text{constant}}$$

$$= \frac{I_{c1} - I_{c2}}{I_{e1} - I_{e2}} \xrightarrow{} ①M$$

It's typical value is – 0.98 or 0.99.

5|23

h_{ob}: output admittance with input open circuited.

→ It can be obtained as the change in the collector current i.e I_c divided by the change in collector to base voltage i.e V_{CB} for a constant emitter current of the Q-point.

$$\text{i.e} \quad h_{ob} = \frac{\Delta I_c}{\Delta V_{CB}} = \frac{I_{c2} - I_{c1}}{V_{CB2} - V_{CB1}} .$$

→ It's typical value is $\underline{0.49\,\mu A/V}$ → ① M

② M

② ⓐ

Given that, Total current, $I = 0.8mA$

Transistors with $\frac{W}{L} = 100$

$\mu_n C_{ox} = 0.2 mA/V^2$

$V_A = 20V$ and $R_D = 5k\Omega$.

We know that, the total current through MOS differential amplifier is

$$I = \mu_n C_{ox}\left(\frac{W}{L}\right)\frac{(V_{ov})^2}{2} \quad \rightarrow ① M$$

$$\rightarrow 0.8mA = 0.2mA/V^2 \times 100 \times \frac{(V_{ov})^2}{2}$$

$$(V_{ov})^2 = \frac{0.8}{10} = 0.08$$

$$\boxed{V_{ov} = 0.2V} \quad \rightarrow ② M$$

$$g_m = \frac{I}{V_{ov}} = \frac{0.8mA}{0.2V} = 4mA/V \rightarrow ① M$$

$$r_o = \frac{V_A}{I/2} = \frac{20V}{0.4mA} = 50k\Omega \rightarrow ① M$$

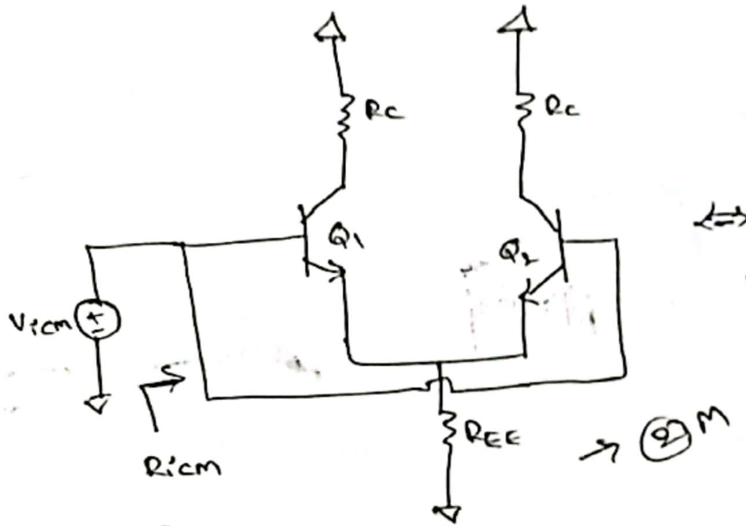
$A_d = g_m (R_D \| r_o)$

$= 4mA/V (5k\Omega \| 50k\Omega)$

$\boxed{A_d = 18.2}$ → ②M

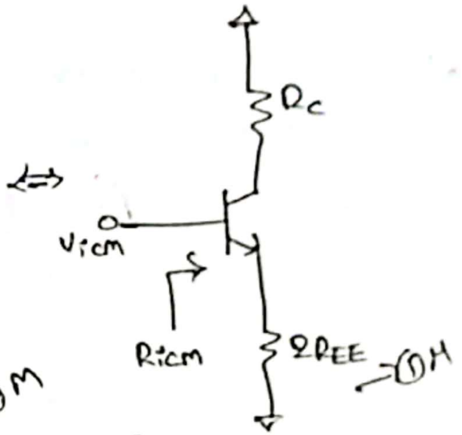
⑦M

②b) The input common-mode registance of BJT differential amplifier is the resistance measured between the two interconnected inputs and ground. It is denoted by Ricm. →①M



→ ②M

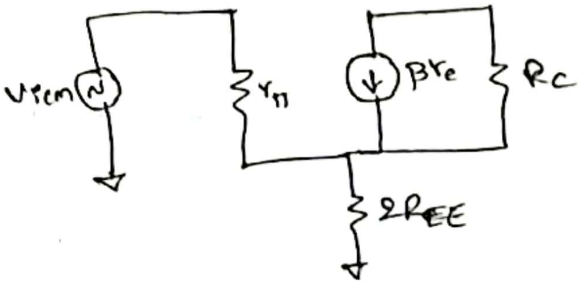
fig: ⓐ Defination of the input common-mode registance



→①M

fig ⓑ :- The equivalent common mode half-circuit.

The equivalent circuit of ~~dif~~ half circuit of differential amplifier is shown in fig.



→ ①M

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→ By applying KVL to the input loop,

$$i_b = \frac{V_{icm}}{r_\pi + 2(\beta+1)R_{EE}}$$

The common mode input resistance is given by

$$R_{icm} = \frac{V_{icm}}{I_b}$$

$$\frac{V_{icm}}{I_b} = r_\pi + 2(\beta+1)R_{EE}$$

$$\therefore \boxed{R_{icm} = r_\pi + 2(\beta+1)R_{EE}} \rightarrow ② M$$

⑦ M

7+7 = ⑭ M

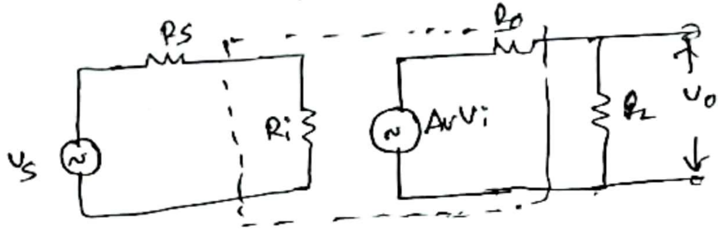
③

ⓐ The amplifiers can be classified into four categories based on the magnitudes of the input impedance and output impedance of an amplifier relative to the source and load impedances. They are
① Voltage Amplifier
② Current Amplifier
③ Transconductance Amplifier and → ②M
④ Transresistance Amplifier.

Voltage Amplifier:- If the amplifier input resistance R_i is large compared with the source resistance R_s then $V_i \simeq V_s$. If the external load resistance R_L is large compared with output resistance R_o of the amplifier, then $V_o = A_v V_i = A_v V_s$. Such

8|23

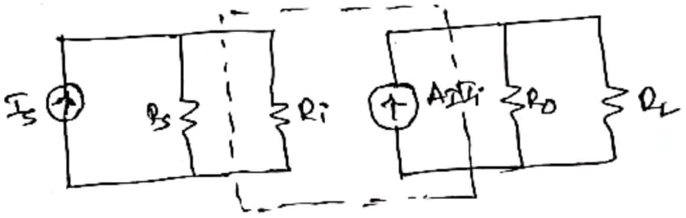
amplifier provides a voltage output proportional to the voltage input. Hence this amplifier is called voltage amplifier.



For ideal cases, $R_i \to \infty$ and $R_o \to 0$ →① M

For practical cases, $R_i >> R_s$ and $R_L >> R_o$

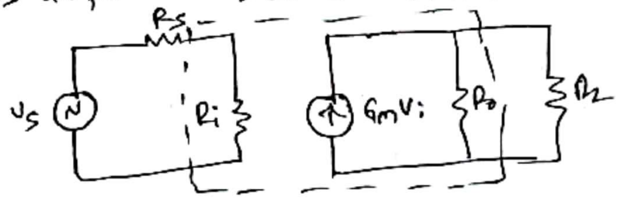
Current Amplifier :- If the amplifier R_i is small then $I_i \simeq I_s$ and the amplifier R_o large compared with R_L then $I_L \simeq A_I I_i$. Such amplifier provides a current output proportinal to the signal current. Hence this amplifier is called current amplifier.



For ideal cases, $R_i \to 0$ and $R_o \to \infty$

For practical cases, $R_i << R_s$ and $R_L << R_o$ (→① M

Transconductance Amplifier :- If the amplifier R_i is large compared with R_s then $V_i \simeq V_s$ and if the amplifier R_o is large compared with R_L then $I_L \simeq G_m V_i$. Such an amplifier provides a current output is ~~por~~ proportional to the input voltage. Hence this amplifier is called transconductance amplifier.



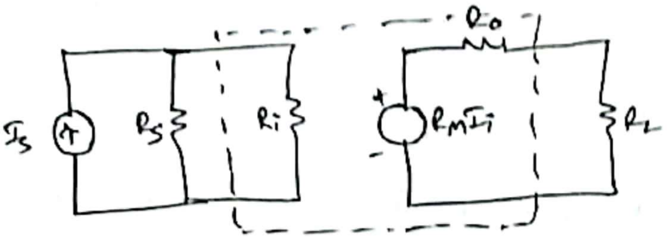
→① M

For ideal cases, $R_i \to \infty$ and $R_o \to \infty$

For practical cases, $R_i >> R_s$ and $R_o >> R_L$ ($R_L << R_o$)

(9|93)

Transresistance Amplifier :- If the amplifier R_i is small compared to R_s then $I_i \simeq I_s$ and if the amplifier R_o is large compared to R_L then $V_o \simeq R_M I_i$. Such amplifier circuit provides a voltage output is proportional to the source current. Hence this amplifier is called transresistance amplifier.



→ ①M

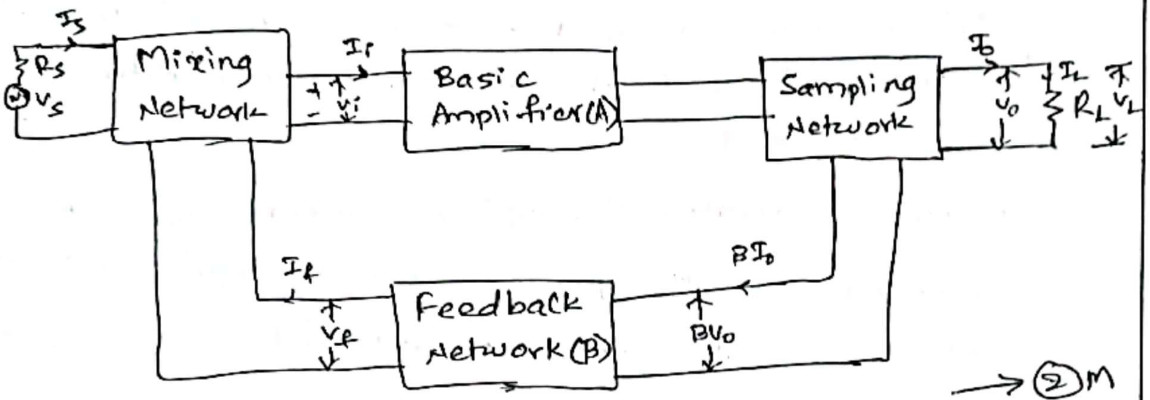
For ideal cases, $R_i \to 0$ and $R_o \to 0$

For practical cases, $R_i << R_s$ and $R_L >> R_o$

⑥M

③

ⓑ



→ ②M

fig:- Block diagram of single loop feedback connection.

Sampling Network:- There are two ways to sample the output according to the sampling parameter, either voltage (or) current. The output voltage is sampled by connecting the feedback network in shunt across the output as shown in fig ①. This type of connection is referred to as voltage (or) node sampling. The output current is sampled by connecting the feedback network in series with the output as shown in fig.②. This type of connection is referred as current or loop sampling.

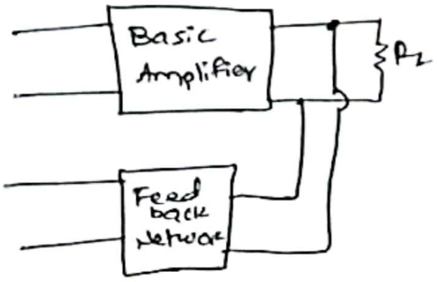


fig.① Voltage or node sampling

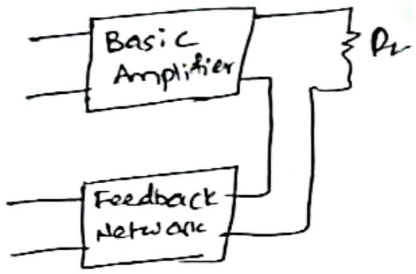


fig:② Current or loop sampling.

→②M

Feedback Network :- It may consists of resistors, capacitors or inductors. Most often it is simply a resistive configuration. It provides reduced portion of the output as feedback signal to the input mixer network. It is given as

$$\boxed{v_f = \beta V_o}$$

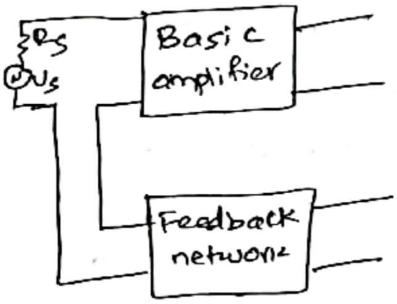
where β is a feedback factor or feedback ratio, which lies between 0 and 1. It is totally different from β symbol used to represent current gain in CE amplifier which is greater than 1.

→①M

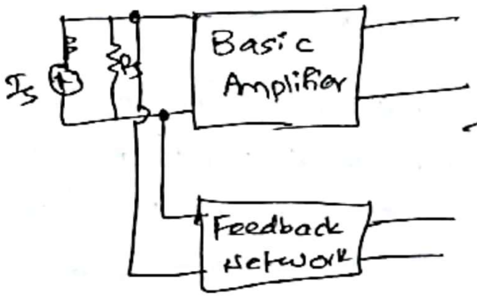
Mixer Network :- Like sampling, there are two ways of mixing feedback signal with the input signal. These are

① series input connection and

② Shunt input connection.



ⓐ Series Mixing



ⓑ Shunt Mixing

→②M

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Basic Amplifier :- Here the basic amplifier may be either voltage or current or transconductance or tranresistance amplifier based on the way of sampling and the way of mixing the feedback signal with input with transfer gains of A_v, A_I, G_M and R_m without feedback. It can also be represented as A_{vf}, A_{If}, G_{Mf} and R_{Mf} with feed-back. These can be defined as

$A_v = \frac{V_o}{V_i}$ = Voltage gain. , $A_{vf} = \frac{V_o}{V_s}$ = Voltage gain with feedback

$A_I = \frac{I_o}{I_i}$ = Current gain , $A_{If} = \frac{I_o}{I_s}$ = current gain with feed back

$G_M = \frac{I_o}{V_i}$ = Transconductance, $G_{Mf} = \frac{I_o}{V_s}$ = Transconduc-tance with feedback

$R_M = \frac{V_o}{I_i}$ = Transresistance . , $R_{Mf} = \frac{V_o}{I_s}$ = Transresistance with feedback.

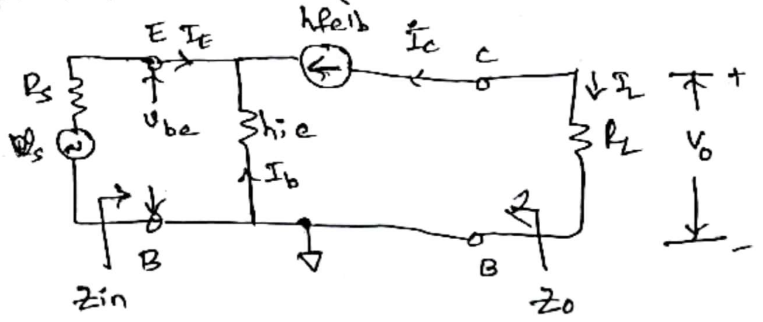
↳ ① M

⑧ M

6+8=⑭ M

④

ⓐ The simplified h-parameter model of a CB amplifier can be drawn by giving input to emitter, taking output from collector and making base common. The below figure shows the simplified h-parameter model of a CB amplifier.



→ ② M

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Current Gain, (A_I) :- It is defined as a ratio of output current to input current. In CB amplifier, input current is emitter current, I_E and output current is collector current I_c.

$$A_I = \frac{I_O}{I_E} = \frac{-I_c}{I_E}$$

From circuit, $I_c = h_{fe} i_b$ and

$$I_e = -(1+h_{fe}) i_b$$

$$A_I = \frac{\cancel{-} h_{fe} \cancel{i_b}}{\cancel{-}(1+h_{fe}) \cancel{i_b}}$$

$$\therefore \boxed{A_I = \frac{h_{fe}}{1+h_{fe}}} \longrightarrow ② M.$$

Input Impedance, (Z_{in}) :- It is defined as a ratio of input voltage to input current. In CB amplifier, input voltage is emitter to base voltage V_{be} and input current is emitter current, I_E.

$$\therefore Z_{in} = \frac{V_{be}}{I_E}$$

From circuit, $V_{be} = -h_{ie} i_b$ and

$$I_e = -(1+h_{fe}) i_b$$

$$Z_{in} = \frac{\cancel{-} h_{ie} \cancel{i_b}}{\cancel{-}(1+h_{fe}) \cancel{i_b}}$$

$$\therefore \boxed{Z_{in} = \frac{h_{ie}}{1+h_{fe}}} \longrightarrow ② M$$

13|2 3

Voltage gain, (Av) :- It is defined as a ratio of output voltage to input voltage. In CB amplifier, input voltage is ~~Vb~~ emitter to base voltage, V_{be} and output voltage is collector to base voltage V_{bc}.

$$\therefore A_V = \frac{V_o}{V_{in}} = \frac{I_o R_L}{I_e R_{in}} = \frac{A_I R_L}{Z_{in}}$$

$$A_V = \frac{\frac{h_{fe}}{1+h_{\cancel{fe}}}}{\frac{h_{ie}}{1+h_{\cancel{fe}}}} \cdot R_L$$

$$\therefore \boxed{A_V = \frac{h_{fe} R_L}{h_{ie}}} \longrightarrow ② M.$$

Output Impedance, (Z_o) :- It is defined as a ratio of output voltage to output current by making ~~R_s~~ $V_s = 0$ and $R_L \to \infty$. In CB amplifier, output voltage is V_{bc} and output current is I_c.

$$Z_o = \left.\frac{V_o}{I_o}\right|_{V_s = 0}$$

when $V_s = 0$, the current through input loop is zero. i.e $I_b = 0$ hence $I_c = 0$

$$\therefore Z_o = \frac{V_o}{0} = \infty.$$

By considering the load resistance into account then output impedance becomes

$$Z_o' = Z_o \| R_L = \infty \| R_L \longrightarrow ② M$$

$$\boxed{Z_o' = R_L}$$

⑩ M

④ 14/23

ⓑ Comparison of CE, CB and CC amplifiers:-

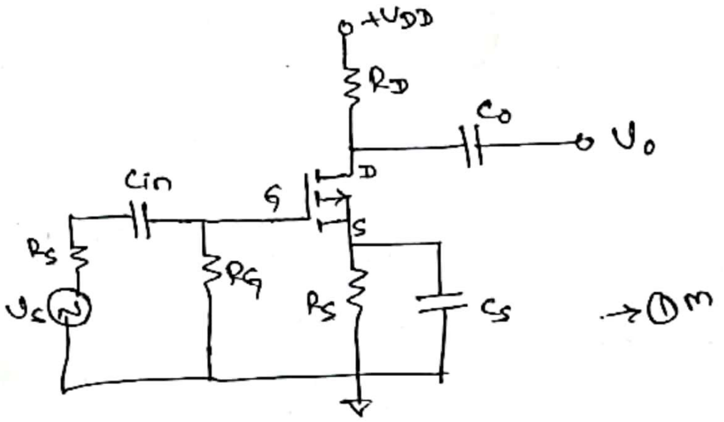
S.No	Characteristic	Common Base	Common Emitter	Common Collector
1.	Input Resistance	Very low (<20Ω)	Low (1KΩ)	High (>100KΩ)
2.	Output Resistance	very high (1MΩ)	High (40KΩ)	Low (50Ω)
3.	Current Gain	Less than unity	High (20 to few hundreds)	High (20 to few hundreds)
4.	voltage gain	Medium (>100)	Medium (>100)	Low (<1)
5.	Current amplification factor	$\alpha = \frac{I_C}{I_E}$ (0.96 to 0.99)	$\beta = \frac{I_C}{I_B}$ (20 to 500)	$\gamma = \frac{I_E}{I_B}$ (20 to 500).
6.	Applications	As a input stage of multistage Amplifier.	For audio signal amplification	For impedance matching.

→④M

10+4=⑭M

⑤

ⓐ Circuit diagram of capacitive coupled MOSFET Amplifier:-



→①M

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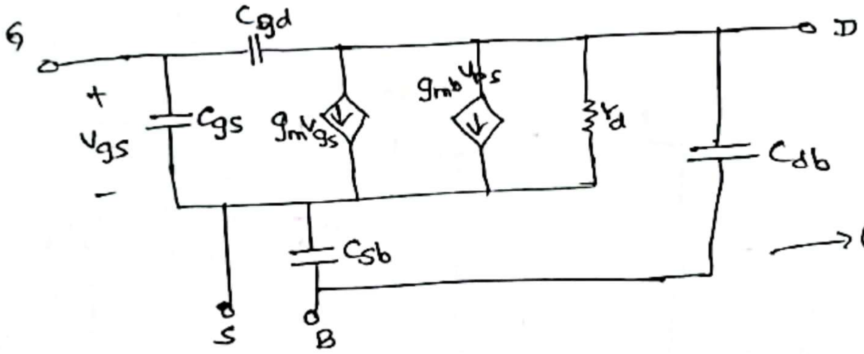
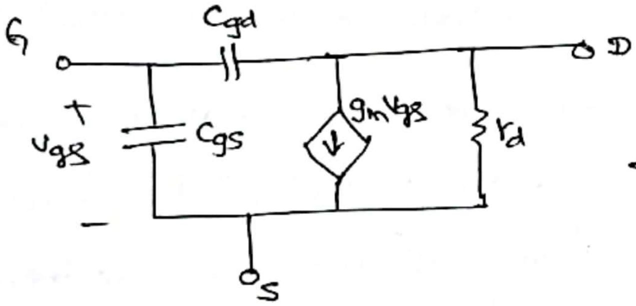
High frequency equivalent model of MOSFET:– The below figure shows the small signal model of the MOSFET, including the four capacitances C_{gs}, C_{gd}, C_{sb} and C_{db}. This model can be used to predict the high frequency response of MOSFET amplifiers. → ① M



→ ① M

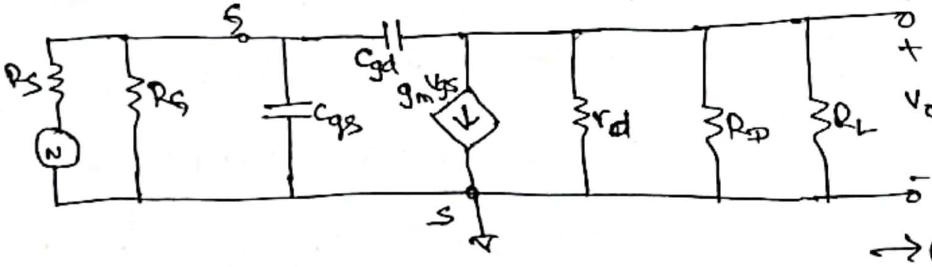
The above model can be simplified by neglecting C_{sb} and C_{db}.



→ ① M

④ M

⑤ ⓑ The below figure shows the high frequency equivalent circuit model of a CS amplifier. It is obtained by replacing the MOSFET in an amplifier circuit such that as shown in above figure by its high frequency equivalent circuit model.



→ ② M

The above equivalent circuit can be simplified by utilizing Thevenin's theorem at the input side and by combining the three parallel resistances at the output side. The resulting simplified circuit is shown in figure.

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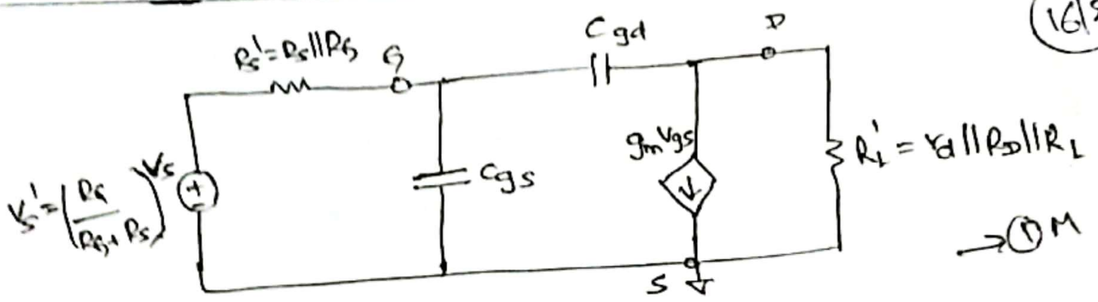
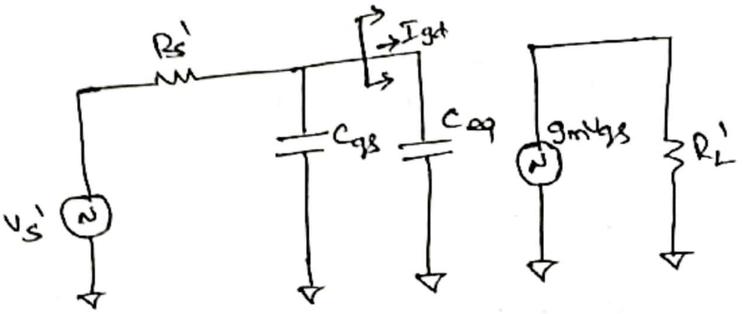


→ ① M



→ ① M

where $C_{eq} = C_{gd}(1+g_m R_L')$

From above circuit, the output voltage is given by

$$V_o = -(g_m V_{gs}) R_L' \quad \text{where } R_L' = r_d || R_D || R_L \rightarrow ① M$$

Since $V_o = V_{ds}$ indicates that the gain from gate to drain is $-g_m R_L'$, the same value as in the midband. The current I_{gd} can now be found as

$$I_{gd} = s C_{gd} (V_{gs} - V_o)$$

$$= s C_{gd} (V_{gs} - (-g_m R_L' V_{gs}))$$

$$= s C_{gd} V_{gs} (1 + g_m R_L') \rightarrow ① M$$

From circuit, the value of $I_{gd} = s C_{eq} V_{gs}$

$$\therefore \cancel{s} C_{eq} \cancel{V_{gs}} = \cancel{s} C_{gd} \cancel{V_{gs}} (1 + g_m R_L')$$

$$\Rightarrow \boxed{C_{eq} = C_{gd}(1+g_m R_L')} \rightarrow ① M$$

The expression for the high frequency gain of the CS amplifier

$$A_v = \frac{V_o}{V_s} = \left(\frac{R_G}{R_G+R_s}\right) g_m R_L' \cdot \frac{1}{1+\frac{s}{\omega_o}} \rightarrow ① M$$

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which can be expressed in the form

$$\frac{V_o}{V_s} = \frac{A_m}{1+\frac{s}{\omega_H}}$$

where the mid band gain $A_m = \frac{R_G}{R_G+R_s}(g_m R_L')$ and

ω_H is the upper 3-dB frequency,

$$\omega_H = \omega_0 = \frac{1}{C_{in} R_s'} \quad \text{and}$$

$$f_H = \frac{\omega_H}{2\pi} = \frac{1}{2\pi C_{in} R_s'} \rightarrow ②M$$

where $C_{in} = C_{gs} + C_{gd}(1+g_m R_L')$

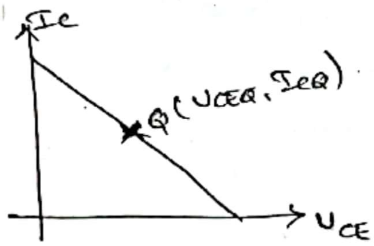
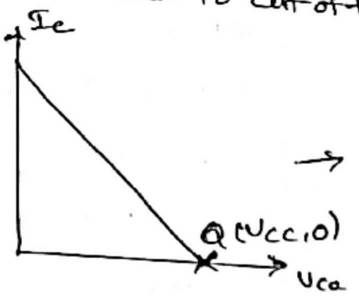
$$R_s' = R_s \| R_G .$$

⑩M

4 + 10 = ⑭M

⑥

ⓐ

Class A Power Amplifier	class B power amplifier
① The power amplifier is said to be class A amplifier if the Q point and the input signal are selected such that the output signal is obtained for a full input cycle.	① The power amplifier is said to be class B amplifier if the Q-point and the input signal are selected such that the output signal is obtained only for one half cycle for a full cycle input.
② For this class, position of the Q-point is approximately at the mid point of the load line. 	② For this class, the Q point is shifted on x-axis i.e the transistor is biased to cut-off.  → ③M
③ For all values of input signal, the transistor remains in the active region.	③ The transistor remains in active region only for positive half cycle of input.

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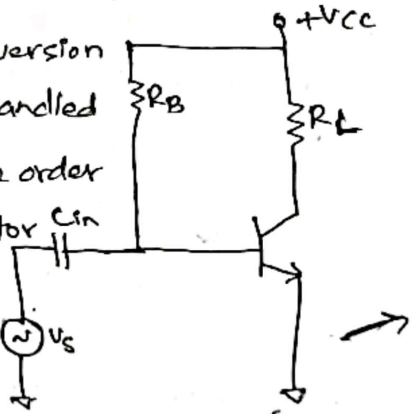
Class A power Amplifier	Class B power Amplifier.
④ Here signal is faithfully reproduced at the output without any distortion.	④ Here only a half cycle is obtained at the output for full cycle of input so the output signal is distorted.
⑤ It uses only one transistor.	⑤ It uses two transistors.
⑥ It requires one transformer at the output.	⑥ It requires two transformer.
⑦ These are of two types. ① Series fed class A amp. ② Transformer coupled class A amplifier	⑦ These are also two types ① Push pull class B ② ~~Symmetry~~ Complementary-symmetry class B
⑧ It's efficiency is low range from 25% to 50%.	⑧ It's efficiency is high i.e 78.5%.
⑨ Power dissipation is more	⑨ Power dissipation is less.
⑩ The output impedance is high hence can not be used for low low impedances.	⑩ Low impedance matching is possible due to transformers

→ (4)M

(7)M

⑥ ⓑ **Series Fed class A Amplifier** :- A simple fixed bias circuit can be used as a large signal class A amplifier.

The difference between small signal version of this circuit is that the singals handled by this large signal circuit are of the order of few volts. Similarly the transistor used is a power transistor.



→ (1)M

→ The value of R_B is selected in such a way that the Q point lies at the center of the d.c load line.

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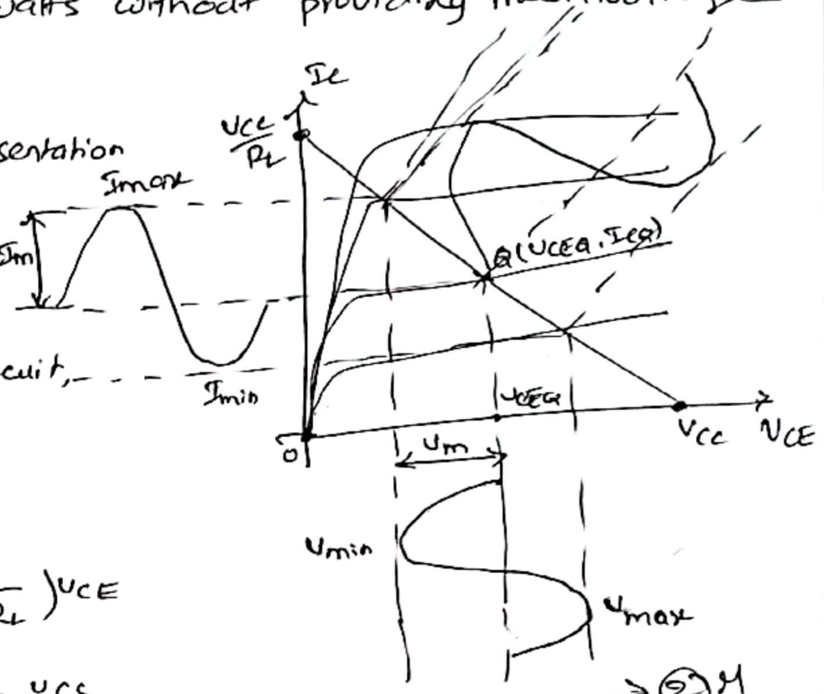
→ The circuit represents the directly coupled class A amplifier as the load resistance is directly connected in the collector circuit. Most of the times the load is a loud speaker, the impedance of which varies from 3 to 4 ohms to 16 ohms. The β value of the transistor is less than 100.

→ The overall circuit handles large power in the range of a few to tens of watts without providing much voltage gain.

→ The graphical representation of a class A amplifier is shown in fig.



→ Applying KVL to the circuit,-

$$V_{CC} = I_C R_L + V_{CE}$$

$$I_C R_L = V_{CC} - V_{CE}$$

$$I_C = \frac{V_{CC}}{R_L} + \left(-\frac{1}{R_L}\right) V_{CE}$$

$$I_C = -\left(\frac{1}{R_L}\right) V_{CE} + \frac{V_{CC}}{R_L}$$

$\rightarrow$ ② M

The above equation is similar to $y = mx + c$ and thus the slope of the load line is $-\frac{1}{R_L}$ while the y-intercept is $\frac{V_{CC}}{R_L}$.

D.C operation:- The collector supply voltage V_{CC} and R_B decides the d.c base bias current I_{BQ}.

$$I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B} = \frac{V_{CC} - 0.7V}{R_B}$$

The corresponding collector current is

$$I_{CQ} = \beta I_{BQ}.$$

The corresponding collector to emitter voltage is

$$V_{CEQ} = V_{CC} - I_{CQ} R_L$$ $\rightarrow$ ① M

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Hence the Q point can be defined as $Q(V_{CEQ}, I_{CQ})$.

D.C power input:- The d.c power input is provided by the supply. With no a.c input signal, the d.c current drawn is the collector bias current I_{CQ}. Hence d.c power input is

$$\boxed{P_{dc} = V_{CC} \cdot I_{CQ}.} \rightarrow ①M$$

A.C Power output:- When an input a.c signal is applied, the base current varies sinusoidally. Then the output voltage and output current also varies sinusoidally around its Q-point which delivers an a.c power output to the load. It is given by

$$P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8} \rightarrow ①M$$

Efficiency!- It represents the amount of a.c power delivered to the load from the d.c source i.e accepting the d.c power input.

$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{CC} I_{CQ}} \times 100$$

For maximum efficiency, $V_{max} = V_{CC}$ and $V_{min} = 0$

$I_{max} = 2I_{CQ}$ and $I_{min} = 0$

$$\% \eta_{max} = \frac{(V_{CC} - 0)(2I_{CQ} - 0)}{8 V_{CC} I_{CQ}} \times 100$$

$$= \frac{2 V_{CC} I_{CQ}}{8 V_{CC} I_{CQ}} \times 100$$

$$\boxed{\% \eta_{max} = 25\%} \rightarrow ①M$$

Power dissipation!- The amount of power that must be dissipated by the transistor is the difference between the d.c power input and the a.c power delivered to the load.

$$P_d = P_{dc} - P_{ac} \Rightarrow (P_d)_{max} = V_{CC} I_{CQ}.$$

⑦M

7+7 = ⑭M

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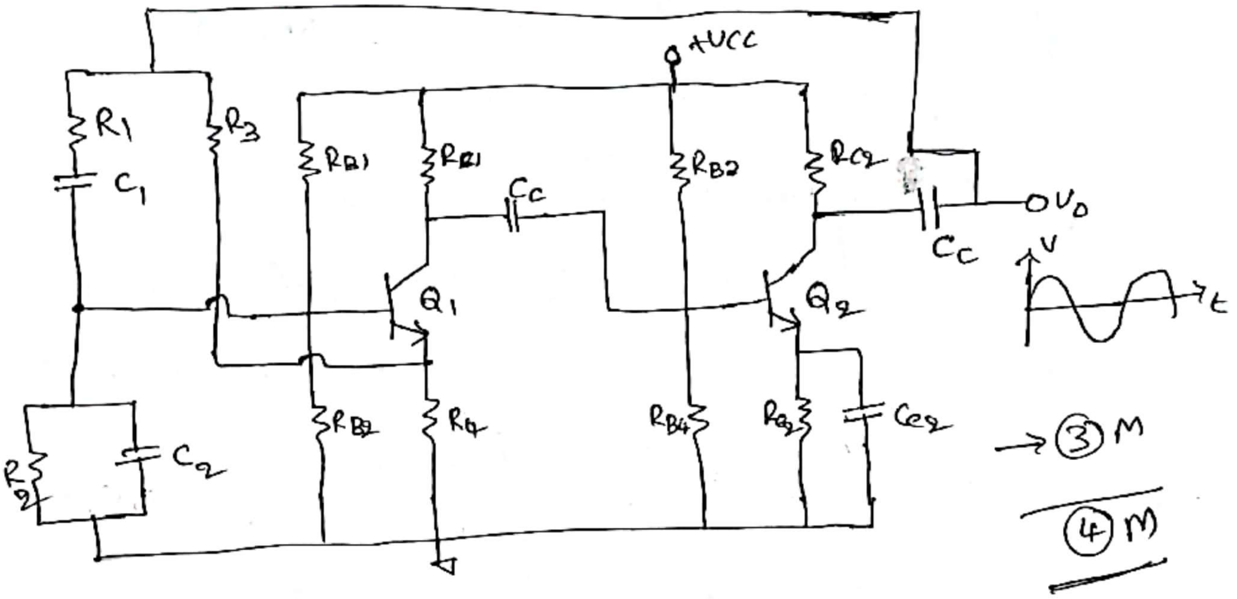
⑦ ⓐ

→ In this circuit, two stage common emitter transistor amplifier is used. Each stage contributes 180° phase shift hence the total phase shift due to the amplifier stage ~~is~~ becomes 360° (or) 0° which is necessary as per the oscillator conditions.

→ The bridge circuit consists of R and C in series, R and C in parallel, R_3 and R_4 in arm bridges. The feedback is applied from the collector of Q_2 through the coupling capacitor to the bridge circuit. The resistance R_4 serves the dual purpose of emitter resistance of the transistor Q_1 and also the element of the wien bridge. → ① M



→ ③ M

④ M

⑦ ⓑ

A basic wien bridge used in this oscillator and an amplifier stage is shown in above figure. The output of the amplifier is applied between the terminals 1 and 3 which is the input to the feedback network. →① M While the amplifier input is supplied from the diagonal terminals 2 and 4 which is the output from the feedback network. Thus amplifier supplied its own input through the wien bridge as a feedback network.

→ The two arms of the bridge namely R,C in series and R.C in parallel are called frequency sensitive arms. This is because the components of these two arms decide the frequency of the oscillator. → ②M

Derivation for frequency of oscillations:-

→ If the bridge is balanced, product of ~~po~~ opposite arms of impedances are equal (or) the ratio of adjacent arms are equal.

i.e $\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$ → ①M

$\Rightarrow Z_2 Z_3 = Z_1 Z_4$

From wien bridge, $Z_1 = R_1 - jX_{C_1}$

$Z_2 = R_2 \| X_{C_2} = \frac{-jR_2 X_{C_2}}{R_2 - jX_{C_2}}$

$Z_3 = R_3$

$Z_4 = R_4.$ → ①M

$$\Rightarrow \frac{-jR_2 X_{C_2}}{R_2 - jX_{C_2}} \times R_3 = (R_1 - jX_{C_1}) R_4$$

$$\Rightarrow R_2 R_3 (-jX_{C_2}) = (R_1 - jX_{C_1})(R_2 - jX_{C_2}) R_4$$

$$\Rightarrow -jX_{C_2} R_2 R_3 = (R_1 R_2 - jX_{C_2} R_1 - jX_{C_1} R_2 - X_{C_1} X_{C_2}) R_4$$

$$\Rightarrow -jX_{C_2} R_2 R_3 = R_1 R_2 R_4 - jX_{C_2} R_1 R_4 - jX_{C_1} R_2 R_4 - X_{C_1} X_{C_2} R_4$$

$\Rightarrow \quad R_1R_2R_4 - X_{C_1}X_{C_2}R_4 + j(R_2R_3X_{C_2} - R_1R_4X_{C_2} - R_2R_4X_{C_1}) =$

$\rightarrow$ ② M

Equating real part to zero, we can get the frequency of oscillations.

i.e $\quad R_1R_2R_4 - X_{C_1}X_{C_2}R_4 = 0$

$$\Rightarrow R_1R_2 = X_{C_1}X_{C_2}$$

$$\Rightarrow R_1R_2 = \frac{1}{\omega C_1}\frac{1}{\omega C_2}$$

$$\Rightarrow \omega^2 = \frac{1}{R_1R_2C_1C_2}$$

$$\Rightarrow \omega = \frac{1}{\sqrt{R_1R_2C_1C_2}}$$

$$\Rightarrow f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}} \rightarrow ② M$$

if $R_1 = R_2 = R$

$C_1 = C_2 = C$ then

$$\boxed{f = \frac{1}{2\pi RC}} \rightarrow ① M$$

⑩ M

4+10 = ⑭ M

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14/7/22

CO- PO Attainment Process (Model Calculations)

Academic Year **2022-23**

Regulations **R20**

Year **II** **Sem** **II**

Batch **21**

Branch **ECE**

Subject (Code) **ECA&D&A0409204**

Name of the Faculty **Dr.Y MADHU SUDHANA REDDY**

External Question Paper Marks --> Cos

Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	Total
1 a)				2			2
b)			2				2
c)						2	2
d)		2					2
e)	2						2
f)					2		2
g)				2			2
2 a)					7		7
b)					7		7
c)							0
3 a)		6					6
b)		8					8
c)							0
4 a)				8			8
b)				6			6
c)							0
5 a)	6						6
b)	8						8
c)							0
6 a)			5				5
b)			4				4
c)			5				5
7 a)						7	7
b)						7	7
c)							0
Total	16	16	16	18	16	16	98

Mid I Marks --> Cos

Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	Total
1 a)	1						1
b)			1				1
c)		1					1
d)	1						1
e)			1				1
2 a)	3						3
b)				2			2
3 a)			3				3
b)					2		2
4 a)					3		3
b)		2					2
5 a)						3	3
b)						2	2
Total	5	3	5	2	5	5	25

Mid II Marks --> Cos

Q.No.	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	Total
1 a)	1						1
b)		1					1
c)			1				1
d)						1	1
e)					1		1
2 a)	2						2
b)				3			3
3 a)		3					3
b)					2		2
4 a)			3				3
b)				2			2
5 a)						3	3
b)	2						2
Total	5	4	4	5	3	4	25

Assignment 1 Marks --> Cos

	CO 1	CO2	CO3	CO4	CO5	CO6	Total
	2	2	2	2	1	1	10
Total	2	2	2	2	1	1	10

Assignment 2 Marks --> Cos

	CO1	CO2	CO3	CO4	CO5	CO6	Total
	2	2	2	2	1	1	10

Total	2	2	2	2	1	1	10

Total	4	4	4	4	2	2	20

Total	4	4	4	4	2	2	20

R20 **Regulation Weightage of Marks**

Final exam	Internal tests	Ass/Quiz
70	20	10
0.7	0.2	0.1

Weightage marks for each CO

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	Total
EM	16	16	16	18	16	16	98
IM	10	7	9	7	8	9	50
AM	4	4	4	4	2	2	20

% Weightage of each CO

	CO 1	CO 2	CO 3	CO 4	CO 5	CO 6	Total
EM (%)	16.3265	16.3265	16.3265	18.3673	16.3265	16.3265	100
IM (%)	20	14	18	14	16	18	100
AM (%)	20	20	20	20	10	10	100
Avg	17.4286	16.2286	17.0286	17.6571	15.6286	16.0286	100

S.No	Reg.No.	Internal marks	Assignment marks	Final Internal marks	Total Final Marks		External Marks
1	21091A0401	-10	10	0	0		0
2	21091A0402	12	10	22	49		27
3	21091A0403	11	10	21	21		0
4	21091A0404	13	10	23	41		18
5	21091A0405	10	10	20	40		20
6	21091A0406	13	10	23	56		33

7	21091A0407	18	10	28	76		48
8	21091A0408	16	10	26	51		25
9	21091A0409	16	10	26	66		40
10	21091A0410	9	10	19	50		31
11	21091A0411	18	10	28	79		51
12	21091A0412	11	10	21	35		14
13	21091A0413	5	10	15	20		5
14	21091A0414	9	10	19	19		0
15	21091A0415	10	10	20	31		11
16	21091A0416	12	10	22	56		34
17	21091A0417	13	10	23	50		27
18	21091A0418	15	10	25	62		37
19	21091A0419	11	10	21	39		18
20	21091A0420	17	10	27	55		28
21	21091A0421	16	10	26	66		40
22	21091A0422	12	10	22	51		29
23	21091A0423	16	10	26	61		35
24	21091A0424	16	10	26	61		35
25	21091A0426	12	10	22	47		25
26	21091A0427	14	10	24	60		36
27	21091A0428	10	10	20	50		30
28	21091A0429	16	10	26	57		31
29	21091A0430	14	10	24	50		26
30	21091A0431	12	10	22	48		26
31	21091A0432	5	10	15	24		9
32	21091A0433	9	10	19	28		9
33	21091A0434	16	10	26	69		43
34	21091A0435	14	10	24	59		35
35	21091A0436	8	10	18	43		25
36	21091A0437	7	10	17	30		13
37	21091A0438	5	10	15	30		15
38	21091A0439	13	10	23	33		10
39	21091A0440	15	10	25	58		33
40	21091A0441	11	10	21	46		25
41	21091A0442	17	10	27	76		49
42	21091A0443	7	10	17	36		19
43	21091A0444	5	10	15	24		9
44	21091A0445	10	10	20	31		11
45	21091A0446	13	10	23	53		30
46	21091A0447	18	10	28	65		37
47	21091A0448	19	10	29	67		38
48	21091A0449	18	10	28	74		46
49	21091A0450	5	10	15	22		7
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51	21091A0452	12	10	22	60		38
52	21091A0453	14	10	24	50		26

53	21091A0454	18	10	28	73		45
54	21091A0455	11	10	21	47		26
55	21091A0456	11	10	21	50		29
56	21091A0457	5	10	15	26		11
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58	21091A0459	13	10	23	49		26
59	21091A0460	17	10	27	77		50
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61	21091A0462	17	10	27	64		37
62	21091A0463	18	10	28	80		52
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64	22095A0402	15	10	25	57		32
65	22095A0403	13	10	23	55		32
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76	21091A0467	11	10	21	55		34
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78	21091A0469	13	10	23	49		26
79	21091A0470	18	10	28	77		49
80	21091A0471	11	10	21	36		15
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82	21091A0473	18	10	28	77		49
83	21091A0474	7	10	17	34		17
84	21091A0475	18	10	28	64		36
85	21091A0476	10	10	20	52		32
86	21091A0477	10	10	20	46		26
87	21091A0478	9	10	19	26		7
88	21091A0479	9	10	19	38		19
89	21091A0480	5	10	15	23		8
90	21091A0481	16	10	26	81		55
91	21091A0482	18	10	28	81		53
92	21091A0483	10	10	20	45		25
93	21091A0484	8	10	18	31		13
94	21091A0485	11	10	21	36		15
95	21091A0486	17	10	27	55		28
96	21091A0487	15	10	25	50		25
97	21091A0488	15	10	25	50		25
98	21091A0489	9	10	19	32		13

99	21091A0490	12	10	22	63		41
100	21091A0491	16	10	26	65		39
101	21091A0493	18	10	28	78		50
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121	21091A04B3	16	10	26	73		47
122	21091A04B4	5	10	15	40		25
123	21091A04B5	11	10	21	46		25
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126	21091A04B9	13	10	23	49		26
127	21091A04C0	19	10	29	80		51
128	21091A04C1	10	10	20	45		25
129	21091A04C2	5	10	15	32		17
130	21091A04C3	17	10	27	60		33
131	21091A04C4	17	10	27	53		26
132	21091A04C5	17	10	27	81		54
133	21091A04C6	19	10	29	87		58
134	21091A04C7	11	10	21	46		25
135	22095A0407	18	10	28	77		49
136	22095A0408	13	10	23	62		39
137	22095A0409	15	10	25	53		28
138	22095A0411	18	10	28	73		45
139	22095A0413	18	10	28	69		41
140	22095A0415	15	10	25	65		40
141	22095A0417	18	10	28	75		47
142	22095A0422	19	10	29	85		56
143	22095A0428	14	10	24	24		
144	22095A0429	18	10	28	71		43

145	22095A0435	17	10	27	55		28
146	22095A0436	16	10	26	61		35
147	21091A04C8	14	10	24	47		23
148	21091A04C9	17	10	27	48		21
149	21091A04D0	7	10	17	41		24
150	21091A04D1	16	10	26	51		25
151	21091A04D2	11	10	21	48		27
152	21091A04D3	17	10	27	40		13
153	21091A04D4	17	10	27	44		17
154	21091A04D5	17	10	27	45		18
155	21091A04D6	17	10	27	49		22
156	21091A04D7	18	10	28	51		23
157	21091A04D8	18	10	28	55		27
158	21091A04D9	13	10	23	49		26
159	21091A04E0	19	10	29	56		27
160	21091A04E1	11	10	21	47		26
161	21091A04E2	18	10	28	52		24
162	21091A04E3	15	10	25	45		20
163	21091A04E4	19	10	29	46		17
164	21091A04E5	12	10	22	39		17
165	21091A04E6	9	10	19	41		22
166	21091A04E7	19	10	29	52		23
167	21091A04E8	17	10	27	54		27
168	21091A04E9	19	10	29	56		27
169	21091A04F0	17	10	27	54		27
170	21091A04F1	17	10	27	52		25
171	21091A04F2	18	10	28	53		25
172	21091A04F3	17	10	27	46		19
173	21091A04F4	14	10	24	49		25
174	21091A04F5	12	10	22	47		25
175	21091A04F6	13	10	23	45		22
176	21091A04F7	19	10	29	48		19
177	21091A04F8	11	10	21	46		25
178	21091A04F9	17	10	27	45		18
179	21091A04G0	14	10	24	42		18
180	21091A04G1	15	10	25	50		25
181	21091A04G2	12	10	22	44		22
182	21091A04G3	13	10	23	50		27
183	21091A04G4	13	10	23	48		25
184	21091A04G5	17	10	27	48		21
185	21091A04G6	10	10	20	37		17
186	21091A04G7	13	10	23	48		25
187	21091A04G8	12	10	22	47		25
188	21091A04G9	17	10	27	47		20
189	21091A04H0	17	10	27	45		18
190	21091A04H1	14	10	24	52		28

191	21091A04H2	12	10	22	48		26
192	21091A04H3	13	10	23	47		24
193	21091A04H5	13	10	23	48		25
194	21091A04H6	15	10	25	53		28
195	21091A04H7	15	10	25	53		28
196	21091A04H8	11	10	21	46		25
197	21091A04H9	19	10	29	54		25
198	21091A04J0	19	10	29	56		27
199	21091A04J1	19	10	29	55		26
200	21091A04J2	17	10	27	52		25
201	21091A04J3	18	10	28	49		21
202	21091A04J4	19	10	29	52		23
203	21091A04J5	15	10	25	48		23
204	21091A04J6	10	10	20	46		26
205	21091A04J7	19	10	29	43		14
206	21091A04J8	18	10	28	52		24
207	21091A04J9	19	10	29	46		17
208	22095A0401	15	10	25	42		17
209	22095A0405	14	10	24	48		24
210	22095A0412	17	10	27	52		25
211	22095A0414	19	10	29	56		27
212	22095A0418	16	10	26	45		19
213	22095A0419	19	10	29	51		22
214	22095A0421	19	10	29	54		25
215	22095A0425	19	10	29	47		18
216	22095A0426	18	10	28	57		29
217	22095A0430	16	10	26	52		26
218	22095A0432	19	10	29	54		25
219	22095A0437	13	10	23	51		28
220	19091A04N9	15	10	25	26		1
221	20091A0482	13	10	23	23		
222	20091A0498	13	10	23	23		
223	20091A04A1	8	10	18	29		11
224	20091A04F0	10	10	20	45		25
225	20091A04M4	14	10	24	53		29
226	21091A04K0	16	10	26	61		35
227	21091A04K1	11	10	21	35		14
228	21091A04K2	18	10	28	57		29
229	21091A04K3	15	10	25	63		38
230	21091A04K4	13	10	23	25		2
231	21091A04K5	7	10	17	24		7
232	21091A04K6	8	10	18	24		6
233	21091A04K7	10	10	20	33		13
234	21091A04K8	15	10	25	62		37
235	21091A04K9	12	10	22	26		4
236	21091A04M0	17	10	27	61		34

237	21091A04M1	18	10	28	59		31
238	21091A04M2	14	10	24	54		30
239	21091A04M3	18	10	28	71		43
240	21091A04M4	7	10	17	42		25
241	21091A04M5	5	10	15	19		4
242	21091A04M6	19	10	29	73		44
243	21091A04M7	18	10	28	59		31
244	21091A04M8	14	10	24	53		29
245	21091A04M9	9	10	19	35		16
246	21091A04N0	12	10	22	30		8
247	21091A04N1	8	10	18	34		16
248	21091A04N2	7	10	17	42		25
249	21091A04N3	12	10	22	50		28
250	21091A04N4	16	10	26	67		41
251	21091A04N5	12	10	22	53		31
252	21091A04N7	13	10	23	54		31
253	21091A04N8	18	10	28	69		41
254	21091A04N9	17	10	27	73		46
255	21091A04P0	11	10	21	36		15
256	21091A04P1	18	10	28	83		55
257	21091A04P2	16	10	26	64		38
258	21091A04P3	19	10	29	82		53
259	21091A04P4	15	10	25	53		28
260	21091A04P5	7	10	17	42		25
261	21091A04P6	16	10	26	54		28
262	21091A04P7	8	10	18	18		0
263	21091A04P8	15	10	25	65		40
264	21091A04P9	16	10	26	59		33
265	21091A04Q0	12	10	22	52		30
266	21091A04Q1	17	10	27	60		33
267	21091A04Q2	7	10	17	46		29
268	21091A04Q3	11	10	21	35		14
269	21091A04Q4	11	10	21	49		28
270	21091A04Q5	11	10	21	34		13
271	21091A04Q6	8	10	18	22		4
272	21091A04Q7	13	10	23	48		25
273	21091A04Q8	12	10	22	38		16
274	21091A04Q9	10	10	20	35		15
275	21091A04R0	6	10	16	41		25
276	21091A04R1	11	10	21	46		25
277	21091A04R2	16	10	26	32		6
278	21091A04R3	5	10	15	16		1
279	21091A04R4	10	10	20	45		25
280	21091A04R5	18	10	28	78		50
281	21091A04R6	11	10	21	49		28
282	21091A04R7	9	10	19	49		30

283	21091A04R8	11	10	21	38		17
284	21091A04R9	18	10	28	63		35
285	21091A04S0	12	10	22	50		28
286	21091A04S1	5	10	15	15		0
287	22095A0423	19	10	29	64		35
288	22095A0431	15	10	25	54		29
289	22095A0434	14	10	24	53		29

% of IM	**% of AM**	**% of EM**		**N CO 1**	**N CO 2**	**N CO 3**	**N CO 4**	**N CO 5**	**N CO 6**
-50	100	0		0	3.697183	1.174497	3.398058	-3.8391225	-4.99109
60	100	38.57143		50.53864	49.83903	50.3164	48.92742	46.8895273	47.2167
55	100	0		24.09836	21.81338	23.37248	20.04854	17.6599634	18.5918
65	100	25.71429		43.25527	41.64738	42.74449	40.3583	38.5113607	39.1724
50	100	28.57143		41.68618	41.07143	41.49089	40.0601	37.529381	37.84059
65	100	47.14286		57.30679	56.73793	57.12608	55.96163	54.1812484	54.45124
90	100	68.57143		77.09602	76.14185	76.79291	75.52936	74.969966	75.34505
80	100	35.71429		53.25527	51.27767	52.62704	50.01849	48.8952729	49.6715
80	100	57.14286		67.30679	66.36821	67.00863	65.62182	64.5651606	64.95034
45	100	44.28571		50.84309	51.27515	50.98035	50.70966	47.996866	47.92208
90	100	72.85714		79.90632	79.15996	79.66922	78.65002	78.1039436	78.40081
55	100	20		37.21311	35.89789	36.7953	34.61165	32.285192	32.85205
25	100	7.142857		21.89696	21.66751	21.82407	20.49237	16.7406634	16.94678
45	100	0		21.80328	20.08803	21.25839	18.46278	15.6124314	16.34581
50	100	15.71429		33.25527	32.0171	32.86194	30.6981	28.1274484	28.67329
60	100	48.57143		57.09602	56.88129	57.0278	56.20897	54.2021416	54.34683
65	100	38.57143		51.68618	50.70171	51.37344	49.7203	47.9132933	48.3397
75	100	52.85714		63.34895	62.48742	63.07526	61.70828	60.4074171	60.77158
55	100	25.71429		40.96019	39.92203	40.63039	38.77254	36.4638287	36.92641
85	100	40		57.21311	55.15845	56.5604	53.93204	53.0530165	53.85027
80	100	57.14286		67.30679	66.36821	67.00863	65.62182	64.5651606	64.95034
60	100	41.42857		52.41218	51.85111	52.23394	51.00786	48.9788457	49.25388
80	100	50		62.62295	61.33803	62.21477	60.42071	59.3418647	59.8574
80	100	50		62.62295	61.33803	62.21477	60.42071	59.3418647	59.8574
60	100	35.71429		48.66511	47.82696	48.39885	46.84697	44.8002089	45.17953
70	100	51.42857		61.26464	60.61871	61.05944	59.87517	58.3389919	58.63
50	100	42.85714		51.05386	51.13179	51.07862	50.46232	47.9759728	48.02648
80	100	44.28571		58.87588	57.31388	58.37967	56.25982	55.163228	55.78304
70	100	37.14286		51.89696	50.55835	51.47172	49.47295	47.8924001	48.4441
60	100	37.14286		49.60187	48.833	49.35762	47.88719	45.8448681	46.19812
25	100	12.85714		25.64403	25.69165	25.65916	24.65326	20.9193001	21.02114
45	100	12.85714		30.23419	29.14235	29.88734	27.82478	25.0143641	25.51311
80	100	61.42857		70.1171	69.38632	69.88495	68.74249	67.6991382	68.00611
70	100	50		60.32787	59.61268	60.10067	58.83495	57.2943327	57.61141
40	100	35.71429		44.07494	44.37626	44.17066	43.67545	40.7051449	40.68755

35	100	18.57143		31.68618	31.44115	31.60834	30.39991	27.1454688	27.34148
25	100	21.42857		31.26464	31.72787	31.41179	30.89459	27.1872552	27.13267
65	100	14.28571		35.76112	33.59909	35.0743	32.03652	30.1540872	31.02368
75	100	47.14286		59.60187	58.46328	59.24017	57.54739	56.2287804	56.69722
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
85	100	70		76.88525	76.28521	76.69463	75.7767	74.9908592	75.24064
35	100	27.14286		37.30679	37.47736	37.36098	36.64124	33.4134239	33.45302
25	100	12.85714		25.64403	25.69165	25.65916	24.65326	20.9193001	21.02114
50	100	15.71429		33.25527	32.0171	32.86194	30.6981	28.1274484	28.67329
65	100	42.85714		54.49649	53.71982	54.24976	52.84096	51.0472708	51.39547
90	100	52.85714		66.79157	65.07545	66.2464	64.08692	63.4787151	64.14057
95	100	54.28571		68.87588	66.94416	68.26222	65.92002	65.5471402	66.28215
90	100	65.71429		75.22248	74.12978	74.87536	73.44891	72.8806477	73.30787
25	100	10		23.77049	23.67958	23.74161	22.57282	18.8299817	18.98396
65	100	41.42857		53.55972	52.71378	53.29099	51.80074	50.0026116	50.37688
60	100	54.28571		60.84309	60.90543	60.8629	60.36986	58.3807783	58.42119
70	100	37.14286		51.89696	50.55835	51.47172	49.47295	47.8924001	48.4441
90	100	64.28571		74.28571	73.12374	73.91659	72.40869	71.8359885	72.28928
55	100	37.14286		48.45433	47.97032	48.30058	47.09431	44.8211021	45.07512
55	100	41.42857		51.26464	50.98843	51.17689	50.21498	47.9550797	48.13089
25	100	15.71429		27.51756	27.70372	27.5767	26.7337	23.0086184	23.05831
50	100	51.42857		56.67447	57.16801	56.83126	56.70365	54.2439279	54.13802
65	100	37.14286		50.74941	49.69567	50.41467	48.68007	46.8686341	47.32111
85	100	71.42857		77.82201	77.29125	77.6534	76.81692	76.0355184	76.25923
90	100	71.42857		78.96956	78.15392	78.71045	77.6098	77.0592844	77.38223
85	100	52.85714		65.64403	64.21278	65.18936	63.29404	62.4549491	63.01757
90	100	74.28571		80.84309	80.166	80.628	79.69025	79.1486028	79.4194
25	100	4.285714		20.02342	19.65543	19.90652	18.41193	14.651345	14.9096
75	100	45.71429		58.66511	57.45724	58.2814	56.50717	55.1841212	55.67864
65	100	45.71429		56.37002	55.73189	56.16731	54.92141	53.1365892	53.43265
95	100	44.28571		62.3185	59.90191	61.55081	58.63847	58.234526	59.15202
95	100	67.14286		77.30679	75.99849	76.89118	75.28202	74.9490729	75.44945
80	100	40		56.06557	54.29577	55.50336	53.13916	52.0292505	52.72727
65	100	38.57143		51.68618	50.70171	51.37344	49.7203	47.9132933	48.3397
65	100	58.57143		64.80094	64.78622	64.79626	64.2834	62.5385218	62.59995
60	100	11.42857		32.74005	30.72435	32.09971	29.1632	27.0410029	27.86351
45	100	35.71429		45.22248	45.23893	45.22771	44.46833	41.7289109	41.81054
75	100	35.71429		52.10773	50.41499	51.56999	49.22561	47.8715069	48.54851
70	100	40		53.77049	52.57042	53.38926	51.5534	49.9817185	50.48128
60	100	42.85714		53.34895	52.85714	53.19271	52.04808	50.0235048	50.27247
55	100	48.57143		55.94848	56.01861	55.97076	55.41609	53.1783756	53.22383
25	100	11.42857		24.70726	24.68561	24.70038	23.61304	19.8746409	20.00255
65	100	37.14286		50.74941	49.69567	50.41467	48.68007	46.8686341	47.32111
90	100	70		78.03279	77.14789	77.75168	76.56958	76.0146252	76.36364
55	100	21.42857		38.14988	36.90392	37.75407	35.65187	33.3298511	33.87064
50	100	40		49.18033	49.11972	49.16107	48.38188	45.8866545	45.9893

90	100	70		78.03279	77.14789	77.75168	76.56958	76.0146252	76.36364
35	100	24.28571		35.43326	35.46529	35.44343	34.5608	31.3241055	31.41584
90	100	51.42857		65.8548	64.06942	65.28763	63.04669	62.4340559	63.12198
50	100	45.71429		52.9274	53.14386	52.99616	52.54276	50.0652912	50.06366
50	100	37.14286		47.30679	47.10765	47.24353	46.30143	43.7973361	43.95213
45	100	10		28.36066	27.13028	27.9698	25.74434	22.9250457	23.47594
45	100	27.14286		39.60187	39.20272	39.47507	38.227	35.4609559	35.69901
25	100	11.42857		24.70726	24.68561	24.70038	23.61304	19.8746409	20.00255
80	100	78.57143		81.35831	81.45875	81.39022	81.22515	80.2350483	80.22918
90	100	75.71429		81.77986	81.17203	81.58677	80.73047	80.1932619	80.43799
50	100	35.71429		46.37002	46.10161	46.28476	45.26121	42.7526769	42.93354
40	100	18.57143		32.83372	32.30382	32.66539	31.19279	28.1692348	28.46448
55	100	21.42857		38.14988	36.90392	37.75407	35.65187	33.3298511	33.87064
85	100	40		57.21311	55.15845	56.5604	53.93204	53.0530165	53.85027
75	100	35.71429		52.10773	50.41499	51.56999	49.22561	47.8715069	48.54851
75	100	35.71429		52.10773	50.41499	51.56999	49.22561	47.8715069	48.54851
45	100	18.57143		33.98126	33.1665	33.72244	31.98567	29.1930008	29.58747
60	100	58.57143		63.6534	63.92354	63.73921	63.49052	61.5147558	61.47695
80	100	55.71429		66.37002	65.36217	66.04986	64.5816	63.5205014	63.93175
90	100	71.42857		78.96956	78.15392	78.71045	77.6098	77.0592844	77.38223
75	100	42.85714		56.79157	55.44517	56.36385	54.42672	53.0948028	53.64146
80	100	50		62.62295	61.33803	62.21477	60.42071	59.3418647	59.8574
90	100	55.71429		68.66511	67.08753	68.16395	66.16736	65.5680334	66.17774
90	100	54.28571		67.72834	66.08149	67.20518	65.12714	64.5233742	65.15915
40	100	10		27.21311	26.26761	26.91275	24.95146	21.9012797	22.35294
90	100	67.14286		76.15925	75.13581	75.83413	74.48914	73.9253069	74.32646
45	100	35.71429		45.22248	45.23893	45.22771	44.46833	41.7289109	41.81054
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
65	100	41.42857		53.55972	52.71378	53.29099	51.80074	50.0026116	50.37688
70	100	42.85714		55.64403	54.58249	55.30681	53.63384	52.0710368	52.51846
90	100	45.71429		62.10773	60.04527	61.45254	58.88581	58.2554192	59.04762
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
60	100	18.57143		37.42389	35.75453	36.89358	34.36431	32.2642988	32.95646
70	100	38.57143		52.83372	51.56439	52.43049	50.51318	48.9370593	49.46269
90	100	71.42857		78.96956	78.15392	78.71045	77.6098	77.0592844	77.38223
70	100	41.42857		54.70726	53.57646	54.34803	52.59362	51.0263776	51.49987
70	100	57.14286		65.01171	64.64286	64.89453	64.03606	62.5176286	62.70435
40	100	35.71429		44.07494	44.37626	44.17066	43.67545	40.7051449	40.68755
40	100	22.85714		35.64403	35.32193	35.54171	34.31345	31.3032123	31.52024
80	100	67.14286		73.86417	73.41046	73.72004	72.90337	71.8777749	72.08047
25	100	35.71429		40.63232	41.78823	40.99952	41.29681	37.633847	37.31856
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
35	100	15.71429		29.81265	29.42907	29.6908	28.31946	25.0561504	25.3043
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
65	100	37.14286		50.74941	49.69567	50.41467	48.68007	46.8686341	47.32111
95	100	72.85714		81.05386	80.02264	80.72627	79.4429	79.1277096	79.52381

50	100	35.71429		46.37002	46.10161	46.28476	45.26121	42.7526769	42.93354
25	100	24.28571		33.13817	33.73994	33.32934	32.97503	29.2765735	29.16985
85	100	47.14286		61.89696	60.18863	61.35427	59.13315	58.2763124	58.94321
85	100	37.14286		55.33958	53.14638	54.64286	51.8516	50.9636981	51.81309
85	100	77.14286		81.56909	81.31539	81.48849	80.97781	80.2141551	80.33359
95	100	82.85714		87.61124	87.06489	87.43768	86.72446	86.4403238	86.65393
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
90	100	70		78.03279	77.14789	77.75168	76.56958	76.0146252	76.36364
65	100	55.71429		62.9274	62.77414	62.87872	62.20296	60.4492034	60.56277
75	100	40		54.91803	53.4331	54.44631	52.34628	51.0054845	51.60428
90	100	64.28571		74.28571	73.12374	73.91659	72.40869	71.8359885	72.28928
90	100	58.57143		70.53864	69.0996	70.0815	68.2478	67.6573518	68.21492
75	100	57.14286		66.15925	65.50553	65.95158	64.82894	63.5413946	63.82735
90	100	67.14286		76.15925	75.13581	75.83413	74.48914	73.9253069	74.32646
95	100	80		85.7377	85.05282	85.52013	84.64401	84.3510055	84.61676
70	100	0		27.54098	24.40141	26.54362	22.42718	20.7312614	21.96078
90	100	61.42857		72.41218	71.11167	71.99904	70.32825	69.7466701	70.2521
85	100	40		57.21311	55.15845	56.5604	53.93204	53.0530165	53.85027
80	100	50		62.62295	61.33803	62.21477	60.42071	59.3418647	59.8574
70	100	32.85714		49.08665	47.54024	48.5954	46.35229	44.7584226	45.38834
85	100	30		50.65574	48.1162	49.84899	46.65049	45.7404022	46.72014
35	100	34.28571		41.99063	42.50755	42.15484	41.84235	38.6367198	38.54596
80	100	35.71429		53.25527	51.27767	52.62704	50.01849	48.8952729	49.6715
55	100	38.57143		49.3911	48.97636	49.25935	48.13454	45.8657613	46.09371
85	100	18.57143		43.16159	40.06791	42.17881	38.32871	37.3831288	38.57143
85	100	24.28571		46.90867	44.09205	46.0139	42.4896	41.5617655	42.64579
85	100	25.71429		47.84543	45.09809	46.97267	43.52982	42.6064247	43.66437
85	100	31.42857		51.59251	49.12223	50.80777	47.69071	46.7850614	47.73873
90	100	32.85714		53.67681	50.99095	52.82359	49.52381	48.8534866	49.88032
90	100	38.57143		57.42389	55.01509	56.65868	53.6847	53.0321233	53.95467
65	100	37.14286		50.74941	49.69567	50.41467	48.68007	46.8686341	47.32111
95	100	38.57143		58.57143	55.87777	57.71572	54.47758	54.0558893	55.07767
55	100	37.14286		48.45433	47.97032	48.30058	47.09431	44.8211021	45.07512
90	100	34.28571		54.61358	51.99698	53.78236	50.56403	49.8981457	50.89891
75	100	28.57143		47.42389	45.38481	46.77613	44.0245	42.648211	43.45556
95	100	24.28571		49.20375	45.8174	48.128	44.07536	43.6092975	44.89177
60	100	24.28571		41.17096	39.77867	40.72867	38.5252	36.4429355	37.03081
45	100	31.42857		42.41218	42.22082	42.35139	41.34767	38.5949334	38.75477
95	100	32.85714		54.82436	51.85362	53.88063	50.31669	49.8772525	51.00331
85	100	38.57143		56.27635	54.15241	55.60163	52.89182	52.0083573	52.83168
95	100	38.57143		58.57143	55.87777	57.71572	54.47758	54.0558893	55.07767
85	100	38.57143		56.27635	54.15241	55.60163	52.89182	52.0083573	52.83168
85	100	35.71429		54.40281	52.14034	53.68408	50.81137	49.9190389	50.7945
90	100	35.71429		55.55035	53.00302	54.74113	51.60425	50.9428049	51.91749
85	100	27.14286		48.7822	46.10412	47.93145	44.57004	43.6510838	44.68296
70	100	35.71429		50.96019	49.55231	50.51294	48.43273	46.8477409	47.42552

60	100	35.71429		48.66511	47.82696	48.39885	46.84697	44.8002089	45.17953
65	100	31.42857		47.00234	45.67153	46.57958	44.51919	42.6899974	43.24675
95	100	27.14286		51.07728	47.82948	50.04554	46.1558	45.6986158	46.92895
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
85	100	25.71429		47.84543	45.09809	46.97267	43.52982	42.6064247	43.66437
70	100	25.71429		44.40281	42.51006	43.80153	41.15118	39.5351267	40.29539
75	100	35.71429		52.10773	50.41499	51.56999	49.22561	47.8715069	48.54851
60	100	31.42857		45.8548	44.80885	45.52253	43.72631	41.6662314	42.12376
65	100	38.57143		51.68618	50.70171	51.37344	49.7203	47.9132933	48.3397
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
85	100	30		50.65574	48.1162	49.84899	46.65049	45.7404022	46.72014
50	100	24.28571		38.87588	38.05332	38.61457	36.93944	34.3954035	34.78482
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
60	100	35.71429		48.66511	47.82696	48.39885	46.84697	44.8002089	45.17953
85	100	28.57143		49.71897	47.11016	48.89022	45.61026	44.695743	45.70155
85	100	25.71429		47.84543	45.09809	46.97267	43.52982	42.6064247	43.66437
70	100	40		53.77049	52.57042	53.38926	51.5534	49.9817185	50.48128
60	100	37.14286		49.60187	48.833	49.35762	47.88719	45.8448681	46.19812
65	100	34.28571		48.87588	47.6836	48.49712	46.59963	44.7793157	45.28393
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
75	100	40		54.91803	53.4331	54.44631	52.34628	51.0054845	51.60428
75	100	40		54.91803	53.4331	54.44631	52.34628	51.0054845	51.60428
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
95	100	35.71429		56.69789	53.86569	55.79818	52.39713	51.9665709	53.04049
95	100	38.57143		58.57143	55.87777	57.71572	54.47758	54.0558893	55.07767
95	100	37.14286		57.63466	54.87173	56.75695	53.43736	53.0112301	54.05908
85	100	35.71429		54.40281	52.14034	53.68408	50.81137	49.9190389	50.7945
90	100	30		51.80328	48.97887	50.90604	47.44337	46.7641682	47.84314
95	100	32.85714		54.82436	51.85362	53.88063	50.31669	49.8772525	51.00331
75	100	32.85714		50.23419	48.40292	49.65244	47.14517	45.7821886	46.51133
50	100	37.14286		47.30679	47.10765	47.24353	46.30143	43.7973361	43.95213
95	100	20		46.39344	42.7993	45.25168	40.95469	40.4753199	41.83601
90	100	34.28571		54.61358	51.99698	53.78236	50.56403	49.8981457	50.89891
95	100	24.28571		49.20375	45.8174	48.128	44.07536	43.6092975	44.89177
75	100	24.28571		44.61358	42.3667	43.89981	40.90384	39.5142335	40.3998
70	100	34.28571		50.02342	48.54628	49.55417	47.39251	45.8030817	46.40693
85	100	35.71429		54.40281	52.14034	53.68408	50.81137	49.9190389	50.7945
95	100	38.57143		58.57143	55.87777	57.71572	54.47758	54.0558893	55.07767
80	100	27.14286		47.63466	45.24145	46.8744	43.77716	42.6273178	43.55997
95	100	31.42857		53.88759	50.84759	52.92186	49.27647	48.8325934	49.98472
95	100	35.71429		56.69789	53.86569	55.79818	52.39713	51.9665709	53.04049
95	100	25.71429		50.14052	46.82344	49.08677	45.11558	44.6539566	45.91036
90	100	41.42857		59.29742	57.02716	58.57622	55.76514	55.1214416	55.99185
80	100	37.14286		54.19204	52.2837	53.58581	51.05871	49.9399321	50.69009
95	100	35.71429		56.69789	53.86569	55.79818	52.39713	51.9665709	53.04049
65	100	40		52.62295	51.70775	52.33221	50.76052	48.9579525	49.35829

75	100	1.428571		29.62529	26.27012	28.55944	24.26029	22.7996866	24.10237
65	100	0		26.39344	23.53873	25.48658	21.6343	19.7074954	20.83779
65	100	0		26.39344	23.53873	25.48658	21.6343	19.7074954	20.83779
40	100	15.71429		30.96019	30.29175	30.74784	29.11234	26.0799164	26.4273
50	100	35.71429		46.37002	46.10161	46.28476	45.26121	42.7526769	42.93354
70	100	41.42857		54.70726	53.57646	54.34803	52.59362	51.0263776	51.49987
80	100	50		62.62295	61.33803	62.21477	60.42071	59.3418647	59.8574
55	100	20		37.21311	35.89789	36.7953	34.61165	32.285192	32.85205
90	100	41.42857		59.29742	57.02716	58.57622	55.76514	55.1214416	55.99185
75	100	54.28571		64.28571	63.49346	64.03404	62.7485	61.4520763	61.79017
65	100	2.857143		28.26698	25.5508	27.40412	23.71475	21.7968138	22.87497
35	100	10		26.06557	25.40493	25.8557	24.15858	20.8775137	21.22995
40	100	8.571429		26.27635	25.26157	25.95398	23.91123	20.8566205	21.33435
50	100	18.57143		35.12881	34.02918	34.77948	32.77855	30.2167668	30.71047
75	100	52.85714		63.34895	62.48742	63.07526	61.70828	60.4074171	60.77158
60	100	5.714286		28.99297	26.7002	28.26462	25.00231	22.8623662	23.78915
85	100	48.57143		62.83372	61.19467	62.31304	60.17337	59.3209715	59.9618
90	100	44.28571		61.17096	59.03924	60.49377	57.84558	57.21076	58.02903
70	100	42.85714		55.64403	54.58249	55.30681	53.63384	52.0710368	52.51846
90	100	61.42857		72.41218	71.11167	71.99904	70.32825	69.7466701	70.2521
35	100	35.71429		42.9274	43.51358	43.11361	42.88257	39.681379	39.56455
25	100	5.714286		20.96019	20.66147	20.86529	19.45215	15.6960042	15.92819
95	100	62.85714		74.49649	72.98038	74.01486	72.16135	71.8150953	72.39368
90	100	44.28571		61.17096	59.03924	60.49377	57.84558	57.21076	58.02903
70	100	41.42857		54.70726	53.57646	54.34803	52.59362	51.0263776	51.49987
45	100	22.85714		36.79157	36.18461	36.59875	35.10633	32.3269783	32.64324
60	100	11.42857		32.74005	30.72435	32.09971	29.1632	27.0410029	27.86351
40	100	22.85714		35.64403	35.32193	35.54171	34.31345	31.3032123	31.52024
35	100	35.71429		42.9274	43.51358	43.11361	42.88257	39.681379	39.56455
60	100	40		51.47541	50.84507	51.27517	49.96764	47.9341865	48.23529
80	100	58.57143		68.24356	67.37425	67.9674	66.66204	65.6098198	65.96893
60	100	44.28571		54.28571	53.86318	54.15149	53.0883	51.068164	51.29106
65	100	44.28571		55.43326	54.72586	55.20853	53.88118	52.09193	52.41406
90	100	58.57143		70.53864	69.0996	70.0815	68.2478	67.6573518	68.21492
85	100	65.71429		74.07494	73.2671	73.81831	72.65603	71.8568817	72.18487
55	100	21.42857		38.14988	36.90392	37.75407	35.65187	33.3298511	33.87064
90	100	78.57143		83.6534	83.1841	83.50431	82.81091	82.2825803	82.47517
80	100	54.28571		65.43326	64.35614	65.09108	63.54138	62.4758423	62.91317
95	100	75.71429		82.9274	82.03471	82.64382	81.52335	81.2170279	81.56099
75	100	40		54.91803	53.4331	54.44631	52.34628	51.0054845	51.60428
35	100	35.71429		42.9274	43.51358	43.11361	42.88257	39.681379	39.56455
80	100	40		56.06557	54.29577	55.50336	53.13916	52.0292505	52.72727
40	100	0		20.65574	19.22535	20.20134	17.6699	14.5886654	15.22282
75	100	57.14286		66.15925	65.50553	65.95158	64.82894	63.5413946	63.82735
80	100	47.14286		60.74941	59.32596	60.29722	58.34027	57.2525464	57.82022
60	100	42.85714		53.34895	52.85714	53.19271	52.04808	50.0235048	50.27247

85	100	47.14286		61.89696	60.18863	61.35427	59.13315	58.2763124	58.94321
35	100	41.42857		46.67447	47.53773	46.94871	47.04346	43.8600157	43.63891
55	100	20		37.21311	35.89789	36.7953	34.61165	32.285192	32.85205
55	100	40		50.32787	49.98239	50.21812	49.17476	46.9104205	47.1123
55	100	18.57143		36.27635	34.89185	35.83653	33.57143	31.2405328	31.83346
40	100	5.714286		24.40281	23.2495	24.03643	21.83079	18.7673022	19.29717
65	100	35.71429		49.81265	48.68964	49.4559	47.63985	45.8239749	46.30252
60	100	22.85714		40.23419	38.77264	39.76989	37.48497	35.3982763	36.01222
50	100	21.42857		37.00234	36.04125	36.69703	34.85899	32.3060851	32.74764
30	100	35.71429		41.77986	42.65091	42.05657	42.08969	38.657613	38.44156
55	100	35.71429		47.51756	46.96429	47.3418	46.05409	43.7764429	44.05653
80	100	8.571429		35.45667	32.16298	34.41035	30.25428	29.0467485	30.31831
25	100	1.428571		18.14988	17.64336	17.98897	16.33148	12.5620266	12.87242
50	100	35.71429		46.37002	46.10161	46.28476	45.26121	42.7526769	42.93354
90	100	71.42857		78.96956	78.15392	78.71045	77.6098	77.0592844	77.38223
55	100	40		50.32787	49.98239	50.21812	49.17476	46.9104205	47.1123
45	100	42.85714		49.90632	50.26911	50.02157	49.66944	46.9522068	46.90349
55	100	24.28571		40.02342	38.916	39.67162	37.73232	35.4191695	35.90782
90	100	50		64.91803	63.06338	64.32886	62.00647	61.3893967	62.10339
60	100	40		51.47541	50.84507	51.27517	49.96764	47.9341865	48.23529
25	100	0		17.21311	16.63732	17.0302	15.29126	11.5173675	11.85383
95	100	50		66.06557	63.92606	65.38591	62.79935	62.4131627	63.22638
75	100	41.42857		55.8548	54.43913	55.40508	53.3865	52.0501436	52.62287
70	100	41.42857		54.70726	53.57646	54.34803	52.59362	51.0263776	51.49987

	CO 1		**CO 2**		**CO 3**		**CO 4**		**CO 5**		**CO 6**	
	No. of students Attained	**Weightage Points**	**No. of students Attained**	**Weightage Points**	**No. of students Attained**	**Weightage Points**	**No. of students Attained**	**Weightage Points**	**No. of students Attained**	**Weightage Points**	**No. of students Attained**	**Weightage Points**
>= 50%	167	3	152	3	163	3	138	3	120	3	130	3
40% to 50%	65	2	76	2	67	2	89	2	96	2	88	2
<40%	57	1	61	1	59	1	62	1	73	1	71	1
Total No. of students	289		289		289		289		289		289	
Atainment value		**2.38**		**2.31**		**2.36**		**2.26**		**2.16**		**2.20**

% of Attainment		**57.79**		**52.60**		**56.40**		**47.75**		**41.52**		**44.98**
Attained or not		**YES**		**YES**		**YES**		**NO**		**NO**		**NO**

II Year Threshold
50

CO	**CO Attainment Value**	**PO 1**	**PO 2**	**PO 3**	**PO 4**	**PO 5**	**PO 6**	**PO 7**	**PO 8**	**PO 9**	**PO 10**	**PO 11**	**PO 12**	**PSO 1**	**PSO 2**	**PSO 3**
CO 1	2.17	1	3	2	0	1	0	0	0	0	0	0	1	**3**	**1**	**0**
CO 2	2.10	2	2	0	0	2	0	0	0	0	0	0	2	**3**	**2**	**0**
CO 3	2.15	2	3	2	2	1	0	0	0	0	0	0	2	**0**	**2**	**1**
CO 4	2.07	1	3	2	2	0	0	0	0	0	0	0	1	**1**	**2**	**1**
CO 5	2.01	3	1	0	0	1	0	0	0	0	0	0	2	**0**	**2**	**1**
CO 6	2.03	**2**	**1**	**1**	**2**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**1**
ECA&D		**2.08**	**2.11**	**2.11**	**2.08**	**2.10**	**-**	**-**	**-**	**-**	**-**	**-**	**2.10**	**2.10**	**2.09**	**2.07**

Code: A0409204R0723

RGM COLLEGE OF ENGINEERING & TECHNOLOGY (AUTONOMOUS)
20th July 2023
II B.Tech. II Sem. (R20) End Examinations (Regular)
ELECTRONIC CIRCUITS – ANALYSIS AND DESIGN
ECE

Time: 3 Hrs **Total Marks: 70**

Note 1:Answer Question No.1 (Compulsory) and 4 from the remaining
2:All Questions Carry Equal Marks

1a Define current-shunt negative feedback.

b Draw the high-frequency hybrid- Π model of BJT.

c Draw the circuit diagram of class A output stage.

d When the differential pair can be used as a linear amplifier?

e Define h_{ic} and h_{re}

f Define growing oscillations.

g Define voltage-series negative feedback.

2 a) Draw the circuit diagram of RC-phase shift oscillator and explain its operation.(7)
b) Draw the approximate hybrid model of RC phase shift oscillator and derive the output frequency of RC phase shift oscillator. (7)

3 a) Draw the circuit diagram of two-stage CE-CB cascode amplifier and its approximate hybrid model. (6)
b) Explain the h-parameter analysis of the above circuit. (8)

4 a) Draw the topology of Current Series feedback amplifier. Derive the expressions for input and output impedances with feedback. (8)
b) For a current series feedback amplifier with R_S=1KΩ, R_E=1.2KΩ and R_L =2.2KΩ. The transistors with parameters are h_{ie}=1.1KΩ and h_{fe}=50. Calculate G_M, β, D, A_{vf},R_{if} and R_{of} . (6)

5 a) Draw a common-source amplifier using the classical biasing arrangement (voltage divider biasing) and draw its equivalent circuit. (6)
b) Analyse the above circuit to find R_{in}, R_o, and Voltage Gain (8)

6 A common source amplifier has C_{C1}=C_{C2}=C_S=1μF, R_G=10MΩ, R_{Sig}=100KΩ, g_m=2mA/V, R_D=R_L=R_S=10KΩ. Find
a) Mid band gain A_M (3)
b) f_{p1} (2)
c) f_{p2} (2)
d) f_{p3} (2)
e) f_z and f_l (5)

7 a) Show that the maximum efficiency of series fed class A power amplifier is 25%. (7)

b) A class B push pull amplifier supplies power to a resistive load of 12Ω. The output transformer has a turns ratio of 3:1 and efficiency of 78.5%. Assume V_{CC} = 20V and h_{fe} = 25. Calculate (7)

i) Maximum power output
ii) Maximum power dissipation in each transistor.
iii) Maximum base and collector currents for each transistor.

- XXX -

2

a) Based on the RC oscillations are classified into 3 types. They are

1) RC phase
2) LC oscillations
3) crystal oscillators

Again RC oscillators are classified into two types

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VALUATION-II

Q.No.	1	2	3	4	5	6	7
A							
B							
C							
D							
E							
F							
G							
TOTAL							

GRAND TOTAL

(in words)

Signature of the Examiner

Signature of the Scrutinizer

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VALUATION-I

Q.No.	1	2	3	4	5	6	7
A	2	6		7	5		7
B	0	7		4	6		6
C	1						
D	0						
E	2						
F	0						
G	2						
TOTAL	7	13		11	11		13

GRAND TOTAL 55

(in words) fifty five

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2

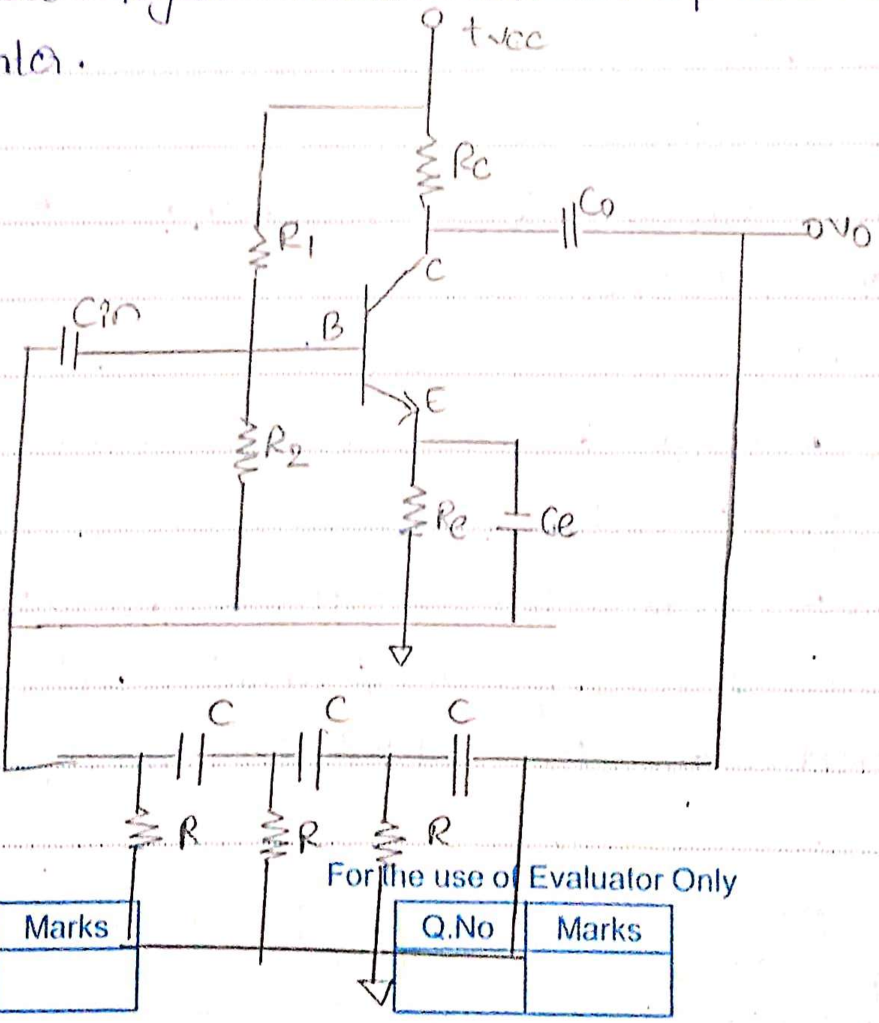
4) Based on the Rc oscillations are classified into 3 types. they are

1) Rc phase
2) Lc oscillations
3) crystal oscillators

Again Rc oscillators are classified into two types they are :

1) Rc phase shift oscillations
2) wein bridge oscillations.

The below figure shows the Rc phase-shift oscillator.



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Q.No	Marks

The above figure shows the Rc-phase shift oscillations and common Emitter amplifier with a voltage divider biasing.

let R_1 and R_2 are the Resistors acts as a voltage divider biasing.

There are 3 capacitor are connected to inseries with 3 resistors (R)

→ In a Rc-phase shift oscillator produces 180° phase shift

→ another feedback network produces a 180° phase shift.

→ overall phase shift produceces a 360° of a oscillators.

→ but general oscillations they can't produce any phase shift.

→ In these possitive feedback Amplifiers also used not negative feedback networks are used. due to sufficient stabilization.

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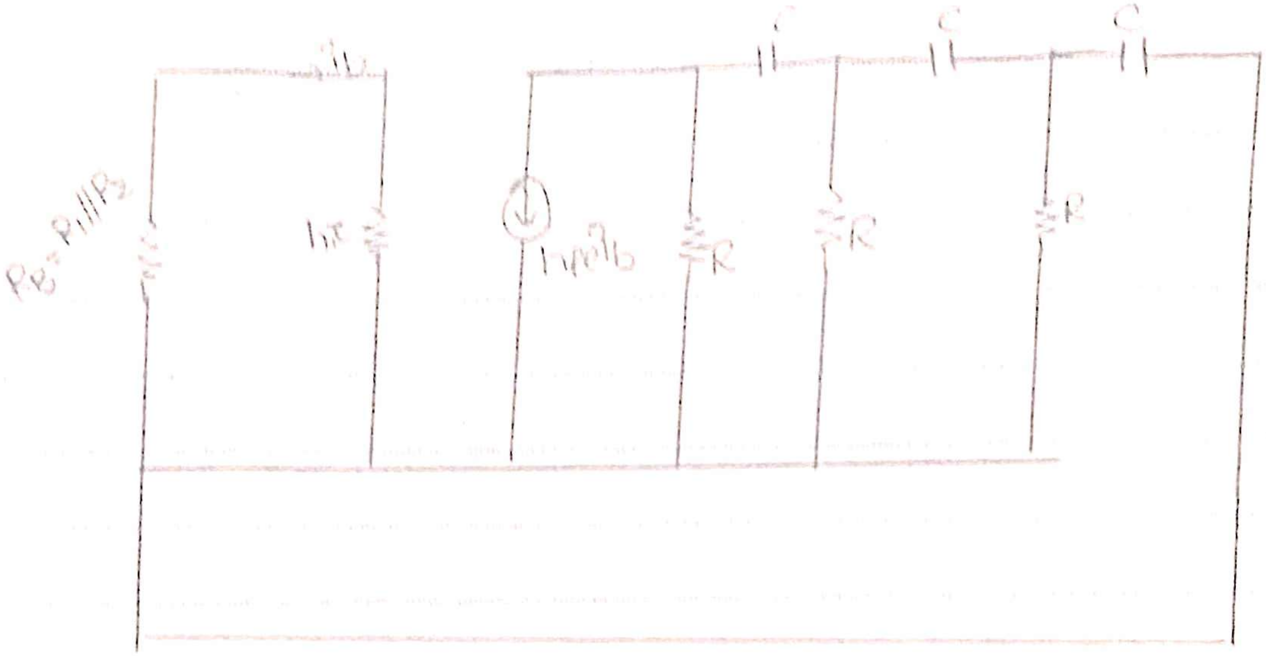
Generalized RC phase shift oscillations are drawn below figure.



where $R_B = R_1 || R_2$

$$\boxed{f = \frac{1}{2\pi RC\sqrt{10}}}$$

$$f = \frac{1}{2\pi RC\sqrt{6+4k}}$$

where $k = \frac{R_C}{R}$ //

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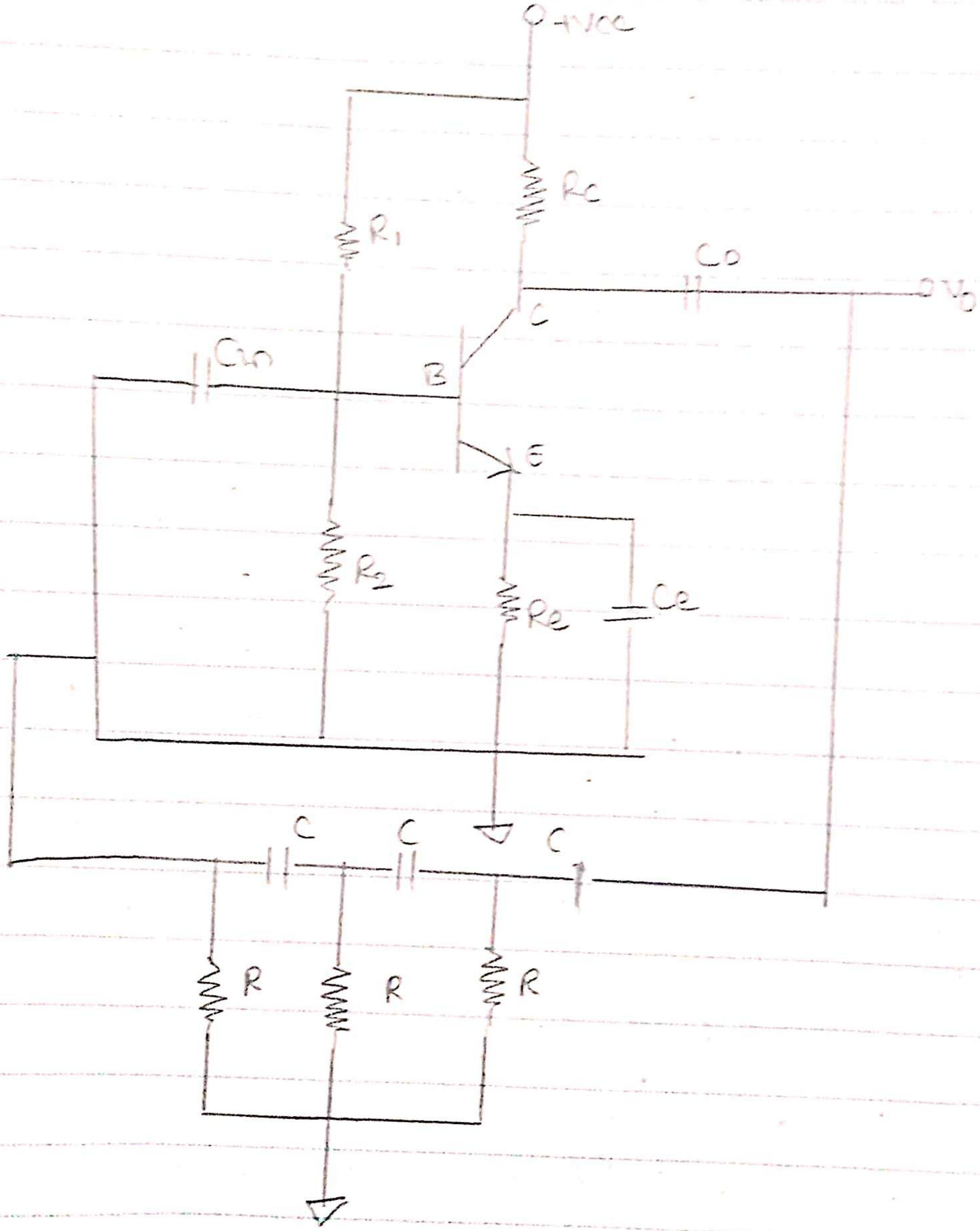
Q.No	Marks

Q.No	Marks
2a	6

Q.No	Marks

b) The below figure shows the RC phase shift oscillations and voltage divider biasing circuit shown in below figure.



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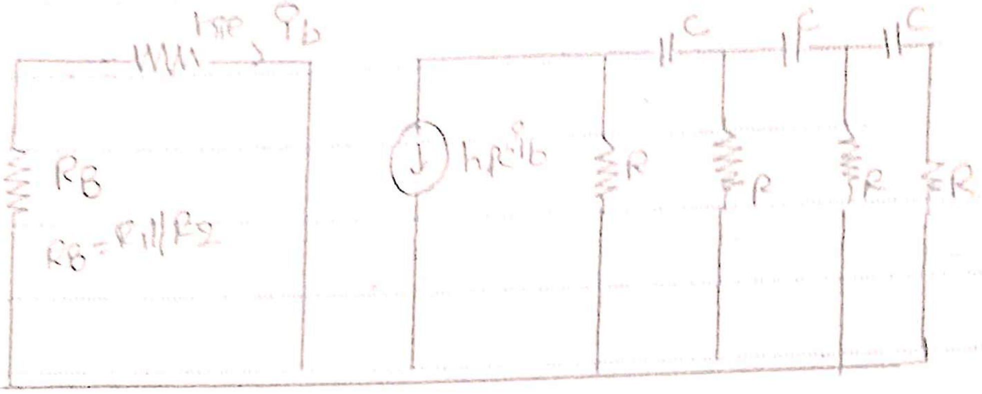
Q.No	Marks

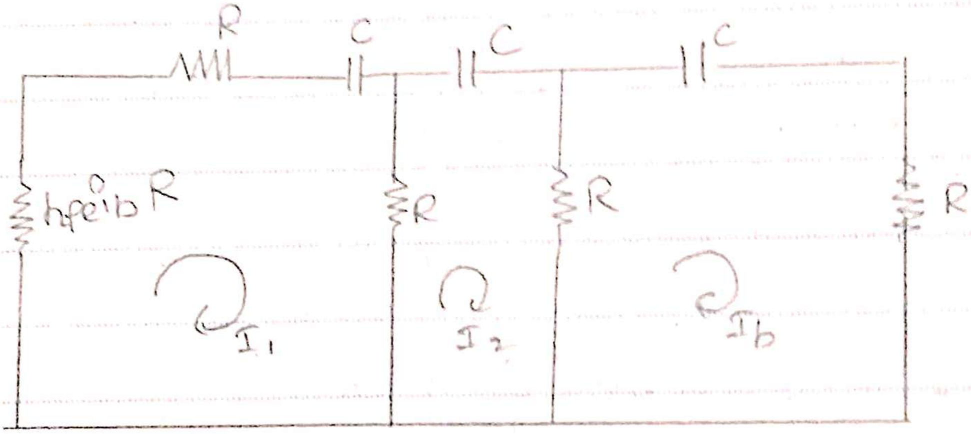
Q.No	Marks

Q.No	Marks

The below figure shows the approximate hybrid model of a RC phase shift oscillator



Consider the below figure



Apply the KVL to the 1st loop; we get

$$h_{fe} i_b R + R I_1 + \frac{I_1}{j\omega C} + R(I_1 - I_2) = 0$$

$$h_{fe} i_b R + R I_1 + \frac{I_1}{j\omega C} + R I_1 - R I_2 = 0$$

$$I_1\left(2R + \frac{1}{j\omega C}\right) - R I_2 + h_{fe} i_b R = 0 \longrightarrow ①$$

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Q.No	Marks

Q.No	Marks

Q.No	Marks

Apply kvl to the 2nd loop

$$\Rightarrow R(I_2-I_1)+\frac{I_2}{j\omega c}+R(I_2-I_b)=0$$

$$RI_2-RI_1+\frac{I_2}{j\omega c}+RI_2-RI_b=0$$

$$-RI_1-R_2I_2+\frac{I_2}{j\omega c}+RI_2-RI_b=0$$

$$-RI_1+I_2\left(2R+\frac{1}{j\omega c}\right)-RI_b=0 \longrightarrow (2)$$

⇒ Apply kvl to the loop3 ; we get

$$R(I_b-I_2)+\frac{I_b}{j\omega c}+RI_b=0$$

$$RI_b-RI_2+\frac{I_b}{j\omega c}+RI_b=0$$

$$-RI_2+I_b\left(2R+\frac{1}{j\omega c}\right)=0 \longrightarrow (3)$$

we can equate the Eq ① & ② & ③ ; we get

let put

$$\frac{1}{j\omega c}=-jX_C$$

then;

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Q.No	Marks

Q.No	Marks

Q.No	Marks

$$\begin{vmatrix} 2R-jX_c & -R & h_{fe}R \\ -R & 2R-jX_c & -R \\ 0 & -R & 2R-jX_c \end{vmatrix} = 0$$

$$2R-jX_c\left[\left((2R-jX_c)(2R-jX_c)-R^2\right)\right]+R\left[-R(2R-jX_c)-0\right]$$

$$+h_{fe}R\left[R^2-0\right]=0$$

$$(2R-jX_c)^3 \overset{-(2R-jX_c)R^2}{+} R\left[-2R^2+jX_cR)\right]+R^3h_{fe}=0$$

$$\boxed{\therefore (a-b)^3 = a^3-b^3-3ab(a-b)}$$

$$(2R)^3-(jX_c)^3-3(2RjX_c)(2R-jX_c)-2R^3+R^2jX_c+R^3h_{fe}=0$$

$$8R^3+jX_c^3-6RjX_c\left[2R-jX_c\right]-2R^3+R^2jX_c-2R^3+R^2jX_c+R^3h_{fe}=0$$

$$\underline{8R^3}+jX_c^3-12R^2jX_c+6Rj^2\underline{X_c^2}-\underline{2R^3}+R^2jX_c-2\underline{R^3}+R^2jX_c+R^3h_{fe}=0$$

$$4R^3+jX_c^3-10R^2jX_c-6RX_c^2+R^3h_{fe}=0$$

$$\left(4R^3-6RX_c^2+R^3h_{fe}\right)+j\left(X_c^3-10R^2X_c\right)=0$$

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Q.No	Marks

Q.No	Marks

Q.No	Marks

By equating the imaginary part

$x_c^3 - 10 x_c R^2 = 0$

$x_c^3 = 10R^2 x_c$

$x_c^2 = 10R^2$

$x_c = \sqrt{10}\, R$,,

By equating the real parts we get

$4R^3 - 6R x_c^2 + R^3 hfe = 0$

$4R^3 - 6R(10R^2) + R^3 hfe = 0$

$4R^3 - 60R^3 + R^3 hfe = 0$

$R^3(4 - 60 + hpc) = 0$

$4 - 60 + hfe = 0$

$-56 + hfe = 0$

$\cancel{-}hfe = \cancel{-}56$

$.\, hfe = 56$

$\therefore \boxed{hfe = 56}$

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Q.No	Marks

Q.No	Marks

Q.No	Marks

$$f = \frac{1}{2\pi R\sqrt{10}}$$

$$f = \frac{1}{2\pi RC\sqrt{6+4k}}$$

where $k = \frac{RC}{C_1}$.

where f = frequency of oscillator

R = resistor

C = capacitor

k = constant.

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Q.No	Marks

Q.No	Marks
2b	7

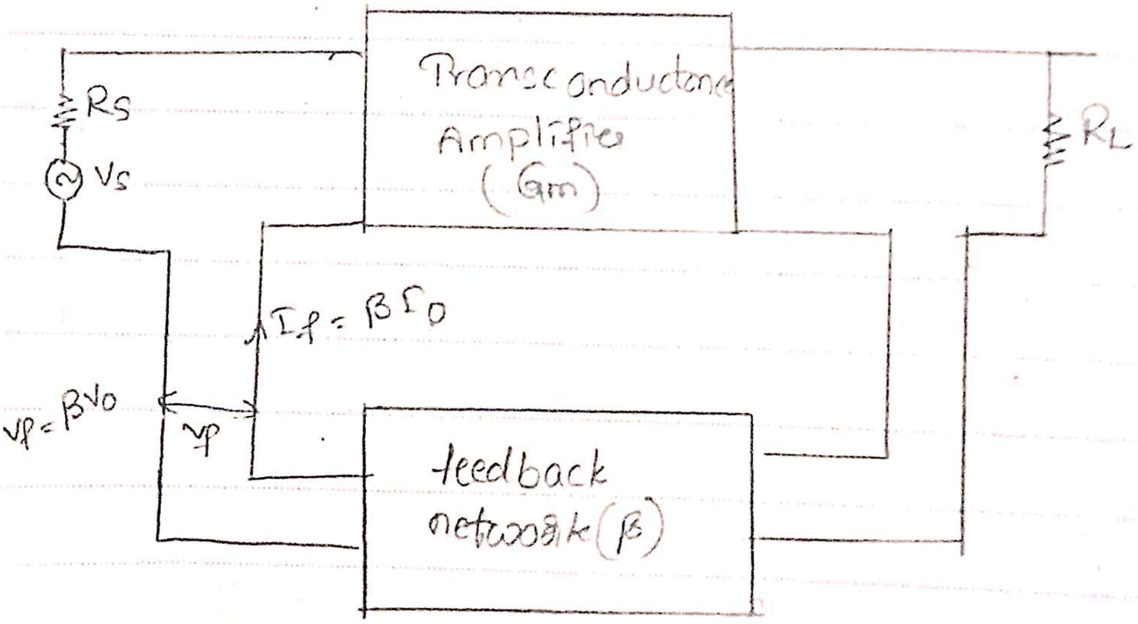
Q.No	Marks

4p.

a) current series feedback amplifier is also called as a series CE amplifier.

→ the current series feedback amplifier the basic amplifier is transconductance and feed back network (β) can be sampled circuit.

the below figure shows the current series feedback amplifier.



Input Impedance:

Input impedance without feedback

$$Z_{in} = \frac{V_{in}}{I_{in}}$$

Input impedance with feed back $Z_{if} = \frac{V_s}{I_{in}}$

$V_{in} = V_s + V_f$

$V_s = V_{in} - V_f$

let $V_f = \beta V_o$

$V_o = A G_m V_{in}$

$V_{in} = (-\beta (G_m V_{in})) + V_s$

$V_{in} + \beta G_m V_{in} = V_s$

$V_{in}(1 + \beta G_m) = V_s$

$$\frac{V_{in}}{I_{in}}(1 + \beta G_m) = \frac{V_s}{I_{in}}$$

$$\frac{V_s}{I_{in}} = \frac{V_{in}}{I_{in}}(1 + \beta G_m)$$

$$\boxed{Z_{if} = Z_{in}(1 + G_m \beta)}$$ //

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

ii output impedance :

output impedance it can be defined by the Zo , where;

$$Z_{of} = \frac{V_o}{I_o}\Big|_{V_s=0\ ;\ R_L\to\infty}$$

$V_{in} = V_s - V_f$

where $V_f = \beta V_o$

$V_o = G_m I_{in}$

where $V_s = 0$; then

$V_{in} = -V_f$

$V_{in} = -\beta V_o$

$\frac{V_o}{I_o} = Z_o(1+G_m\beta)$

$Z_{of} = Z_o \cdot (1+G_m\beta)$

$$\therefore \boxed{Z_{of} = Z_o(1+G_m\beta)}$$ //

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

b) Given that

$R_S = 1 k\Omega$

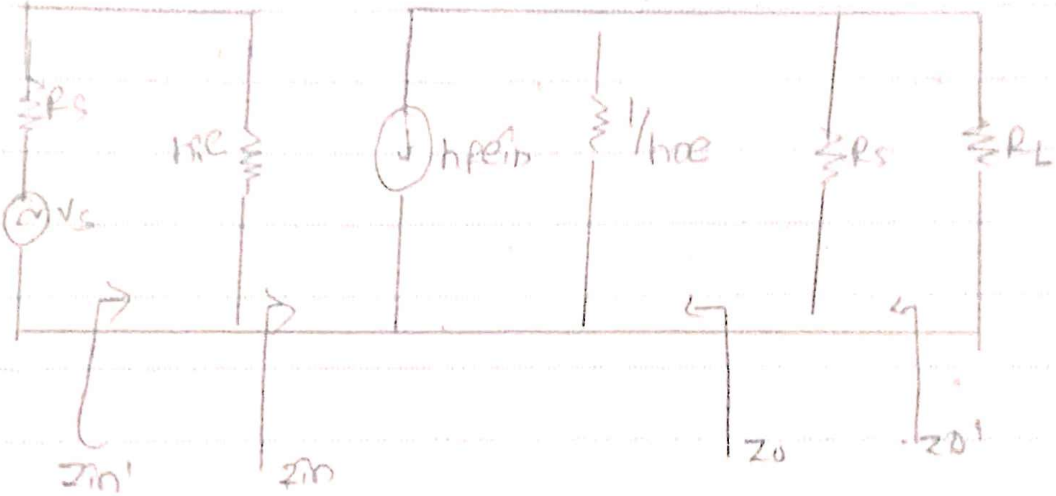
$R_E = 1.2 k\Omega$

$R_L = 2.2 k\Omega$

h-parameters are $h_{ie} = 1.1 k\Omega$

$h_{fe} = 50$

In a current series feedback amplifier



i) $\beta = \frac{V_o}{V_f}$

In common Emitter $V_o = V_f$

$$\beta = \frac{V_o}{V_f}$$

$$\beta = \frac{\cancel{V_f}}{\cancel{V_f}} = 1 \quad \therefore \beta = 1$$

For the use of Evaluator Only

Q.No	Marks
49	7

Q.No	Marks

Q.No	Marks

2) Z_{in} (or) R_i = $h_{ie} - \frac{h_{re} h_{fe}}{h_{oe} + \frac{1}{R_L}}$

$= 1.1k\Omega - \frac{(0.07)(50)}{2.4\times10^{-6} + \frac{1}{2.2k\Omega}}$

$Z_{in} = 8.7k$

3) $A_{vf} = \frac{A_I \cdot R_L}{Z_{in}}$

$A_I = \frac{h_{fe}}{h_{oe} \cdot R_L + 1}$

$= \frac{50}{2.4\times10^{-6}(2.2k\Omega) + 1}$

$A_I = 49.6$

$A_{vf} = \frac{A_I \cdot R_L}{Z_{in}} = \frac{49.6 \times 2.2\times10^{3}}{8.7}$

$A_v = 12.54$

$R_{of} = Z_0 = \frac{h_{ie}}{h_{ie} h_{oe} - h_{re} h_{fe}}$

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

$$\frac{1.132}{1.1\times10^{-3}(24\times10^{3}) - 0.01(56)}$$

KoP = 244.61

$$Gm = \frac{Zm}{D}$$

D = (1 + AvB)

= 1 + 49.6(1)

= 1 + 49.6

= 50.6

$$Gm = \frac{8.7}{50.6}$$

Gm = 0.171

Ref =

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Q.No	Marks
4b	4

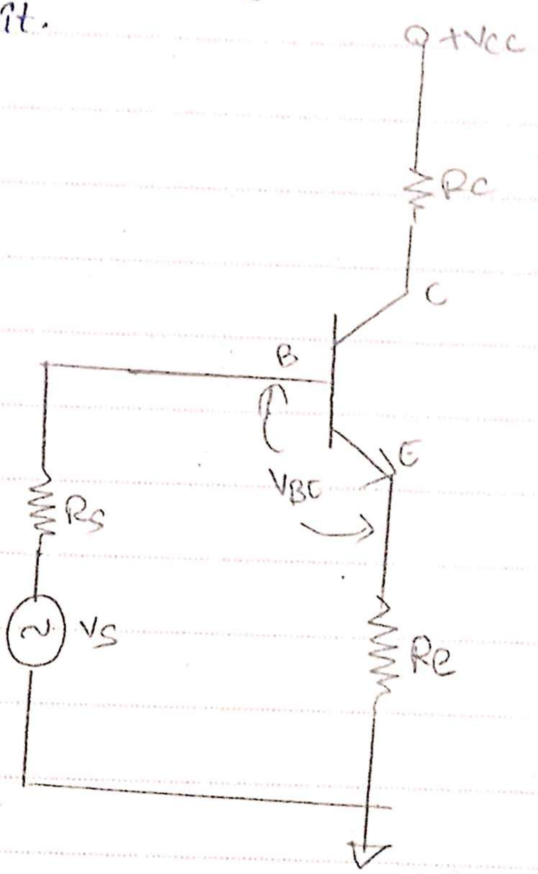
Q.No	Marks

Q.No	Marks

7

2) class A power amplifier it can be defined by the maximum common Emitter configuration with moves from one wave of full cycle to another Half cycles is known.

The below figure shows the comon collector circuit.



Apply kvl to i/p loop

$V_S - V_{BE} - I_E R_e = 0$

$V_S - I_e R_e - V_{BE} = 0$

$V_S = I_e R_e - V_{Be} \Rightarrow V_{BE} = V_S - I_e R_e$

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

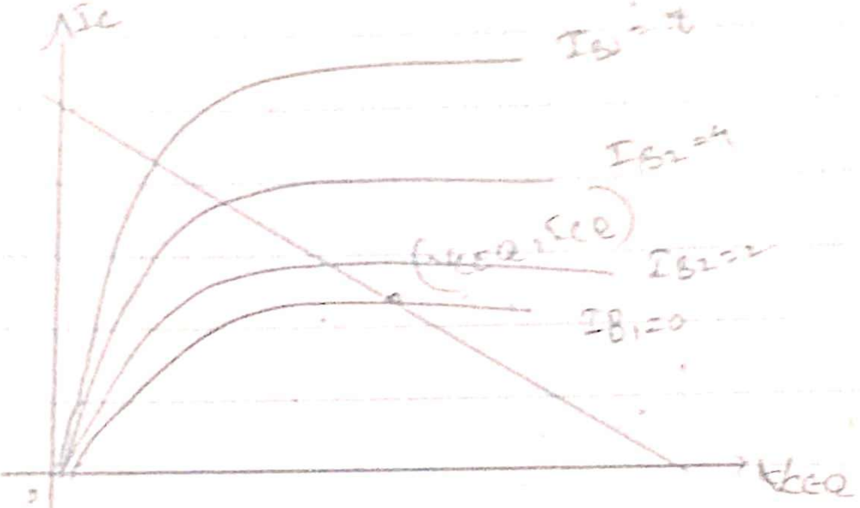
Q.No	Marks

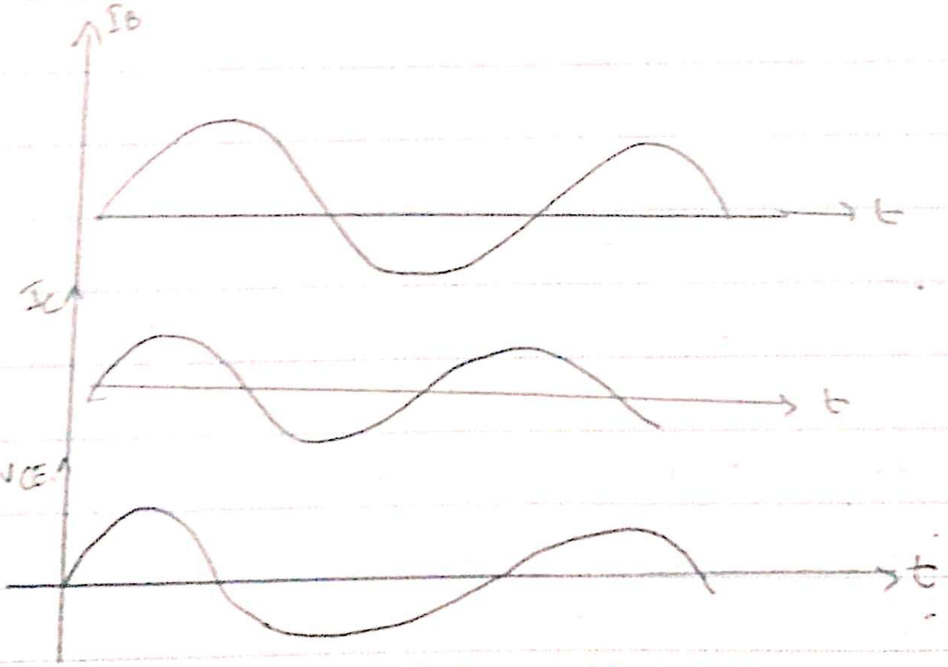
Apply kvl to o/p loop

$V_{CC} - I_C R_C - V_{CE} - I_e R_e = 0$

$V_{CE} = -V_{CC} + I_e R_e + I_C R_C$

The below figure show the class a power amplifier





For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

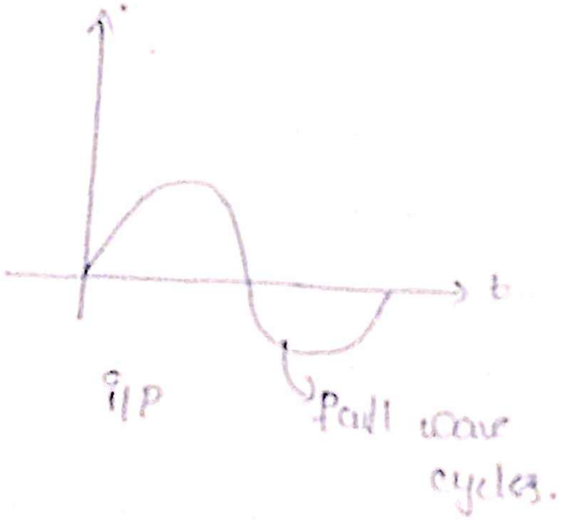
Q.No	Marks

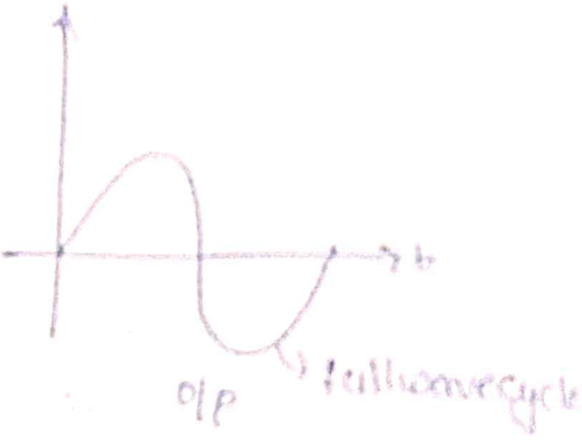
DC power :

In DC power amplifier

$P_{dc} = V_{dc} \times I_{dc}$

The class-A power amplifier it common collector moves to 50% of full wave cycles.





AC power :

$$P_{ac} = \frac{(V_{max} - V_{min}) * (I_{max} - I_{min})}{8}$$

where V_{max} = maximum voltage

V_{min} = minimum voltage

I_{max} = maximum current

Imin = minimum current

Distortion power amplifier:

It can be defined by the maximum power in Distortion power amplifier is equal to power amplifier in AC to power amplifier in dc

i.e. $P_D = P_{dc} - P_{ac}$

% η efficiency:

$$\eta = \frac{P_{ac}}{P_{dc}}$$

$$= \frac{(V_{max} - V_{min}) \times (I_{max} - I_{min})}{8 \times V_{dc} \times I_{dc}} \times 100$$

At $V_{min} = 0$

$I_{min} = 0$

$$= \frac{(V_{max} - 0)\ (2I_{max} - 0)}{8 \times V_{cc} \times I_{dc}} \times 100$$

$V_{cc} = V_{dc}$

$V_{dc} = V_{ac}$

$$= \frac{\cancel{2}\ V_{dc} \times I_{dc}}{\cancel{8}_{4}\ V_{dc} \times I_{dc}} \times 100 \Rightarrow \frac{100}{4} = 25\%$$

$\therefore \eta = 25\%$

For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
7a	7

Q.No	Marks

∴ maximum efficiency of series feed class A power amplifier

$$\eta\% = 25\%$$

b) Given that

A class B push pull amplifier

Resistive load $= 12\Omega$.

output transformer has turns the ratio 3:1

i.e; $\frac{n_1}{n_2} = 3/1$

$\eta = 78.5\%$

Assume $V_{cc} = 20V$

$h_{fe} = 25$.

i) maximum power output

$V_{rms} = \frac{2V_m}{2}$

$I_{rms} = \frac{2V_m}{\pi}$

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Q.No	Marks

Q.No	Marks

Q.No	Marks

$P_{max} = V_{rms} \times I_{rms}$

$\Rightarrow \frac{2V_m}{\pi} * \frac{2V_m}{\pi}$

$= \frac{2V_m}{\pi} + \frac{V_m}{\pi}$

$\Rightarrow \frac{2V_m}{\pi}$

$P_{max} = V_{rms} \times I_{rms}$

$R_L' = \left(\frac{n_1}{n_2}\right) R_L$

$= \frac{3}{1}(12\,\Omega)$

$= 36\,\Omega$

$V_m = I \times R_L'$

$= 36 \times 3.6 \times 10^{-3}$

$= 0.12$

$P_{max} = \frac{2(0.12)}{\pi}$

$= 0.07$ watts

For the use of Evaluator Only

Q.No	Marks	Q.No	Marks	Q.No	Marks

2) maximum power dissipation

$P_D = P_{dc} - P_{ac}$

$P_D = 21.03 - 62.38 \times 10^{-3}$

$P_D = 20.9672$

3) maximum base and collector for each transistor

$$\frac{(V_{max} - V_{min}) \times (I_{max} - I_{min})}{8 \times V_{cc} \times I_c} \% 100$$

$$\frac{(2V_{max} - 0)\ (2I_{max} - 0)}{8 \times V_{CC} \times I_C} \times 100$$

$$\frac{4 \quad V_{CQ} \times I_{CQ}}{8_2 \quad V_{CQ} \times I_{CQ}} \times 100 \qquad I_{BQ} = I_{CQ}$$

$\frac{1}{2} \times 100 = 50\%$ $\qquad h_{fe} = 25 \Rightarrow \frac{h_{fe}}{h_{oe}} = \frac{25}{50} = 0.5$

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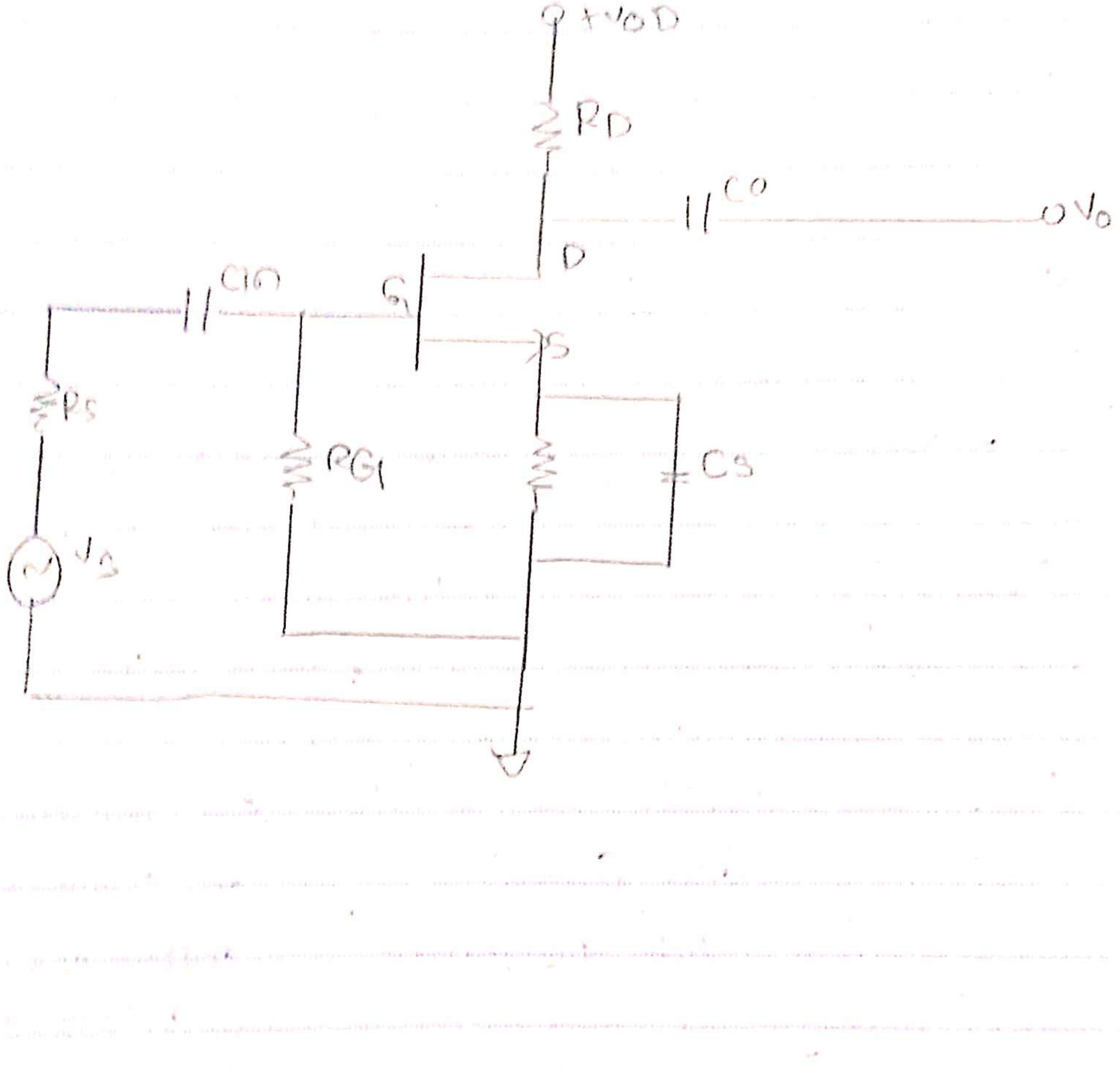
Q.No	Marks
7b	6

Q.No	Marks

Q.No	Marks

ii)

ii) the below figure shows the common source amplifier of FET. and voltage divider biasing R₁ & R₂ will acts as a voltage biasing as shown in a below figure.



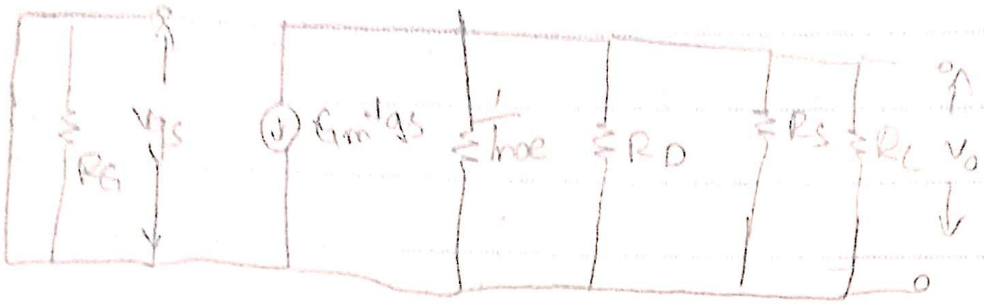
For the use of Evaluator Only

Q.No	Marks

Q.No	Marks

Q.No	Marks

Equivalent circuit of a common source amplifier is



b) The common source amplifier,

Zin (input put impedance)

$$= \frac{Vin}{Iin}$$

Zin = it is the ratio of input voltage to input current than it is known as a input impedance

$$Zin = \frac{Vgs}{IG}$$

·Ro(or) Zo = output impedance

Zo = it is the Ratio of output voltage to output current is known as a output impedance

$$Zo = \frac{O/P\ (voltage)}{O/P\ (Current)}$$

$$= \frac{Vgs}{RD+hie}$$

For the use of Evaluator Only

Q.No	Marks
5a	5

Q.No	Marks

Q.No	Marks

Voltage Gain $A_v = \frac{AI \cdot RL}{Zin}$

$= \frac{V_{gs} \cdot I_G \cdot R_L}{Gm \cdot hfe}$

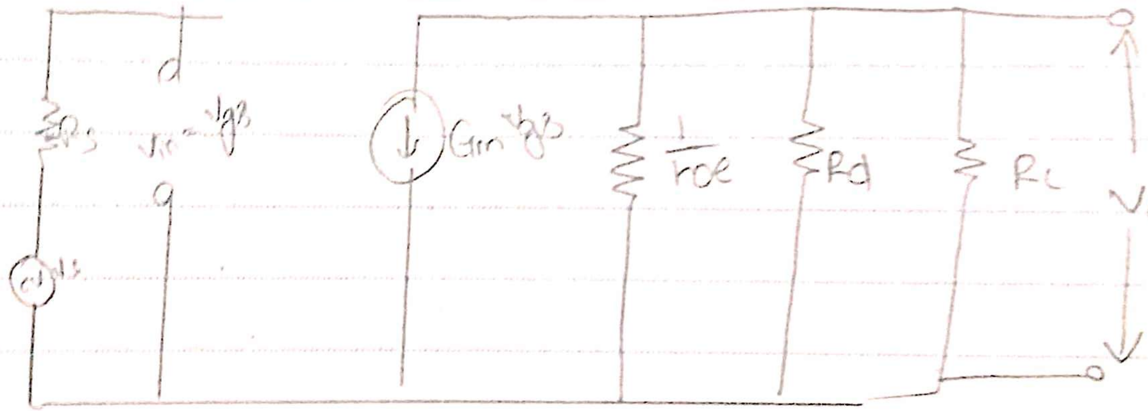
$R_L = R_D \| rd$

Where $\frac{Rd \times rd}{RD + rd}$

Gm = conductance.

votage gain Av it is the ratio of output voltage to input voltage is known as a voltage gain (Av)

Equivalent circuit of a common-source amplifier



$Zin' = \frac{Bm}{D}$

$Z_O' = \frac{ZD}{AI}$

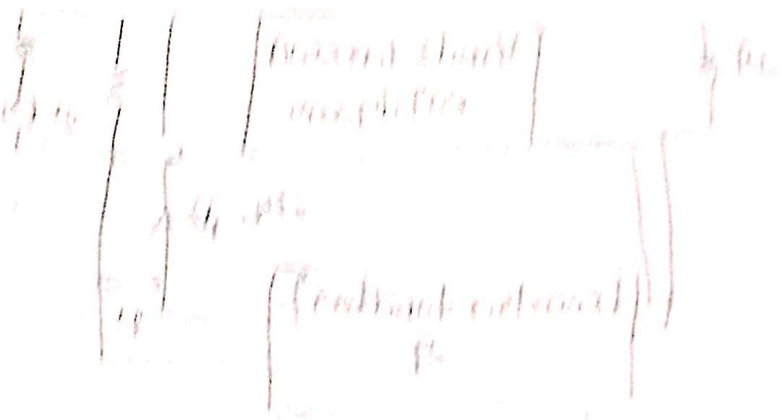
For the use of Evaluator Only

Q.No	Marks

Q.No	Marks
56	6

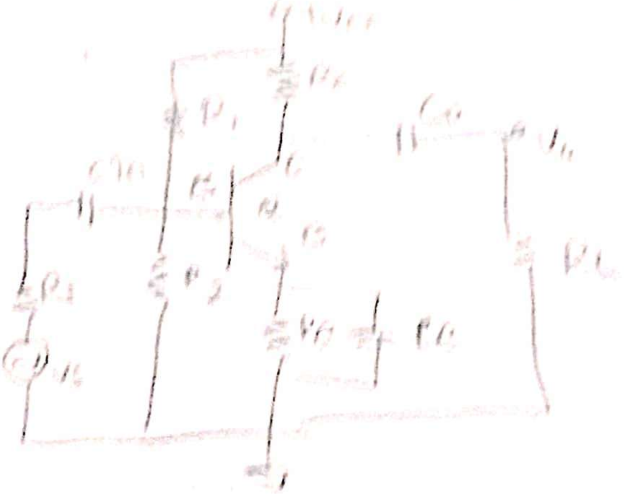
Q.No	Marks

1 (a) Current shunt negative feedback amplifier



In a current shunt feedback network current series is a basic amplifier and feedback network will be a sampled

b)



Here above circuit will be the high frequency model of H- model

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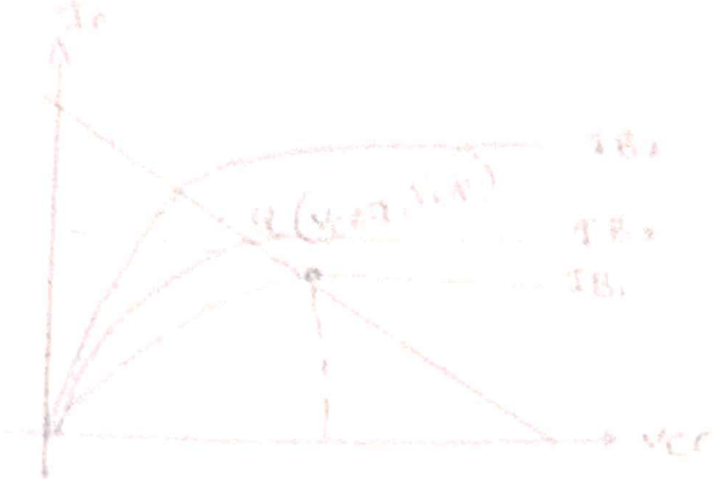
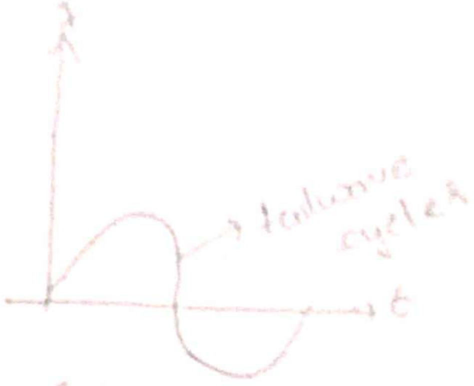
Q No	Marks

Q No	Marks
1a	2

Q No	Marks
1b	0

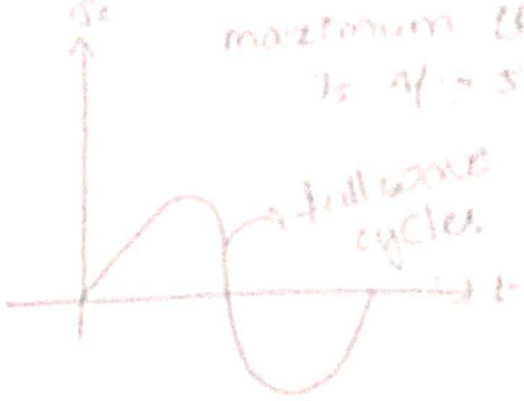
c)





I/P class A Power amplifier

maximum efficiency is η = 50%



O/P class A Power amplifier

These class A powa amplifier is maxlmumum fraquency and cost of the circuit will be less and high frequence signal.

For the use of Evaluator Only

Q No	Marks

Q No	Marks
1c	1

Q No	Marks

d) differential pair can be used as a linear amplifier because of Resistive coupled amplifiers and Inductive coupled amplifier are that are less stability characteristics of single stage and multistage amplifiers are not constant when we go for a differential pair of linear amplifiers.

e) hie :

hie is defined by the i/p voltage to the input current of a common Emitter amplifier.

$$hie = \frac{Vbe}{Ib}$$

This is also called input impedence

hfe :

hfe it can be defined by the output current by input current

i.e; $hfe = \frac{Ic}{Ib}$

It is also called inverse parameter of a circuit

For the use of Evaluator Only

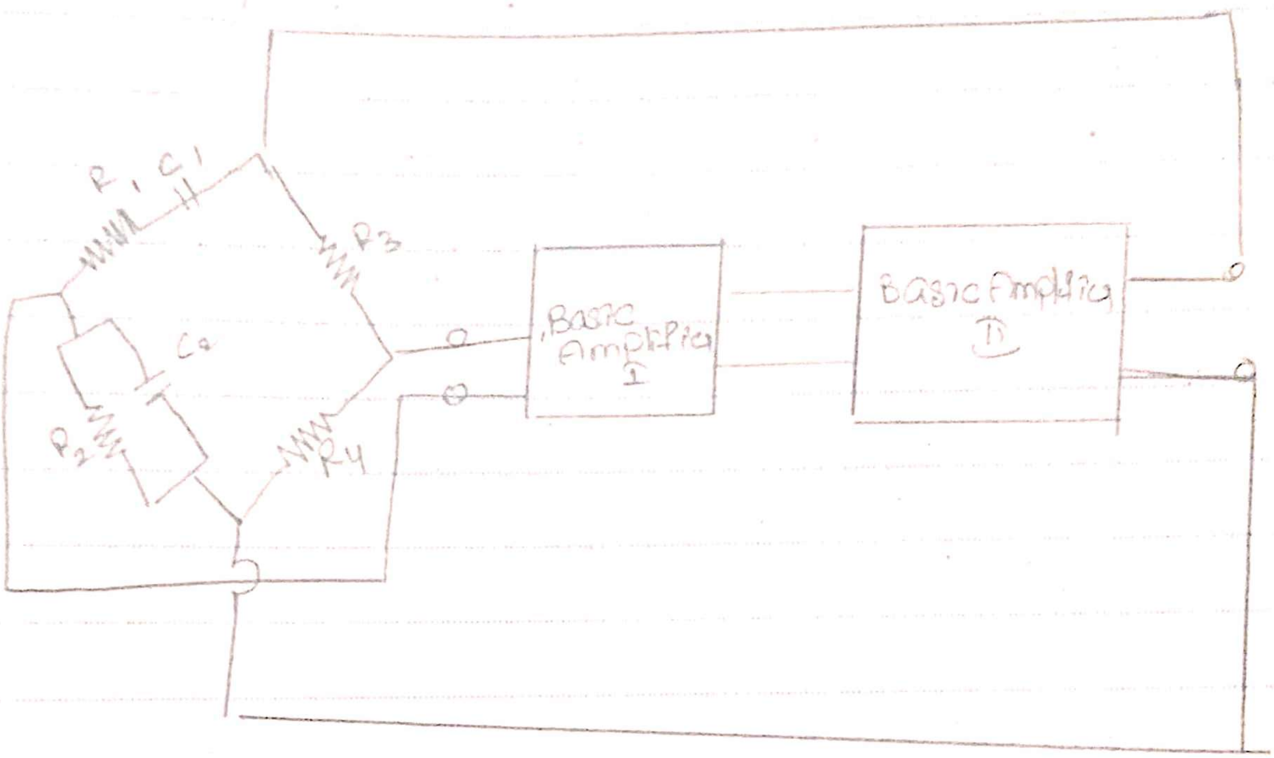
Q.No	Marks
1d	0

Q.No	Marks
1e	2

Q.No	Marks

f) Growing Oscillations.

Growing oscillations means wien bridg oscillator.



For the use of Evaluator Only

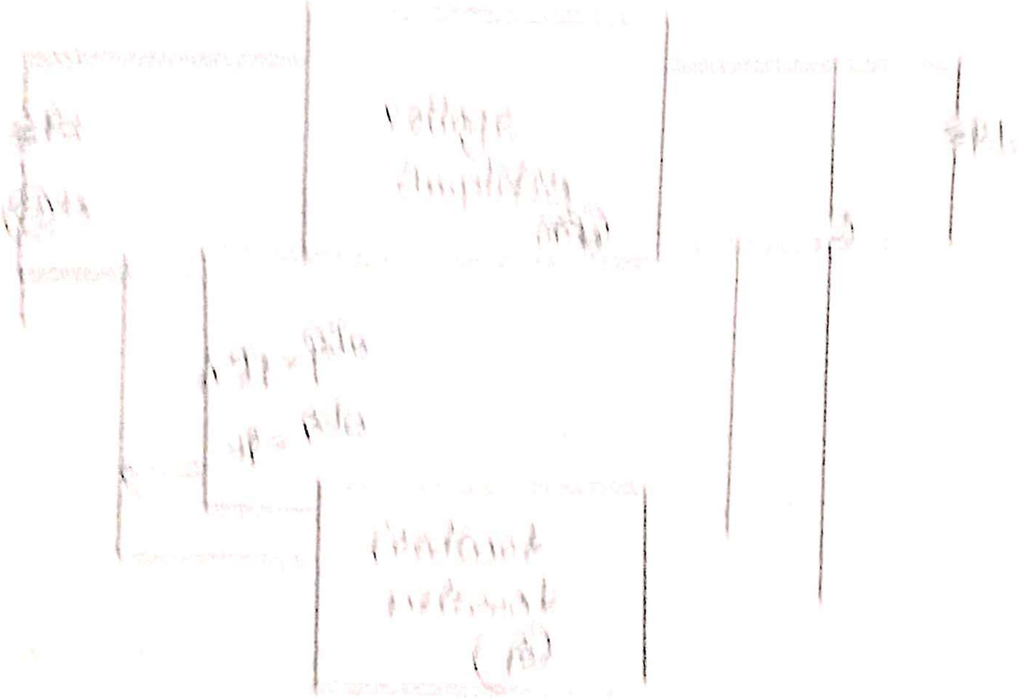
Q.No	Marks
1f	0

Q.No	Marks

Q.No	Marks

Q) Voltage series negative feedback

Voltage series negative feedback amplifier the basic amplifier is voltage series amplifier feedback network is a sampled.



For the use of Evaluator Only

Q No	Marks

Q No	Marks
19	1

Q No	Marks

For the use of Evaluator Only

Q.No	Marks

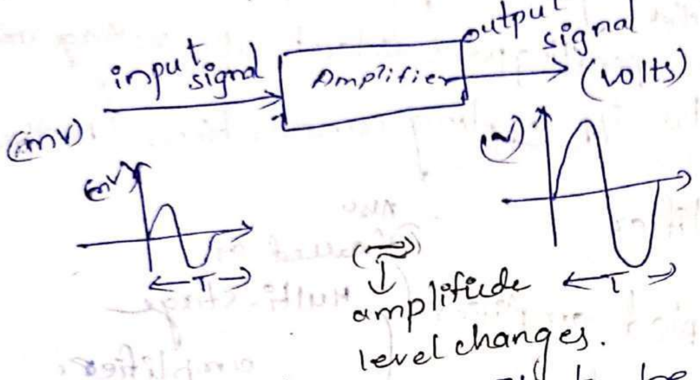
Q.No	Marks

Q.No	Marks

UNIT I - Small Signal Analysis of BJT & MOSFET

An amplifier is an electronic circuit which is used to strengthen | increase the voltage (or) current (or) power levels of the weak input signal without any change in input signal frequency & timeperiod.

Block Diagram:- of an Amplifier



→ The amplifier is said to be small signal ampli when i/p voltage is interms of (mV).

20HZ → 20KHZ → small signal

20KHZ → 20 MHZ → Radio frequency.

→ If we apply input signal in the range of (mV) then it is called small signal amplifier

→ If we apply i/p signal in range of (volts) then it is called large signal amplifier.

2M Classification of amplifiers:- (Based on diff categori

1) A/c to their frequency Range.
2) A/c to mode of operation.
3) Based on i/p coupling connection.
4) Based on o/p coupling connection.
5) Based on application of amplifier.

① A/c to frequency Range:-

Types
1) DC Amplifier (0 Frequency)(No Frequency).
2) Audio Amplifier (or) low frequency amplifier [20HZ → 20KH
3) Radio / High Frequency Amplifier [20KHZ → 2MHZ]

2,3,4 amplifiers are called AC amplifiers.

classification
→ A/c to Mode of Operation:-

a) class A amplifier — Transistor operation should select on Active Region)

op ~~select at~~ → cut~~off region~~

b) class B amplifier

OP Below $I_B=0$ and above voltage axis

c) class AB amplifier

} All are called as large signal (or) power amplifiers.

class B amplifier means operating point select at voltage axis

classification A/c to i/p coupling connection:- / Method of Coupling.

① RC coupled amplifier
② Transformer coupled amplifier
③ Direct coupled amplifier

} Also called as Multi-stage amplifier.

RC is best among three coupled circuits.

If input is given with the help of Resistor & capacitor, it is called as RC coupled amplifier.

similarly Transformer & direct amplifier

classification A/c to type of load:- (~~Application~~) o/p coupling.

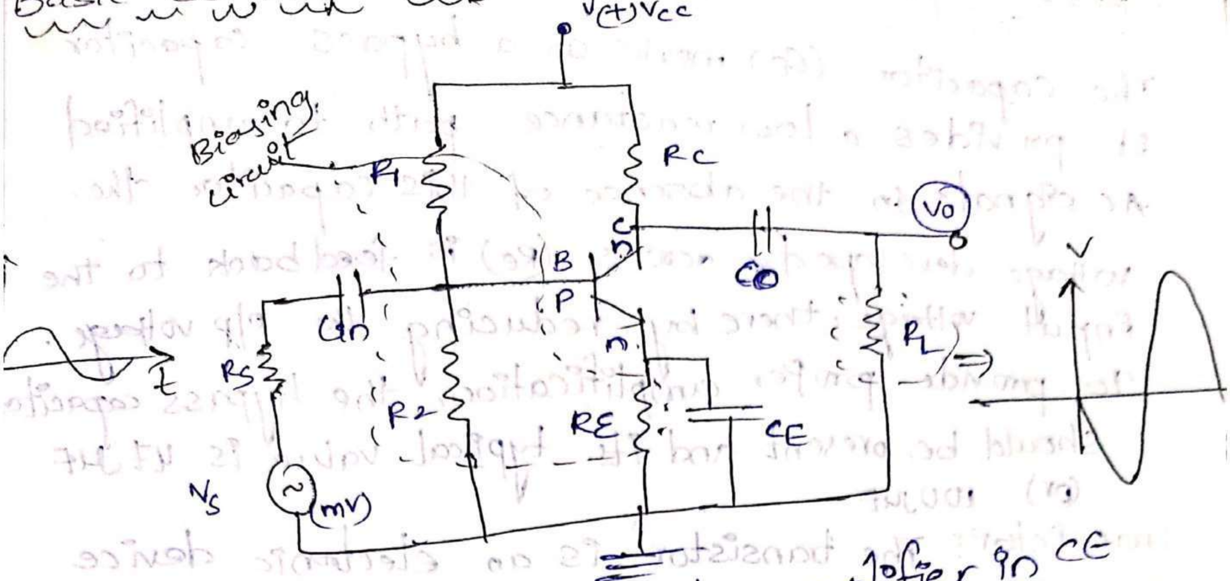
① Resistive load
② Inductive load.

classification A/c to application of amplifier:

ⓐ voltage amplifier → It amplifies voltage level
ⓑ current amplifier → It amplifies current level
ⓒ power amplifier → It amplifies both voltage & current
ⓓ Tuned amplifier → It amplifies single frequency.

When sudden change of range of frequencies, but o/p is constant then it is good amplifier.

Basic CE Amplifier :



Above fig. shows basic transistor amplifier in CE configuration with voltage divider (self Bias). The various circuit elements and their functions are described below :

Biasing circuit : The resistors R1, R2, RE are the elements which forms voltage divider bias. which provides stabilisations. (i.e, It sets the proper operating point which lies middle of the load line

2) Load Resistor (RL) : The resistance (RL) connected at o/p is known as load, when no. of stages are used, when RL represents i/p resistance of next stage

coupling capacitors : Here Cin, Co are called i/p & o/p coupling capacitors. This are used to pass/allow AC signal from one side to another side and blocks any dc signal. It means capacitors acts as open circuit for dc and short-circuit for AC.

and their typical values are 10μF.

4) **By pass capacitor CE**:- (To attain max o/p voltage levels(am

The capacitor (C_E) works as a bypass capacitor it provides a low reactance path to amplified AC signal. In the absence of this capacitor the voltage developed across (R_E) is feed back to the input voltage, there by reducing the o/p voltage. To provide proper amplification, the bypass capacito should be present and its typical value is 47μF (or) 100μF

Transistor:- The transistor is an electronic device which acts as an amplifier when it operates in Active region with proper biasing.

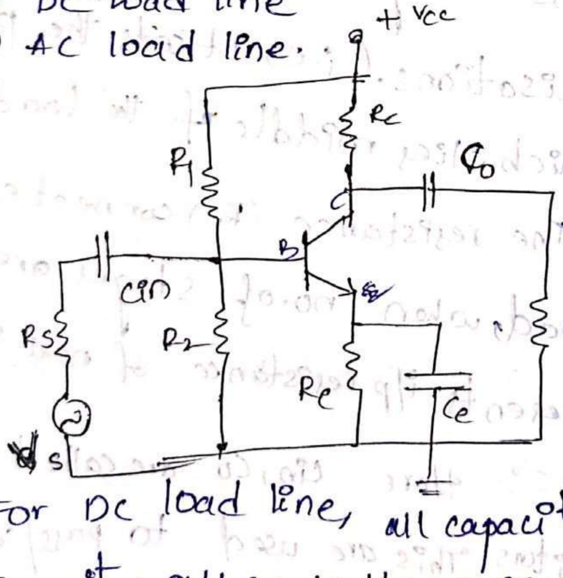
Load Line Analysis:-

Load line:-

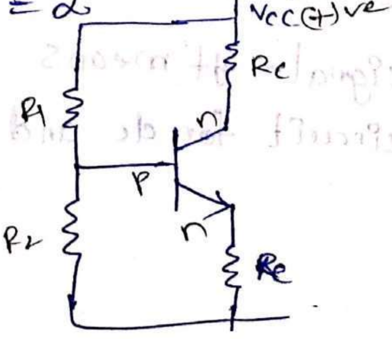
Load line is the line drawn on the o/p characteristics of a transistor by intersecting voltage & current axes.

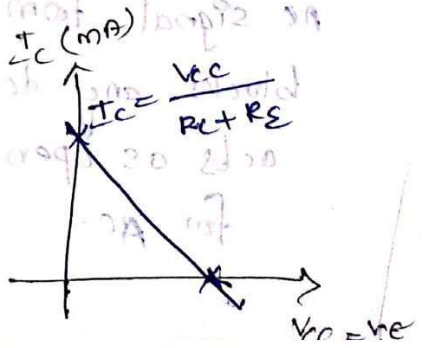
Types

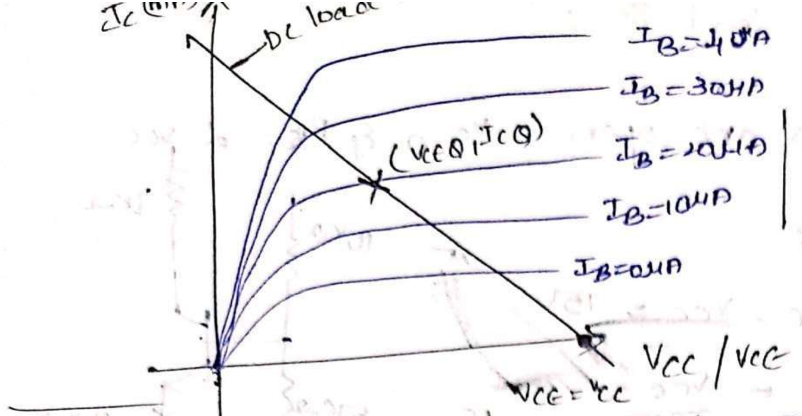
1) DC load line
2) AC load line.



For DC load line, all capacitors acts as open circuit, all ac voltages are short circuit and $R_L = \alpha$

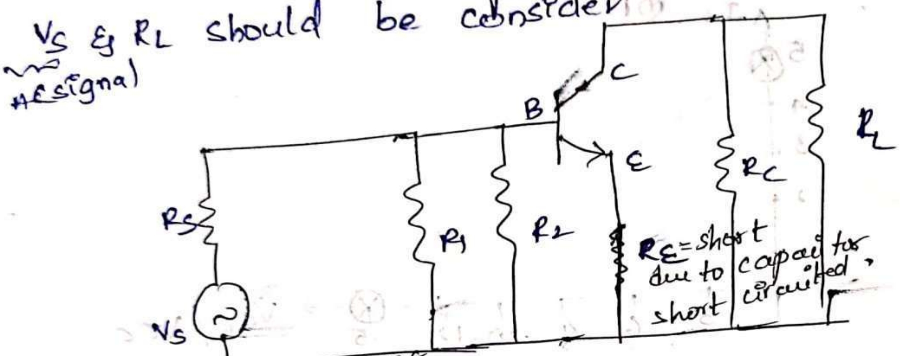


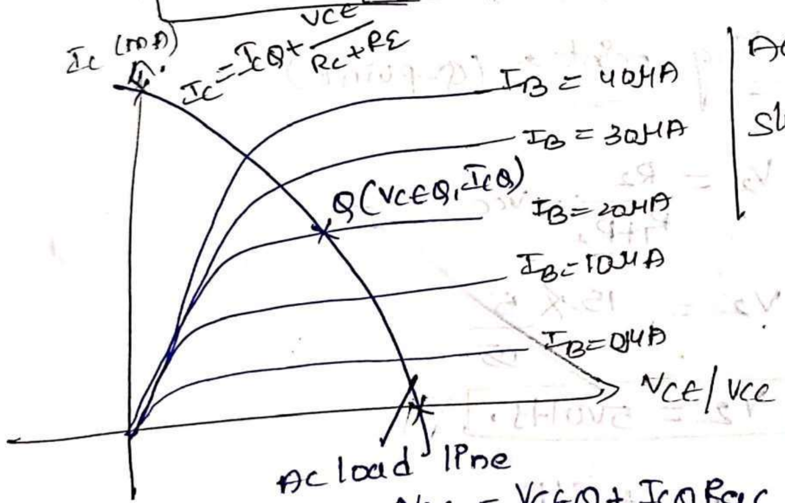




DC load line
slope = $-\frac{1}{R_C}$

To draw AC load line, all capacitors are short circuited, all DC voltages are short circuit and V_S & R_L should be consider
(AC signal)





AC
slope = $\frac{-1}{R_{ac}}$
$\downarrow$
$R_C || R_L$

$V_{CE} = V_{CEQ} + I_{CQ} R_{ac}$

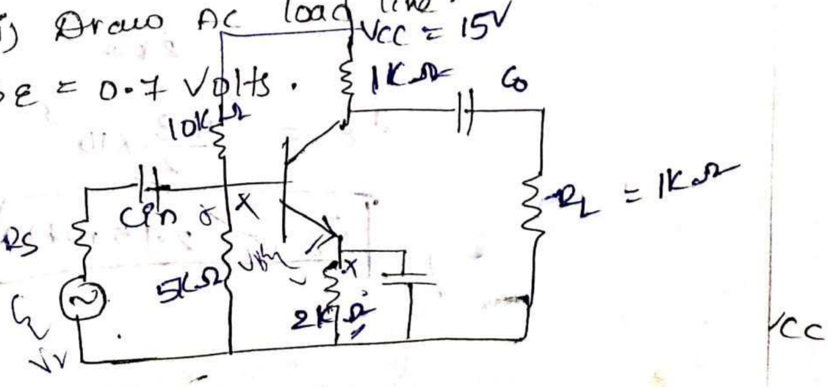
In A transistor amplifier shown in fig. $R_C = 1 K\Omega$, $R_E = 2K\Omega$, $R_1 = 10 K\Omega$; $R_2 = 5K\Omega$ and $R_L = 1K\Omega$

Draw the (i) DC load line

(ii) Determine Q-point

(iii) Draw AC load line. $V_{CC} = 15V$

Assume $V_{BE} = 0.7$ Volts.



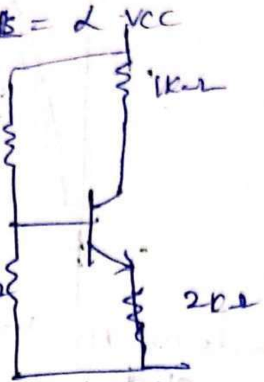
(i) To draw dc load line:

Capacitors are open $V_s = 0$ & $R_L = \propto$

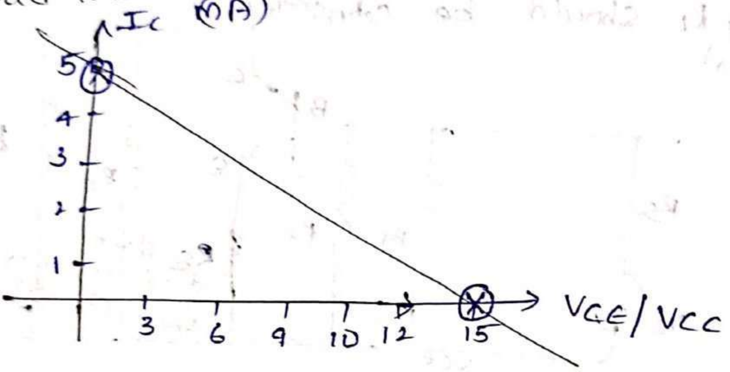
V_{CE}, I_C

Max $V_{CE} = V_{CC} = 15V$

Max $I_C = \frac{V_{CC}}{R_C + R_E} = \frac{15}{3} = 5mA$



Dc load line



(ii) operating point: (Q-point)

$$V_2 = \frac{R_2}{R_1 + R_2} \times V_{CC}$$

$$V_2 = 15 \times \frac{5}{\cancel{15}}$$

$$\boxed{V_2 = 5 \text{volts.}}$$

Apply KVL to i/p

$$-V_2 + V_{BE} + I_E R_E = 0$$

$$I_E R_E = +(V_2 - V_{BE})$$

$$I_E = \frac{5 - 0.7}{2k\Omega}$$

$$I_E = \frac{4.3}{2} \times 10^{-3}$$

$$\boxed{I_E = 2.15 mA}$$

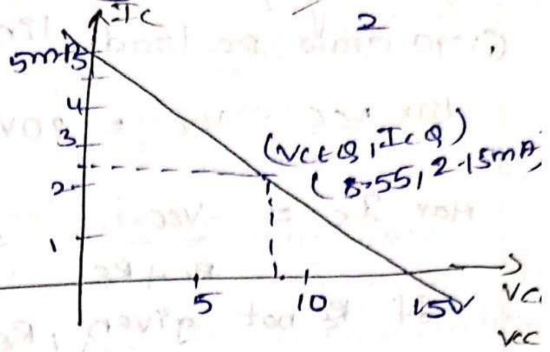
$V_{CEQ} = V_{CC} - I_{CQ}(R_C + R_E)$

$= 15 - 2.15\times10^{-3}[3\times10^{3}]$

$= 15 - 2.15 \times 3$

$= 15 - 6.45$

$\boxed{V_{CEQ} = 8.55V}$



(iii) To draw AC load line :-

Max $V_{CE} = V_{CEQ} + I_c R_{ac}$

$R_{ac} = R_C \| R_L$

$= \frac{1\times1}{2} = \frac{1}{2} = 0.5\,k\Omega$

$\boxed{R_{ac} = 0.5k\Omega}$

$V_{CE} = V_{CEQ} + I_{ac}R_{ac}$

$= 8.55 + 2.15\times10^{-3}\times0.5\times10^{3}$

$= 8.55 + 1.075$

$\boxed{V_{CE} = 9.625V}$

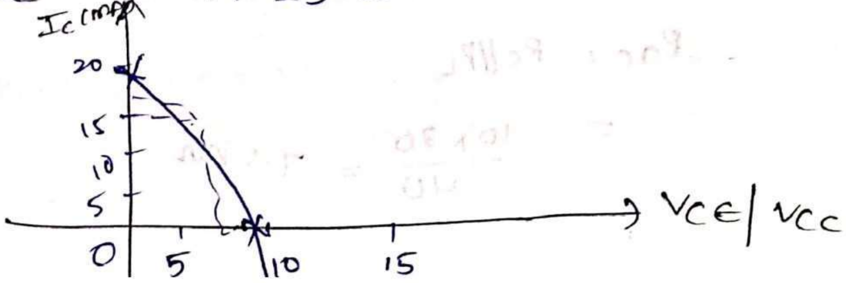
Max $I_c = I_{CEQ} + \frac{V_{CEQ}}{R_{ac}'}$

$= 2.15mA + \frac{8.55}{0.5\times10^{3}}$

$= 2.15mA + 0.017A$

$= 2.15mA + 17.1\,mA$

$I_c = 19.25\,mA$



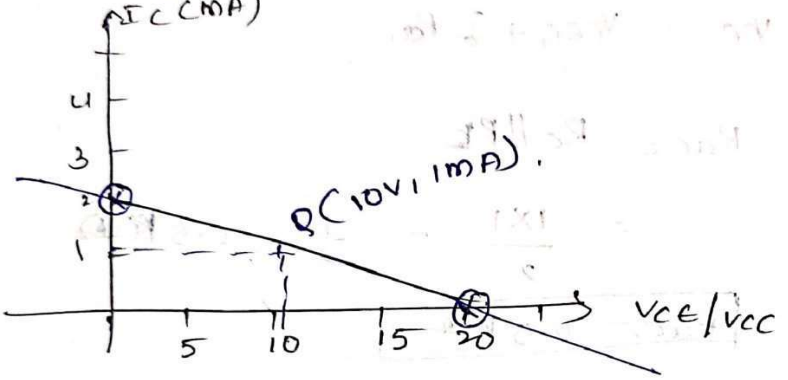
For Transistor amplifier $R_C = 10K\Omega$, $R_L = 30K\Omega$, $V_{CC} = 20V$ the values of R_1 & R_2 such that so as to fin the operating point (10V, 1mA), Draw DC & AC load line.

(i) To draw DC load line

$$\text{Max } V_{CE} = V_{CC} = 20V$$

$$\text{Max } I_C = \frac{V_{CC}}{R_C + R_E} = \frac{2\cancel{0}^{2}}{\cancel{10}K} = 2mA$$

If R_E not given, $R_E = 0$.



(ii) To draw AC load line.

$$\text{Max } V_{CE} = V_{CEQ} + I_{CQ} R_{ac}$$

$$R_{ac} = R_C \parallel R_L$$

$$= \frac{10 \times 30K\Omega}{(10+30)K\Omega} = \frac{30\cancel{0} \times 10^{6}}{4\cancel{0} \times 10^{3}} = 7.5\ K\Omega$$

$$V_{CE} = 10 + 1 \times 10^{-3} \times 7.5 \times 10^{3}$$

$$V_{CE} = 10 + 7.5$$

$$\boxed{V_{CE} = 17.5V}$$

$$I_c = I_{CEQ} + \frac{V_{CEQ}}{R_{ac}} = 1 \times 10^{-3} + \frac{10}{7.5K\Omega} =$$

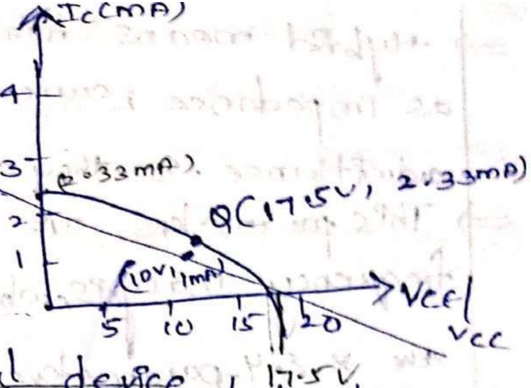
$$R_{ac} = R_C \parallel R_L$$

$$= \frac{10 \times 30}{40} = 7.5K\Omega$$

∴ For AC load line

$V_{CE} = 17.5V$

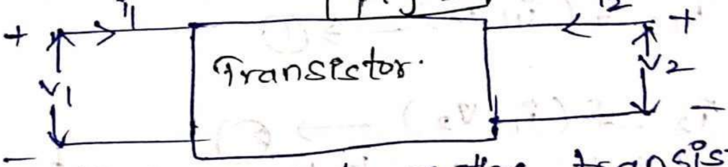
$I_C = 2.33 mA$.



Transistor is a three terminal device, but when it connects /configured to a circuit, it is a four pole n/w (or) 2-port network prrespective of its configuration.

Ex:- Considering a CB configuration, the emitter and base terminals may be regarded as i/p terminals, while the collector & base terminals regarded as o/p terminals.

Fig-1



The above figure shows the transistor as a four pole / two port network. The currents are taken as positive when they are enter into the transistor & (−)ve while they leave the tansistor.

→ The n/w behaviour is specified by V_1, I_1, V_2, and I_2 as external quantities.

→ Among these four variables, any two maybe selected as independent and the remaining two can be expressed as choosen dependent variables. This leads to various parameters, such as.

1) Impedance-parameters [z-parameters]

2) Admittance- parameters [y-parameters]

3) H-parameters (Hybrid).

Among three parameters, only h-parameters model is currently used for transistor circuit analysis.

⇒ Hybrid means mixed parameters/ dimensions such as impedance, current gain, voltage gain and admittance. So, they are called hybrid-parameters.

⇒ This parameters are very useful at low & high frequency analysis, whereas, at high frequencies, the Z & Y-parameters are complex. Hence they are not used.

In h-parameter model $\overbrace{i_1 \; \& \; v_2}^{\text{small letters only (AC analysis)}}$ are taken as independent variables while v_1 & i_2 are dependent variables.

~~(consider~~

$V_1 = f(i_1, V_2)$)

Based on above conditions.

$$V_1 = f(i_1, V_2) \longrightarrow ①$$

$$i_2 = f(i_1, v_2) \longrightarrow ②$$

By taking total differentiation we get

$$dv_1 = \frac{\partial v_1}{\partial i_1} di_1 + \frac{\partial v_1}{\partial v_2} dv_2 \longrightarrow ③$$

$$di_2 = \frac{\partial i_2}{\partial i_1} di_1 + \frac{\partial i_2}{\partial v_2} dv_2 \longrightarrow ④$$

For small signal AC analysis, we can operate the transistor in Active Region. (Linear region) which indicates change in voltages & currents are constant [i.e.) partial derivatives becomes constant].

$$V_1 = \overset{\text{constant notations.}}{h_{11}} i_1 + h_{12} V_2 \longrightarrow ⑤$$

$$i_2 = h_{21} i_1 + h_{22} V_2 \longrightarrow ⑥$$

Eqn ⑤ & ⑥ can be expressed in matrix form

$$\begin{bmatrix} V_1 \\ i_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} i_1 \\ V_2 \end{bmatrix} \longrightarrow ⑦$$

By appropriate choice of (i.e. $i=0$) & short circuit ($V=0$) applied to eqn ⑤ & ⑥, we can define small signal ac values of h-parameters

case 1:- If we short circuit the o/p terminals (i.e.) $V_2=0$

then eqn ⑤ becomes

$$V_1 = h_{11} i_1 + h_{12}(0)$$

$$V_1 = h_{11} i_1$$

$$\boxed{h_{11} = \frac{V_1}{i_1}}$$ input impedence. (ohm)

h_{11} is Ratio of input voltage to input current

then eqn ⑥ becomes

$$i_2 = h_{21} i_1 + h_{22}(0)$$

$$i_2 = h_{21} i_1$$

$$\boxed{h_{21} = \frac{i_2}{i_1}}$$ forward current gain

$h_{21} \equiv$ ratio of o/p current to i/p current.

Case-2:-

If the open circuit i/p terminals (i.e. $i_1=0$)

then eqn ⑤ becomes.

$$V_1 = h_{11}(0) + h_{12}(V_2)$$

$$V_1 = h_{12}(V_2)$$

$$\boxed{h_{12} = \frac{V_1}{V_2}}$$ → Reverse voltage gain.

|||ly:- eqn ⑥ becomes

$$i_2 = h_{21}(0) + h_{22} V_2$$

$$i_2 = h_{22} V_2$$

$$\boxed{h_{22} = \frac{i_2}{V_2}}$$ o/p admittance (mho)

h_{22} = Ratio of o/p current to o/p voltage.

Equivalent circuit of transistor to shown in fig-2

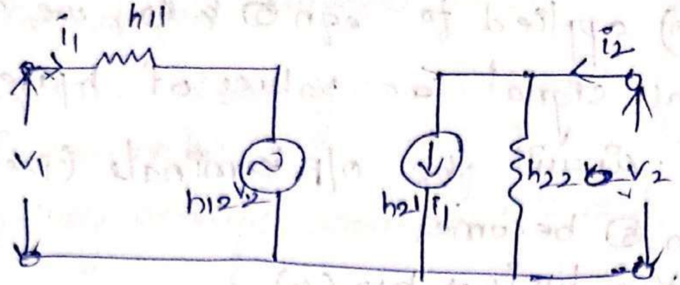


Fig-2

In the above fig, subscripts in 'h' are modify in different configurations of a transistor circui

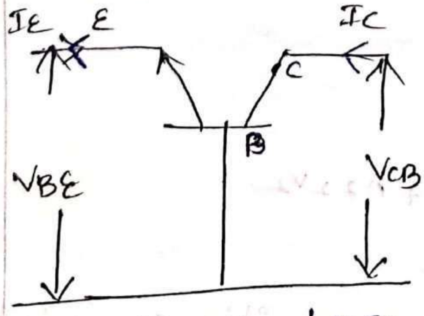
⇒ Here the first letter (h11) indicates whether the particular parameter is input, output, forw reverse, and 2nd letter(s) indicates transistor configuration such as CB, CE, CC

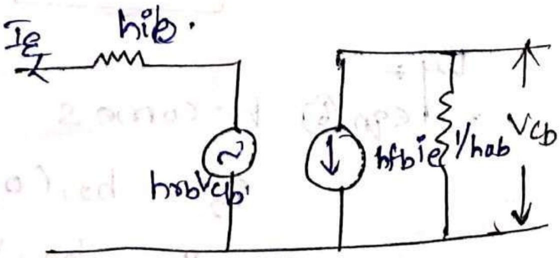
* For example, in case of common Base the hybr parameters used are hib, hFb, hrb, hob.

* Similarly for common emitter and Common coll the h-parameters are hie, hfe, hre, hoe and hic, hfc, hrc, hoc respectively.

* The transistor circuit in different configurati as shown in below.

Equivalent circuit

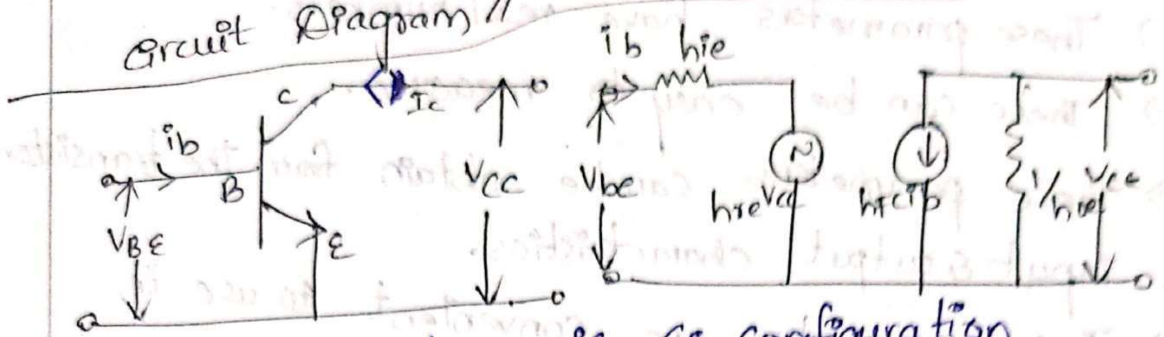




$$V_{be} = h_{ib}i_e + h_{rb}V_{cb}$$

$$i_E = h_{Fb}i_e + h_{ob}V_{bc}$$

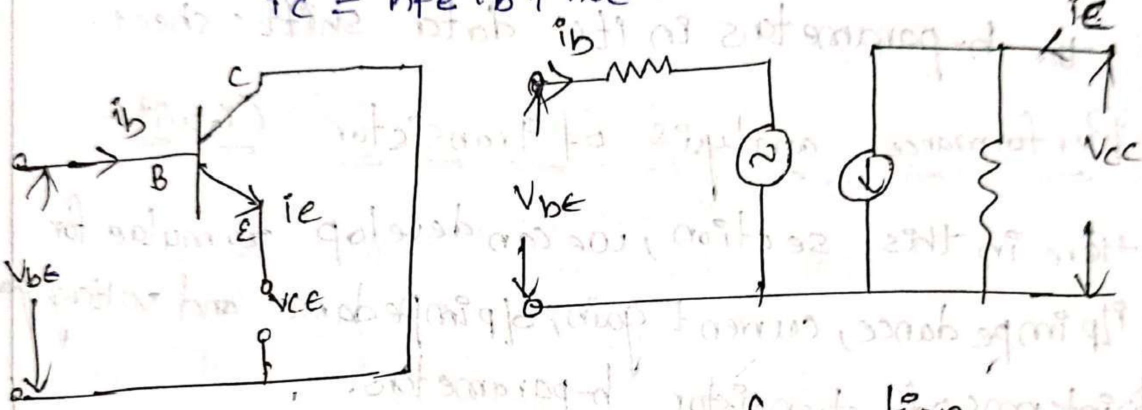
This common base configuration circuit & Equivalent circuit Diagram //



The above figure is CE configuration.

$$V_{be} = h_{ie} i_b + h_{re} V_{CE}$$

$$i_c = h_{fe} i_b + h_{oe} V_{ce}$$



Typical Values of CB configuration.

$h_{ib} = 20\Omega$ $h_{rb} = 2.9 \times 10^{-4}$

$h_{fb} = -0.98$ $h_{ob} = 0.49\ \mu A/V$

$= 0.49 \times 10^{-6}$ mho's

Typical values of CE configuration.

$h_{ie} = 1.1K\Omega$, $h_{fe} = 50$

$h_{re} = 2.5 \times 10^{-4}$, $h_{oe} = 25\mu/v$

$= 25 \times 10^{-6} A/V$

Typical values of CC configuration.

$h_{ic} = 1.\text{Q}K\Omega$ $h_{fc} = -51$

$h_{rc} = 1$ $h_{oe} = 25\mu A/V$

Advantages of h-parameters:- (AV) (or)

⇒ These parametors have real numbers.

⇒ These can be easy to measure.

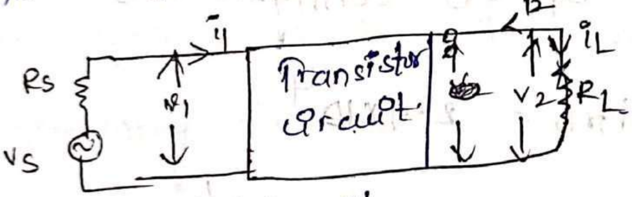
⇒ These parameters can be obtain from the transistor input & output characteristics.

⇒ These parameters are convenient to use in circuit analysis & design.

⇒ Most of the transistor manufactures specify the h-parameters in its data ~~sheet~~ sheet.

Performance analysis of Transistor Circuit:-

Here in this section, we can develop formulae for i/p impedance, current gain, o/p impedance and voltage gain interms of transistor h-parameters.



From above circuit,

$$V_1 = h_{11} i_1 + h_{12} V_2 \rightarrow ①$$

$$i_2 = h_{21} i_1 + h_{22} V_2 \rightarrow ②$$

$$i_L \text{ (or) } i_2 = \frac{-V_2}{R_L} \rightarrow ③ \text{ (opposite direction)}$$

(i) Input Impedance (Z_{in}) It is the ratio of input voltage to input current.

$$\boxed{Z_{in} = \frac{V_1}{i_L}} \rightarrow ④$$

Sub eqn ① in eqn ④

$$Z_{in} = \frac{h_{11} i_1 + h_{12} V_2}{i_1}$$

$$Z_{in} = h_{11} + h_{12} \frac{V_2}{i_1} \longrightarrow ⑤$$

From eqn ② & ③

$$\frac{-V_2}{R_L} = h_{21}i_1 + h_{22}V_2$$

$$h_{21}i_1 = -\frac{V_2}{R_L} - h_{22}V_2$$

$$h_{21}i_1 = -\left[V_2\left[\frac{1}{R_L} + h_{22}\right]\right]$$

$$\frac{V_2}{i_1} = \frac{-h_{21}}{\left(h_{22}+\frac{1}{R_L}\right)} \rightarrow ⑥$$

Sub $\frac{V_2}{i_1}$ in eqn ⑤

$$Z_{in} = h_{11} + h_{12}\left[\frac{-h_{21}}{h_{22}+\frac{1}{R_L}}\right]$$

$$\boxed{Z_{in} = h_{11} - \frac{h_{12}h_{21}}{h_{22}+\frac{1}{R_L}}} \rightarrow ⓐ$$

Current gain (A_I) :- It is the ratio of output current to i/p current. It is denoted by (A_I).

$$\boxed{A_I = \frac{i_2}{i_1}} \rightarrow ⑦$$

From ③, $V_2 = -i_2 R_L$

substitute (V_2) in eqn ②

$$i_2 = h_{21}i_1 + h_{22}(-i_2R_L$$

$$i_2 = h_{21}i_1 - h_{22}i_2R_L$$

$$i_2[1+h_{22}R_L] = h_{21}i_1$$

$$\frac{i_2}{i_1} = \frac{h_{21}}{(1+h_{22}R_L)}$$

$$\boxed{A_I = \frac{h_{21}}{((1+h_{22}R_L))}} \rightarrow ⓑ$$

Voltage gain (A_V) :- It is the ratio of o/p voltage to i/p voltage. It is denoted by (A_V).

$$\boxed{A_V = \frac{V_2}{V_1}} \rightarrow ⑧$$

From eqn ④

$$z_{in} = \frac{v_1}{i_1}$$

$$v_1 = z_{in} i_1$$

sub v_1 in eqn

$$A_v = \frac{v_2}{z_{in} i_1}$$

$$A_v = \frac{v_2}{i_1} \cdot \frac{1}{z_{in}} \rightarrow ⑨$$

substitute eqn ⑥ in eqn ⑨

$$\boxed{A_v = \frac{-h_{21}}{\left(h_{22}+\frac{1}{R_L}\right)} \cdot \frac{1}{z_{in}}} \rightarrow ⓒ$$

$$A_v = \frac{-h_{21}}{\left(h_{22}+\frac{1}{R_L}\right)} \cdot \frac{1}{\left(h_{11} - \frac{h_{21} h_{12}}{h_{22}+\frac{1}{R_L}}\right)}$$

<u>output</u> <u>Impedance</u> (Z_0): It is the ratio of o/p voltage to o/p current by setting i/p voltage [$V_s = 0$ & $R_L = \alpha$ (open) ⊛ Imp note].

$$\boxed{Z_0 = \frac{V_2}{i_2}} \rightarrow ⑩$$

From eqn ②

$$i_2 = h_{21} i_1 + h_{22} v_2$$

$$\frac{i_2}{v_2} = h_{21} \frac{i_1}{V_2} + h_{22} \rightarrow ⑪$$

From eqn ① $v_1 = 0$

$$h_{11} i_1 + h_{12} v_2 = 0$$

$$\frac{i_1}{V_2} = -\frac{h_{12}}{h_{11}} \rightarrow ⑫$$

sub eqn ⑫ in ⑪

$$\frac{i_2}{v_2} = h_{21}\left(\frac{-h_{12}}{h_{11}}\right) + h_{22}$$

$$\frac{i_2}{v_2} = -\frac{h_{12} h_{21}}{h_{11}} + h_{22}$$

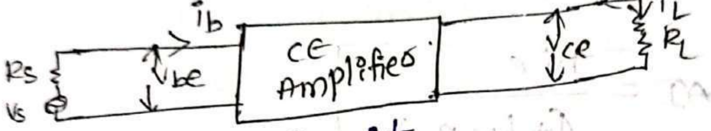
$$\frac{i_D}{V_2} = \frac{h_{11}h_{22} - h_{12}h_{21}}{h_{11}}$$

$$\boxed{Z_0 = \frac{h_{11}}{h_{11}h_{22} - h_{12}h_{21}}} \longrightarrow ⓓ$$

⇒ The above a, b, c and d represents the input impedance, current gain, voltage gain and output impedance of a transistor circuit using h-parameters.

Analysis of CE Amplifier:-

Consider a CE amplifier as shown in figure.



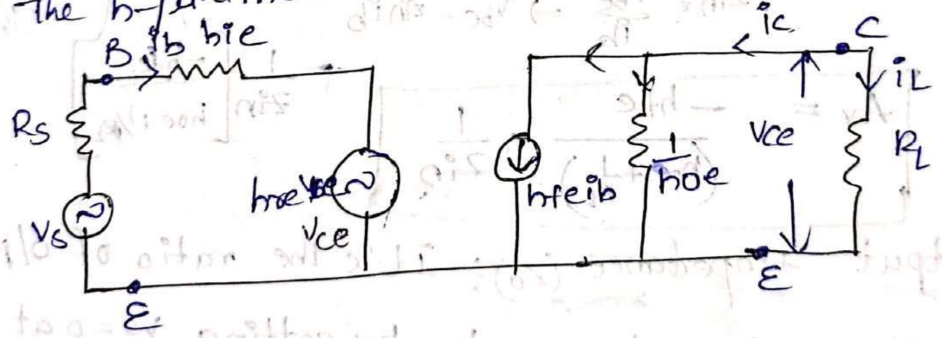
From above circuit

$V_{be} = h_{ie}i_b + h_{re}V_{ce} \rightarrow ①$

$i_c = h_{fe}i_b + h_{oe}V_{ce} \rightarrow ②$

$i_c = i_L = \frac{-V_{CE}}{R_L} \rightarrow ③$

The h-parameter transistor circuit (CE):



Input Impedance $\boxed{(Z_{in}) = \frac{V_{be}}{i_b}} \rightarrow ④$ It is the ratio of i/p voltage (V_{be}) to input current (i_b).

sub eqn ① in ④

$$Z_{in} = \frac{h_{ie}i_b + h_{re}V_{CE}}{i_b}$$

$$Z_{in} = h_{ie} + h_{re}\frac{V_{CE}}{i_b}$$

From eqn ② & ③

$$-\frac{V_{ce}}{R_L} = h_{fe} i_b + h_{oe} V_{ce}$$

$$\frac{V_{ce}}{i_b} = -\left[h_{fe} R_L + h_{oe} \frac{V_{CE}}{R_L}\right]$$

$$\frac{V_{ce}}{i_b} \quad \boxed{Z_{in} = h_{ie} \; h_{re}\left[\frac{h_{fe}}{h_{oe} + 1/R_L}\right]}$$

Current gain (A_I):- It is the ratio of o/p current (i_c) to input current (i_b)

$$A_I = \frac{i_c}{i_b}$$

$$\boxed{A_I = \frac{h_{fe}}{(1 + h_{oe} R_L)}}$$

Voltage gain (A_V):- It is the ratio of o/p voltage to o/p voltage.

$$A_V = \frac{V_{ce}}{V_{be}} = \frac{V_{ce}}{Z_{in} i_b} = \frac{1}{Z_{in}}\left[\frac{V_{ce}}{i_b}\right] = \frac{1}{Z_{in}}\left[\frac{-h_{fe}}{h_{oe} + 1/R_L}\right]$$

$$V_{ce} = h_{fe} i_b + h_{oe} V_{ce}$$

$$V_{ce}[1 + h_{oe}] = h_{fe} i_b$$

$$\frac{V_{ce}}{i_b} = \frac{h_{fe}}{1+h_{fe}}$$

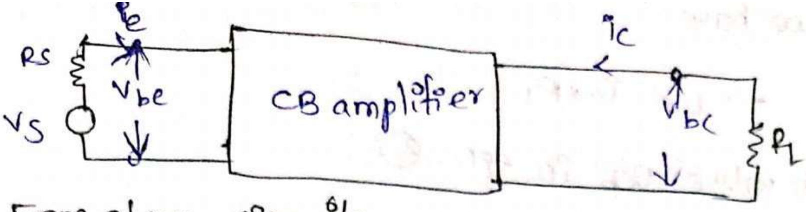
$$Z_{in} = \frac{V_{be}}{i_b} \Rightarrow V_{be} = Z_{in} i_b$$

$$\boxed{A_V = \frac{-h_{fe}}{\left(h_{oe} + \frac{1}{R_L}\right)} \cdot \frac{1}{Z_{in}}}$$

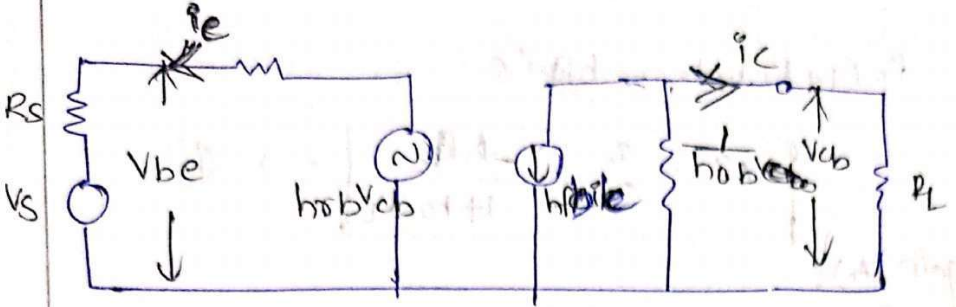
Output Impedance (Z_0):- It is the ratio of o/p voltage to o/p current by setting $V_S = 0$ at $R_L = \alpha$

$$Z_0 = \frac{V_{ce}}{I_C}$$

$$\boxed{Z_0 = \frac{h_{ie}}{h_{ie} h_{oe} - h_{re} h_{fe}}}$$



From above circuit



$$V_{be} = h_{ib} i_E + h_{rb} V_{cb} \rightarrow ①$$

$$i_C = h_{fb} i_E + h_{ob} V_{CB} . \rightarrow ②$$

$$i_C = -\frac{V_{cb}}{R_L} \rightarrow ③$$

Input Impedance :- (Zin)

$$Z_{in} = \frac{V_i}{i_1} = \frac{V_{be}}{i_e} \rightarrow ④$$

from eqn ①

$$Z_{in} = \frac{h_{ib} i_e + h_{rb} V_{cb}}{i_e} \rightarrow ⑤$$

Eqn ③ in eqn ⑤

$$-\frac{V_{cb}}{R_L} = h_{fe} i_c + h_{ob} V_{cb}$$

$$-h_{fe} i_e = h_{ob} V_{cb} + \frac{V_{cb}}{R_L}$$

$$i_e = -\frac{\left[h_{ob} V_{cb} + \frac{V_{cb}}{R_L} \right]}{h_{fe}}$$

$$\frac{i_e}{-V_{cb}} = \frac{h_{ob} + \frac{1}{R_L}}{h_{fb}}$$

$$-\frac{V_{cb}}{i_e} = \frac{h_{fb}}{h_{ob} + 1/R_L} \rightarrow ⑥$$

Sub eqn ⑥ in eqn ⑤

$$Z_{in} = \frac{h_{ib} i_e}{i_e} + h_{rb}\left(\frac{-h_{fb}}{h_{ob} + 1/R_L} \right)$$

$$\boxed{Z_{in} = h_{ib} - \frac{h_{rb} h_{fb}}{h_{ob} + 1/R_L}}$$

Current gain (A_I): $A_I = \frac{i_b}{i_1} = \frac{i_c}{i_e} \rightarrow$ ⑧

From eqn ③ we have

$$-V_{cb} = i_c * R_L$$

sub value V_{cb} in eqn ②

$$i_c = h_{fb} i_e + h_{ob}(-i_c R_L)$$

$$i_c(1 + R_L h_{ob} = h_{fb} i_e$$

$$\boxed{A_I = \frac{i_c}{i_e} = \frac{-h_{fb}}{1 + h_{ob} R_L}} \rightarrow ⑥$$

Voltage gain (A_V):

$$A_V = \frac{V_2}{V_1} = \frac{V_{cb}}{V_{be}} \rightarrow ⑨$$

From eqn

$$Z_{in} = \frac{V_{be}}{i_c}$$

$$V_{bc} = Z_{in} i_c$$

sub V_{bc} in eqn ⑨

$$A_V = \frac{V_{cb}}{Z_{in} i_c} = \frac{V_{cb}}{i_e}\left(\frac{1}{Z_{in}}\right) \rightarrow ⑩$$

sub eqn ⑥ in eqn ⑩

$$\boxed{A_V = +\left[\frac{h_{fe}}{h_{ob} + 1/R_L}\right]\left(1/Z_{in}\right)} \rightarrow ⓒ$$

Output Impedance (Z_0): $Z_0 = \frac{V_2}{i_2} = \frac{V_{cb}}{i_c} \rightarrow$ ⑪

from eqn ②,

$$i_c = h_{fe} i_e + h_{ob} V_{cb}$$

$$\frac{i_c}{V_{cb}} = \frac{h_{fe} i_e}{V_{cb}} + h_{ob}$$

$$\frac{i_c}{V_{cb}} = \frac{h_{fe} i_e + h_{ob} V_{cb}}{V_{cb}} \rightarrow ⑫$$

$$\frac{V_{cb}}{i_c} = \frac{V_{cb}}{h_{fe} i_e + h_{ob} V_{cb}}$$

from eqn ① $v_1 = 0$

$$V_{be} = 0$$

$$V_{be} = h_{ib} i_e + h_{rb} V_{cb}$$

$$h_{ib} i_e = -h_{rb} V_{cb}$$

$$\boxed{\frac{i_e}{V_{cb}} = \frac{-h_{rb}}{h_{ib}}} \rightarrow ⑬$$

sub eq ③ in eqn ②

$$\frac{i_c}{V_{cb}} = h_{fb}\left(\frac{i_e}{V_{cb}}\right) + h_{ob}$$

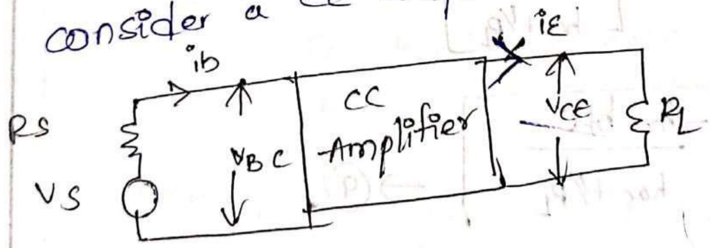
$$\frac{i_c}{V_{cb}} = h_{fb}\left(\frac{-h_{rb}}{h_{ib}}\right) + h_{ob}$$

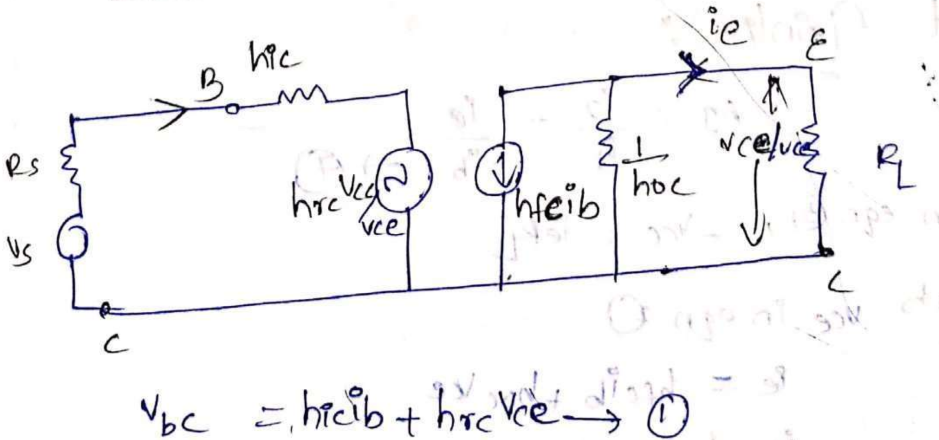
$$\frac{i_c}{V_{cb}} = \frac{-h_{rb}h_{fb} + h_{ib}h_{ob}}{h_{ib}}$$

$$\boxed{z_0 = \frac{V_{cb}}{i_c} = \frac{h_{ib}}{h_{ib}h_{ob} - h_{rb}h_{fb}}}$$

Analyses of CC Amplifier:-

consider a CC amplifier as shown in figure.





$$V_{bc} = h_{ic} i_b + h_{rc} V_{ce} \rightarrow ①$$

$$i_e = h_{fc} i_b + h_{oc} V_{ce} \rightarrow ②$$

$$i_2 = \frac{-V_2}{R_L} \qquad i_e = \frac{+V_{ce}}{R_L} \rightarrow ③$$

Input Impedance: (Zin)

$$Z_{in} = \frac{V_1}{i_1} = \frac{V_{bc}}{i_b} \rightarrow ④$$

from eqn ①

$$Z_{in} = \frac{h_{ic} i_b + h_{rc} V_{ce}}{i_b} \rightarrow ⑤$$

eqn ② = eqn ③

$$\frac{-V_{ce}}{R_L} = h_{fc} i_b + h_{oc} V_{ce}$$

$$-h_{fc} i_b = h_{oc} V_{ce} + \frac{V_{ce}}{R_L}$$

$$-i_b = \frac{h_{oc} V_{ce} + \frac{V_{ce}}{R_L}}{h_{fc}}$$

$$\frac{-i_b}{V_{ce}} = \frac{h_{oc} + \frac{1}{R_L}}{h_{fc}}$$

$$\boxed{\frac{V_{ce}}{i_b} = -\left[\frac{h_{fc}}{h_{oc} + 1/R_L}\right]} \rightarrow ⑥$$

sub. eqn ⑥ in eqn ⑤

$$Z_{in} = h_{ic} + h_{rc}\left[\frac{-h_{fc}}{h_{oc} + 1/R_L}\right]$$

$$\boxed{Z_{in} = h_{ic} - \frac{h_{rc} h_{fc}}{h_{oc} + 1/R_L}} \rightarrow ⑨$$

Current Gain (AI):

$$A_I = \frac{I_2}{I_1} = \frac{i_e}{i_b} \rightarrow ⑦$$

from eqn ③, $-V_{ce} = i_e R_L$

sub V_{ce} in eqn ②

$$i_e = h_{fc} i_b + h_{oc} V_{ce}$$

$$i_e = h_{fc} i_b + h_{oc}(-i_e R_L)$$

$$i_e(1 + h_{oc} R_L) = h_{fc} i_b$$

$$\frac{i_e}{i_b} = \frac{h_{fc}}{1+h_{oc}R_L} \rightarrow ⑥$$

$$\boxed{A_I = \frac{-h_{fc}}{1+h_{oc}R_L}} \rightarrow ⓑ$$

Voltage Gain: (Av): $A_V = \frac{V_2}{V_1} = \frac{V_{ce}}{V_{bc}} \rightarrow ⑨$

from eqn ①, $Z_{in} = \frac{V_{be}}{i_b}$.

$$V_{be} = Z_{in} i_b$$

sub V_{be} in eqn ⑨

$$A_V = \frac{V_{ce}}{Z_{in} i_b}$$

$$A_V = \frac{1}{Z_{in}}\left[\frac{V_{ce}}{i_b}\right] \rightarrow ⑩$$

sub eqn ⑥ in eqn ⑩

$$A_V = \frac{-h_{fc}}{h_{oc}+1/R_L}\left(\frac{1}{Z_{in}}\right)$$

$$\boxed{A_V = \frac{+h_{fc}}{Z_{in}[h_{oc}+1/R_L]}} \rightarrow ⓒ$$

Output Impedance: (Z0):

$$Z_0 = \frac{V_2}{i_2} = \frac{V_{ce}}{i_c} \rightarrow ⑪$$

from eqn ②

$$i_e = h_{fc} i_b + h_{oc}V_{ce}$$

$$\frac{i_e}{V_{ce}} = h_{fc}\left(\frac{i_b}{V_{ce}}\right) + h_{oc} \rightarrow ⑫$$

From eqn ①

$$V_{bc} = h_{ic} i_b + h_{rc}V_{ce}$$

$$0 = h_{ic} i_b + h_{rc}V_{ce}$$

$$-h_{ic} i_b = h_{rc}V_{ce}$$

$$\frac{i_b}{V_{ce}} = \frac{-h_{rc}}{h_{ic}} \rightarrow ⑬$$

sub ⑬ in ⑫

$$\frac{i_e}{V_{ce}} = h_{fc}\left[\frac{-h_{rc}}{h_{ic}}\right] + h_{oc}$$

$$\boxed{\frac{V_{ce}}{i_c} = Z_0 = \frac{h_{ic}}{h_{oc}h_{ic} - h_{rc}h_{fe}}} \rightarrow ⓓ$$

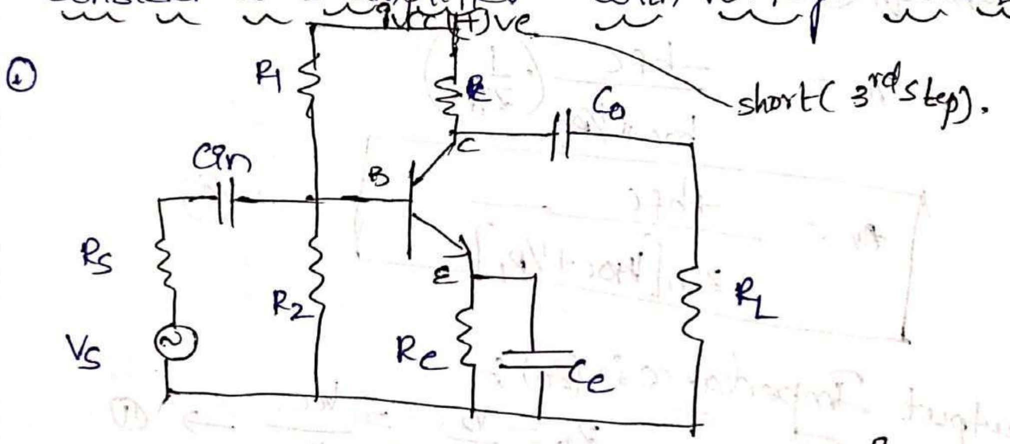
Guidelines of Analysis of CE (amplifier / Transistor ck

→ The analysis of transistor circuits for small signal behaviour can be made by following simple guidelines

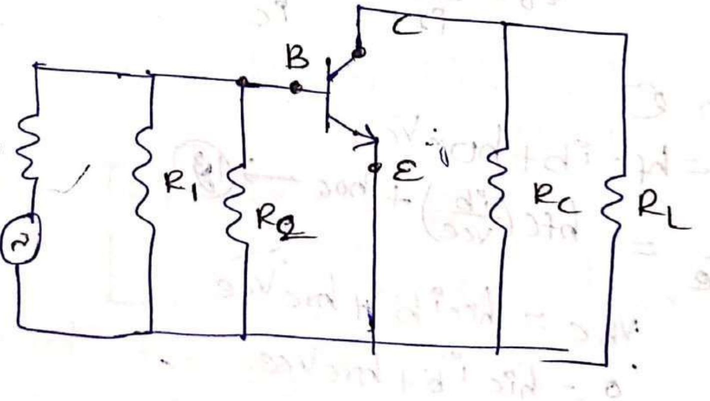
1) Draw the actual circuit diagram from given specification
2) Replace coupling & bypass capacitors as short circuit
3) Replace DC voltage source by a short circuit.
4) Make the points, C, B, E on a circuit diagram and locate this points as the start of the equivalent circuit.
5) Replace the transistor by its h-parameter model.

→ Consider a CE amplifier with voltage divider Bias:

①

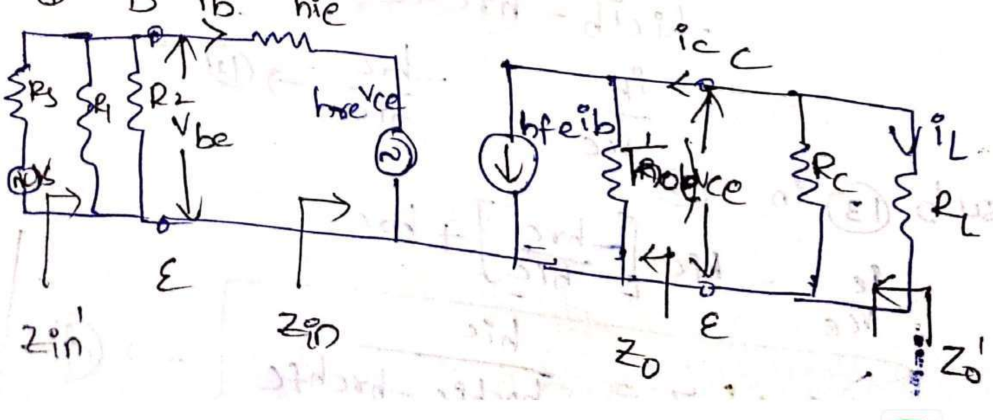


②



[where Rs = input
RL = o/p

④

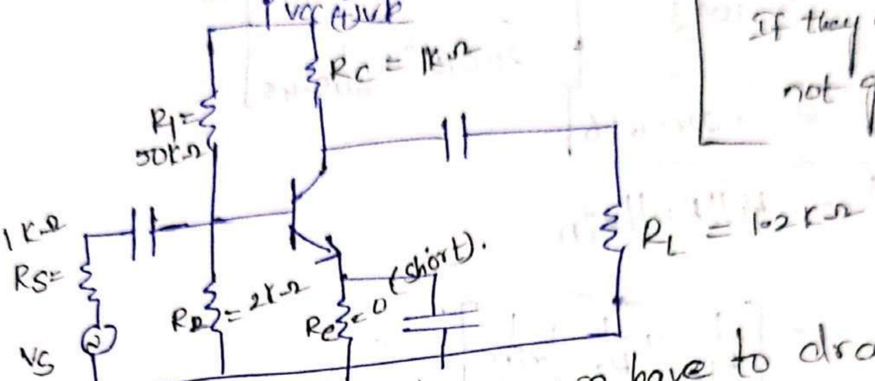


Problem: Consider a single stage CE amplifier with $R_S = 1K\Omega$; $R_1 = 50K\Omega$; $R_2 = 2K\Omega$, $R_C = 1K\Omega$, $R_L = 1.2K\Omega$

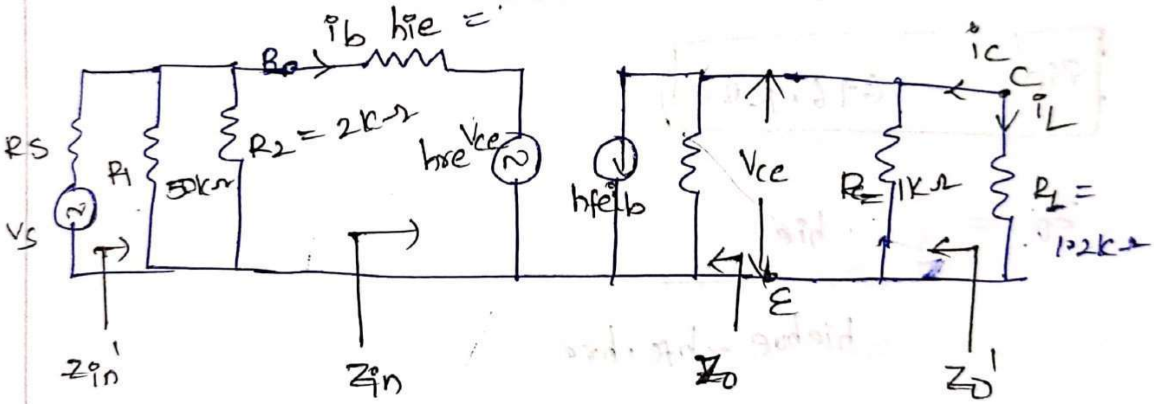
The typical values of h-parameters $h_{ie} = 1.1K\Omega$, $h_{fe} = 50$ $h_{re} = 2.5\times10^{-4}$ $h_{oe} = 25\,\mu A/v$. Calculate Z_{in}, Z_{in}', A_I, A_V, Z_0, Z_0', $A_{VS} = \frac{V_o}{V_S}$ and $A_{IS} = \frac{I_L}{I_S}$.

$$Z_{in} = h_{ie} - h_{re}\left[\frac{h_{fe}}{h_{oe} + 1/R_L}\right]$$

$R_E = 0$ [short If they are not given



with the help of Guidelines, we have to draw equivalent circuit with h-parameters. $\frac{10^6}{} \; 10^3$



Equivalent Load $R_L = R_C \| R_L$

$$= 1K\Omega \| 1.2K\Omega = \frac{(1\times1.2)\times10^6}{(1+1.2)10^3}$$

$$\boxed{R_L = 545.45\,\Omega}$$

$$Z_{in} = h_{ie} - h_{re}\left[\frac{h_{fe}}{h_{oe} + 1/R_L}\right] \quad (\text{total Equ } R_L$$

$$= 1.1K\Omega - 2.5\times10^{-4}\left[\frac{50}{25\times10^{-6} + \frac{1}{545.45}}\right]$$

$$\boxed{Z_{in} \simeq 1093.2735\,\Omega}$$

$$A_I = \frac{h_{fe}}{1+h_{oe}\overset{\text{equ } R_L}{R_L}} = \frac{50}{1+25\times10^{-6}\times545.45} = \boxed{49.327}$$

$$A_V = \frac{1}{Z_{in}}\left[\frac{-h_{fe}}{h_{oe}+\frac{1}{R_L}}\right] = \boxed{-24.616}$$

$$= \frac{1}{1093}\times\left[\frac{-50}{25\times10^{-6}+\frac{1}{545.45}}\right]$$

$$\boxed{A_V = -24.616}$$

$$Z_{in}' = R_1 \| R_2 \| Z_{in}$$

$$= \left[\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{Z_{in}}\right]^{-1}$$

$$= \frac{1}{50\times10^3}+\frac{1}{2k\Omega}+\frac{1}{1.093\times10^3}$$

$$\boxed{Z_{in}' = 696.9\Omega}$$

$$Z_0 = \frac{h_{ie}}{h_{ie}h_{oe}-h_{fe}\cdot h_{re}}$$

$$= \frac{1.1k\Omega}{(1.1k\Omega)(25\times10^{-6})-(50)(2.5\times10^{-4})}$$

$$= 73333.33$$

$$\boxed{Z_0 = 73.333k\Omega}$$

$$Z_0' = R_L \| Z_0 = 545.45 \| 73.333k\Omega$$

$$Z_0' = 541\Omega$$

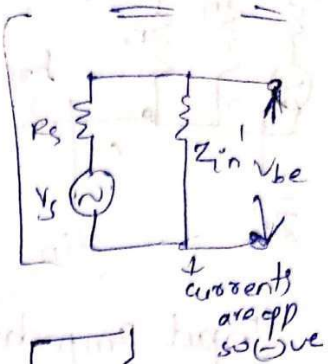
$$A_{VS} = \frac{V_o}{V_{s}} = \left(\frac{V_{ce}}{V_{be}}\right) \times \frac{V_{be}}{V_s} = A_V \times \frac{V_{be}}{V_s}$$

$$= A_V \times \frac{\bar{Z}_{in}}{\bar{Z}_{in}+R_s}$$

$$= -24.69 \times \frac{696.9}{696.9+1\times10^3}$$

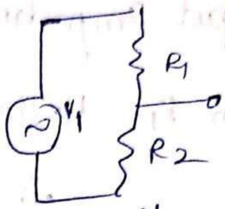
$$\boxed{A_{VS} = -10.107}$$

~~F~~ For i/p ckt

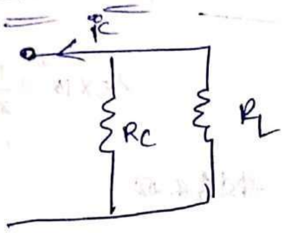


overall current gain.

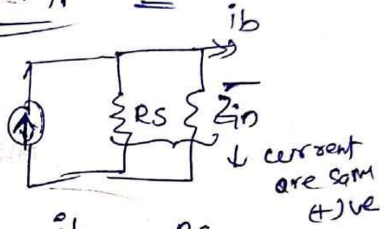
$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_C} \times \frac{I_C}{I_B} \times \frac{I_B}{I_S}$$



from o/p circuit:-



from i/p circuit



$$\frac{i_b}{i_s} = \frac{R_S}{R_S+\bar{Z}_{in}}$$

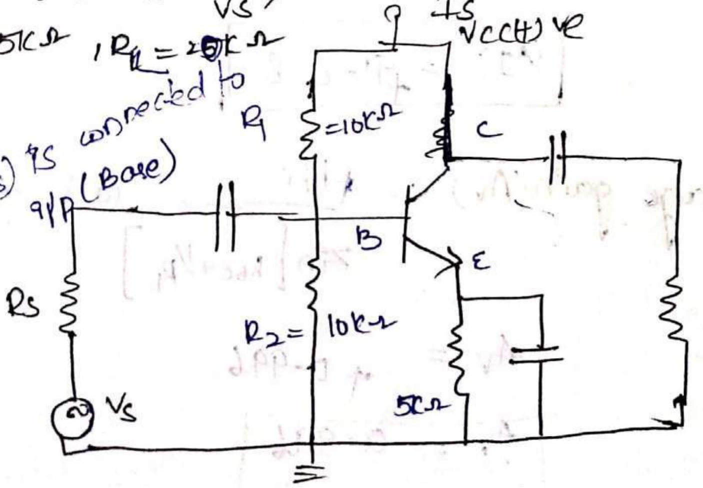
$$A_{IS} = \frac{-R_c}{R_c+R_L} * A_I * \frac{R_S}{R_S+\bar{Z}_{in}'} \Rightarrow -\frac{1\times10^3}{1\times10^3+1.2\times10^3} * 49.3 * \frac{1\times10^3}{1\times10^3+696.}$$

0.000522

$$\boxed{A_{IS} = -13.21}$$

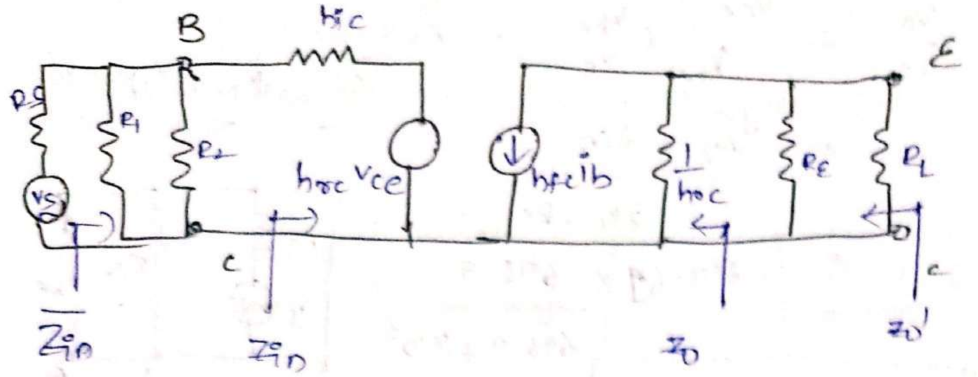
consider CC amplifier as shown in figure

The h-parameters of a transistor is hic = 1.2kΩ hfc = -101 hrc = 1 ; hoc = 25×10^{-6} A/V. Calculate Zin, $\bar{Z}_{in}$, AI, Zo, Zo', Avs = $\frac{V_o}{V_s}$; AIS = $\frac{I_L}{I_S}$, AV ? ; Rs = 1KΩ, R1 = 10KΩ = R2, RE = 5KΩ, RL = 25KΩ



Input (Rs) is connected to i/p (Base)

Load is connected across CE) so o/p is IE 25kΩ so it is CC amplifier



$$\text{Input Impedance } (Z_{in}) = h_{ic} - \frac{h_{rc}h_{fc}}{h_{oc} + 1/R_L}$$

$\underline{\underline{\text{Eqn}}}$ $R_L = R_E \| R_2 = 4K6\,\Omega$

$$\therefore Z_{in} = 1.2\times10^{3} + \frac{1\times101}{25\times10^{-6} + \frac{1}{\cancel{25\times10^{3}}\ 4\times10^{3}\,\Omega}}$$

~~$Z_{in} = 4468\,\Omega$~~

$Z_{in} = +368472$

$Z_{in} = 368472.723$

$$\boxed{Z_{in} = 368.472K\Omega}$$

$$\text{current Gain } (A_I) = \frac{-h_{fc}}{h_{oc}R_L + 1}$$

$$(A_I) = \frac{-(-101)}{(25\times10^{-6})(4\times10^{3}) + 1}$$

$$\boxed{(A_I) = +91.818}$$

$$\text{Voltage gain}(A_v) = \frac{+h_{fe}}{Z_{in}\left[h_{oc} + 1/R_L\right]} \text{ (or) } \frac{A_I R_L}{Z_{in}}$$

$A_v = +0.996$

$$\boxed{A_v = 0.996}$$

CB & CC A_I & A_v signs are same

For CC $A_v = (+)$
$A_I = (+)ve$

For CE = $A_v = (-)$
CE = A_I = (+)ve

For

$$\overline{Z_{in}} = R_1 \| R_2 \| Z_{in}$$

$$= 10k\Omega \,\|\, 10k\Omega \,\|\, 368.472 \times 10^{3}$$

$$\boxed{\overline{Z_{in}} = 4.93k\Omega}$$

$$Z_0 = \frac{h_{ic}}{h_{ic}h_{oc} - h_{fc}h_{rc}} = \frac{1.2 \times 10^{3}}{(1.2 \times 10^{3} \times 25 \times 10^{-6}) - (-101)(1)}$$

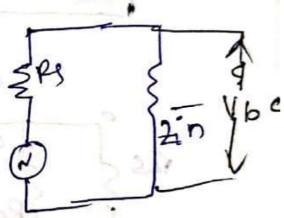
$$Z_0 = 11.87\,\Omega$$

$$Z_0' = R_L \| Z_0 = 4k\Omega \,\|\, 11.87\,\Omega$$

$$\boxed{Z_0' = 11.83}$$

$$A_{VS} = \frac{V_0}{V_S} = \frac{V_{CE}}{V_{bE}} \times \frac{V_{bc}}{V_S}$$

From i/p ckt



$$= A_V \times \frac{\overline{Z_{in}}}{\overline{Z_i} + R_s}.$$

$$= \frac{0.996 \times 4.93k\Omega}{(4.93k\Omega) + (1 \times 10^{3})}$$

$$\boxed{A_{VS} = 0.828}$$

From i/p & o/p circuit

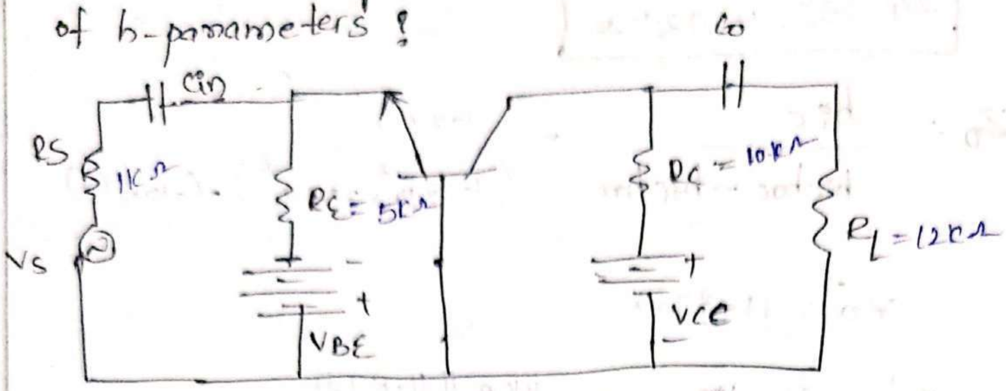
$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_E} \times \frac{I_E}{I_B} \times \frac{I_B}{I_S}$$

$$= \frac{R_E}{R_E + R_L} * A_I * \frac{R_S}{R_S + \overline{Z_{in}}}$$

$$= \frac{5 \times 10^{3}}{(5 \times 10^{3}) + (20k\Omega)} * 91.81 * \frac{1 \times 10^{3}}{(1 \times 10^{3}) + 4.93}$$

$$\boxed{A_{IS} = 3.096}$$

Consider CB amplifier with $R_E = 5K\Omega$, $R_C = 10K\Omega$ $R_S = 1K\Omega$, $R_L = 12K\Omega$. calculate the value of Z_{in}, A_I, A_V, Z_0 for the given circuit. Assume typical values of h-parameters ?



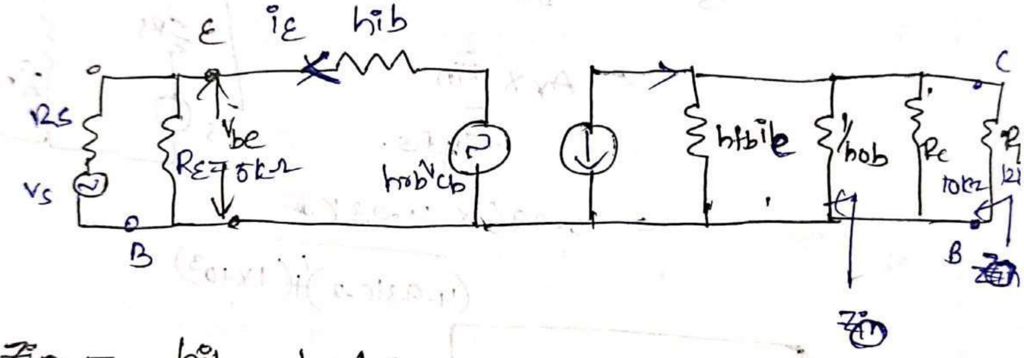
Typical Values of CB configuration

$h_{ib} = 20\Omega$ $h_{rb} = 2.9 \times 10^{-4}$

$h_{fb} = -0.98$ $h_{ob} = 0.49\,\mu A/V$

b. 2.5×10^{-4} in ce

h_{re}



$$Z_{in} = h_{ib} - \frac{h_{rb} h_{fb}}{h_{ob} + 1/R_L}$$

$h_{oe} = 25 \times 10^{-6}$
$= 0.000025$

R_L equivalent $= R_C \| R_L$

$= 10K\Omega \,\|\, 12K\Omega$

$= 5454\,\Omega$

$$\boxed{R_L = 5.454\,K\Omega}$$

$$Z_{in} = 20 - \frac{2.9 \times 10^{-4} \times (-0.98)}{0.49 \times 10^{-6} + \frac{1}{5.454 \times 10^{3}}}$$

$$\boxed{Z_{in} = 21.545\ \Omega}$$

$$\cancel{Z_{in}}' = R_E \| Z_{in}$$

$$= 5k\Omega \| 21.545$$

$$Z_{in}' = 21.452$$

current gain $(A_I) = \dfrac{-h_{fb}}{1 + h_{ob}R_L} = \dfrac{-0.98}{1 + 0.49\times10^{-6}\times5.454\times10^{3}}$

$$\boxed{A_I = +0.977}$$

voltage gain $(A_V) = \dfrac{+h_{fb}}{h_{ob} + \frac{1}{R_L}}\left(\dfrac{1}{Z_{in}}\right)$ (or) $\dfrac{A_I R_L}{Z_{in}}$

$$A_V = \frac{0.977\times5.45\times10^{3}}{21.545}$$

$$\boxed{A_V = 247.19}$$

output Impedance $(Z_0) = \dfrac{h_{ib}}{h_{ob}h_{ib} - h_{ob}h_{fb}}$.

$$Z_0 = \frac{20}{(20\times0.49\times10^{-6}) - ((-0.98\times2.9\times10^{-4})}$$

$$Z_0 = 68027.21$$

$$\boxed{Z_0 = 68.027\,k\Omega}$$

Overall o/p Impedance $Z_0' = Z_0 \| R_C \| R_L$

$$= 68.027k\Omega \| 10k\Omega \| 12k\Omega$$

$$= 5045.7$$

$$\boxed{Z_0' = 5.045\,k\Omega}$$

$$A_{vs} = \frac{V_o}{V_s} = A_v \times \frac{Z_{in}'}{Z_{in}' + R_s}$$

$$= 247.19 \times \frac{21.45}{21.45 + 1\times10^{3}}$$

$$\boxed{A_{vs} = 5.186}$$

$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_C} \times \frac{I_C}{I_E} \times \frac{I_E}{I_S}$$

$$A_{IS} = \frac{R_C}{R_C + R_L} \times A_I \times \frac{R_s}{R_s + Z_{in}}$$

$$\boxed{A_{IS} = 0.43476}$$

Analysis of Transistor Amplifier using Simplified/ Approximat Model:-

→ we have seen the exact calculations of the (Zo), Zin, Av, AI transistor amplifier circuits.

→ In most practical cases, it is approximate to obtain the approximate values of AI, Zin, Av and Zo rather than to carry out more lengthy exact calculations

→ Such an approximate model is justified (without) because h-parameters are not constant / steady but vary considerably for the same type of transistor

→ In h-parameters, the values of hre, hoe signifiance is negligible, because values are very very small.

→ The condition to go for the simplified model.

when do we use h-paramater simplified model / if $\boxed{hoe\ R_L < 0.1}$ then we can go otherwise do the exact Analysis.

Analysis of CE amplifier using simplified h-parameter model)

→ consider a CE amplifier in Exact model as shown in fig 1:

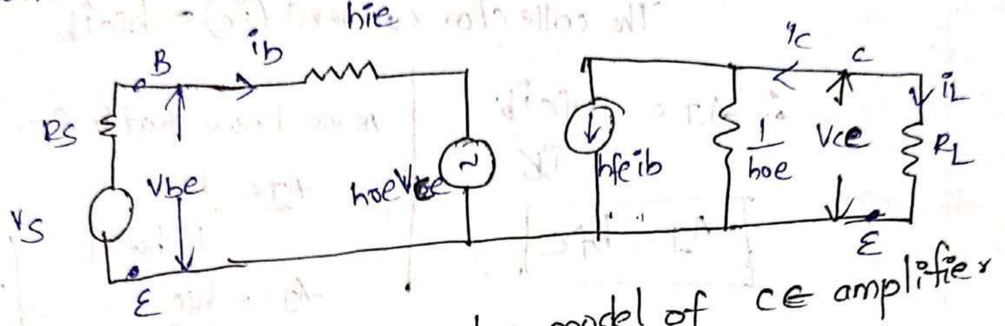


Fig1: Exact h-parameter model of CE amplifier

→ From the input, the value $\boxed{(hre\ \underbrace{Vce}_{=ic})} = hre(\underbrace{i_c R_L}) \quad |V_{CE}=I_C R_L$

$$hre\ V_{ce} = hre\ \underbrace{hfe\ ib}\ R_L \cong 0.001$$

→ When compared to hfeib the term hreVce is very small, so neglect hreVce

$$\frac{\overset{40}{100000}}{\cancel{25}}$$

From output circuit: $\boxed{\frac{1}{hoe} \parallel R_L \cong R_L}$

Ex: $\frac{1}{25\times10^{-6}} \parallel 10K\Omega \Rightarrow 40K\Omega \parallel 10K\Omega = \frac{\overset{8}{\cancel{40}}\times 1\cancel{0}}{\cancel{50}} = 8K\Omega \approx R_L$

Hence, neglect the term $\frac{1}{hoe}$ on output side.

With this Assumptions, the circuit (i.e Fig1) can be redrawn as Fig2:

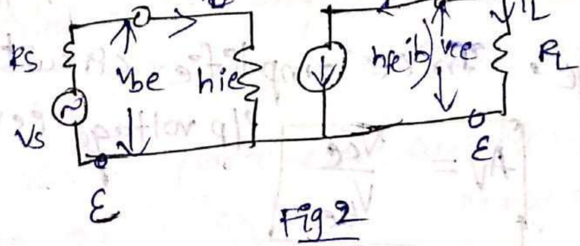


Fig 2

Simplified Model using h-parameters for CE amplifier.

Current Gain (AI): It is the ratio of output current to input current.

In CE, input current is i_b, and output current is i_c

$$\therefore \boxed{A_I = \frac{i_c}{i_b}}$$

From output circuit,

The collector current $(i_c) = h_{fe} i_b$

$$\therefore A_I = \frac{h_{fe}\cancel{i_b}}{\cancel{i_b}}$$

$$\boxed{A_I = h_{fe}}$$

As we know that in Exact model.

$$A_I = \frac{h_{fe}}{1 + h_{oe} R_L}$$

$$A_I = \frac{h_{fe}}{1+0} \quad \left| \because h_{oe} \ll \approx 0 \right.$$

$$\boxed{A_I = h_{fe}}$$

Input Impedance (Zin): It is the ratio of i/p voltage to i/p current. In CE amplifier.

$$\boxed{Z_{in} = \frac{V_{be}}{i_b}}$$

From i/p circuit:

$$V_{be} = h_{ie} i_b$$

$$\therefore Z_{in} = \frac{h_{ie}\cancel{i_b}}{\cancel{i_b}}$$

$$\boxed{Z_{in} = h_{ie}}$$

As we know that from exact Model:

$$Z_{in} = h_{ie} - \frac{h_{fe} h_{re}}{h_{oe} + 1/R_L}$$

$$Z_{in} = h_{ie} - \frac{0}{0} \quad \left[\begin{array}{l} h_{re} \approx 0 \\ h_{oe} \approx 0 \end{array} \right.$$

$$Z_{in} = h_{ie}$$

Voltage gain (Av): It is the ratio of o/p voltage to i/p voltage. In CE amplifier circuit o/p voltage is vce and i/p voltage is Vbe

$$\boxed{A_V = \frac{V_{ce}}{V_{be}}}$$

From o/p circuit:

$$V_{ce} = -i_c R_L$$

$V_{ce} = -h_{fe} i_b R_L$

From i/p circuit

$V_{be} = h_{ie} i_b$

$\therefore$ Voltage gain $(A_V) = \dfrac{-h_{fe} i_b R_L}{h_{ie} i_b}$

$$\boxed{A_V = \frac{-h_{fe} R_L}{h_{ie}}}$$

From Exact

$A_V = \dfrac{-h_{fe}}{h_{oe} + \frac{1}{R_L}} + \frac{1}{Z_i}$

$h_{oe} \simeq 0$

$A_V = \dfrac{-h_{fe} R_L}{R_L + 1} \; Z_i$

$A_V = \dfrac{-h_{fe} R_L}{h_{ie}}$

For CE only

$A_V = (-)$ve

output Impedance(Z_0) : It is the ratio of o/p voltage to o/p current.

$$Z_0 = \frac{V_{ce}}{i_c}$$

In CE amplifier, the o/p voltage is V_{ce} and o/p current is i_c

$\therefore Z_0 = \dfrac{V_{ce}}{i_c}$ | $v_s = 0$ (or) $V_{be} = 0$, $R_L = \alpha$

From o/p circuit

$V_{ce} = -i_c R_L$

$\therefore Z_0 = \dfrac{-i_c R_L}{i_c}$

$\boxed{Z_0 = -R_L}$ As $R_L \sim \alpha$

$\boxed{Z_0 = \alpha}$

(or) $V_{be} = 0$

$i_b = 0$

As $i_b = 0 \Rightarrow i_c = 0$

$\therefore \dfrac{V_{ce}}{0} = \alpha$

From Exact Model

$Z_0 = \dfrac{h_{ie}}{h_{ie} h_{oe} - h_{fe} h_{re}}$

$Z_0 = \dfrac{\cancel{h_{ie}}}{\cancel{h_{ie}} h_{oe}} = \dfrac{1}{h_{oe}}$, $h_{oe} = 0$

$\boxed{Z_0 = \alpha}$

Consider a CE amplifier with $R_S = 1K\Omega$, $R_1 = 50K\Omega$; $R_2 = 2K\Omega$; $R_C = 1K\Omega$; $R_L = 1.2K\Omega$. Transistor parameters are $h_{fe} = 50$. $h_{ie} = 1K\Omega$, $h_{oe} = 25 \times 10^{-6} A/V$. | $\because h_{re}$ is not given then it is simplified model.

condition is $h_{oe}R_L < 0.1$

$R_L = R_C || R_L$

$= 1K\Omega || 1.2K\Omega$

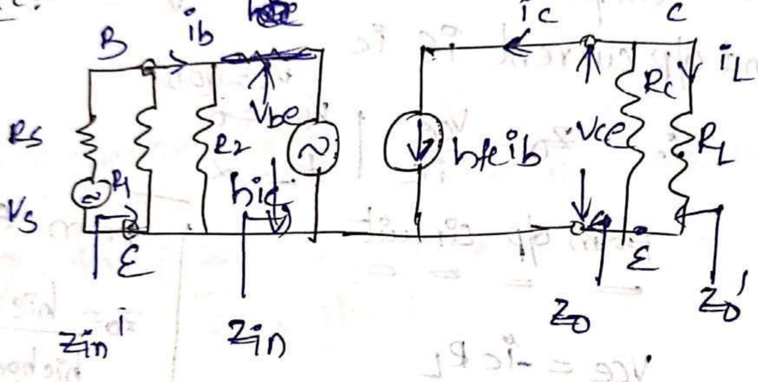
$R_L = 545.45\Omega$

∴ The condition for $h_{oe}R_L = 25\times10^{-6} \times 545.45$

$= 0.013 < 0.1$

So as $h_{oe}R_L < 0.1$ use simplified Model

Circuit:



Input Impedance: (Zin):

$Z_{in} = h_{ie}$

$Z_{in} = 1.1K\Omega$

overall i/p Impedance (Z_{in}'):

$Z_{in}' = Z_{in} || R_1 || R_2$

$50 || 2K\Omega || 1.7K\Omega$

$Z_{in}' = 699.7455\Omega$

Current gain (AI):

$(A_I) = h_{fe}$

$A_I = 50$

voltage gain (A_V) = $\frac{V_{ce}}{V_{be}}$

$$A_V = \frac{-h_{fe}R_L}{h_{ie}} = -\frac{50 \times 545.45}{1.1 \times 10^3}$$

$$\boxed{A_V = -24.793}$$

output Impedance $\boxed{(Z_0) = \alpha}$

$$Z_0' = Z_0 \parallel R_L = R_C \parallel R_L$$

$$= \frac{1}{\alpha} \parallel 1.2\,k\Omega$$

$$= \frac{1}{\alpha} \parallel \frac{1}{\text{[illegible]}}$$

$$= \frac{1}{545.45\,\Omega} + 0$$

$$= 0.00183$$

$$\boxed{Z_0' = \frac{1}{1.83} = 545.45\,\Omega}$$

$$A_{VS} = \frac{V_o}{V_S} = A_V \times \frac{Z_{in}'}{Z_{in}' + R_S}$$

$$= \frac{-24.793 \times 699.745}{699.745 + 1 \times 10^3}$$

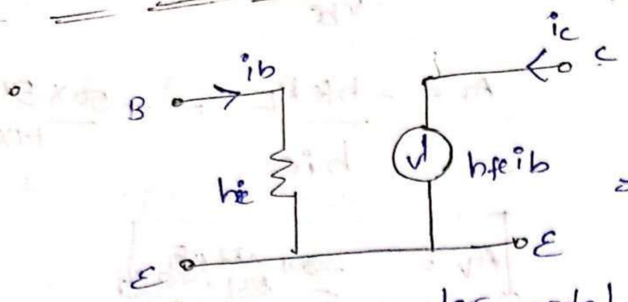
$$= 10.206$$

$$A_{IS} = \frac{I_L}{I_S} = \frac{-R_C}{R_C + R_L} \times A_I \times \frac{R_S}{R_S + Z_{in}}$$

$$= \frac{-1 \times 10^3}{1 \times 10^3 + 1.2 \times 10^3} \times 50 \times \frac{1 \times 10^3}{1 \times 10^3 + 699.745}$$

$$A_{IS} = -13.37$$

Generalised Approximate Model of a Transistor :-



⟹

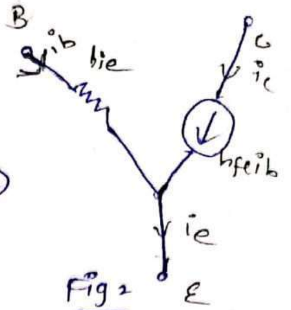


Fig 2

Generalised simplifier h-parameter of a transistor

Fig 1 :- simplified h-parameter model of CE amplifier & redrawn as fig ② :-

→ This model can be used for any configuration by simple grounding the appropriate terminal.

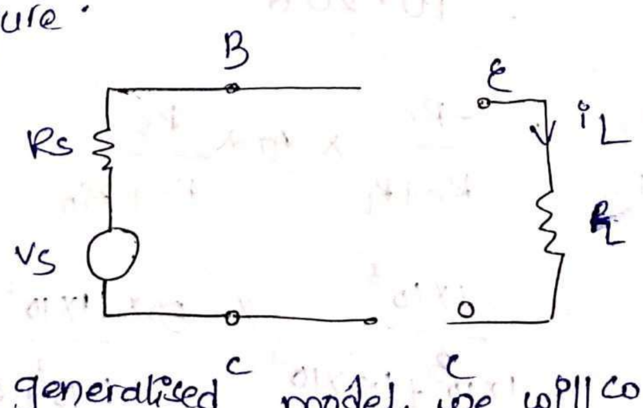
→ In this model, the i/p signal is always applied b/n i/p terminal and ground while the load resistor (R_L) is connected b/n output terminal & ground.

Analysis of CC Amplifier using simplified Model :-

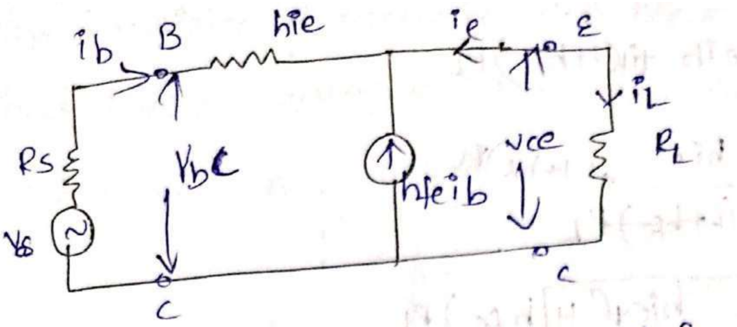
⟹ As we know that in CC, the i/p voltage is connected b/n i/p signal is connected b/n base terminal to collector terminal and the load resistor (R_L) is connected b/n emitter to collector.

⟹ From generalised approximate model, the equivalent circuit of cc amplifier is shown in figure.

⟹



From generalised model, we will connected from Base terminal (hie) is connected and for collector terminal (hfe ib) is connected.



Current Gain (AI) :- In CC, amplifier, the o/p current is i_E and i/p current is i_b

$$\boxed{A_I = \frac{i_e}{i_b}}$$

From o/p circuit

$$i_e = i_b + h_{fe} i_b$$

$$i_e = i_b(1 + h_{fe})$$

$$\therefore \boxed{A_I = 1 + h_{fe}}$$

Voltage Gain (Av) :- In CC amplifier, o/p voltage is V_{CE} and i/p voltage is V_{bc}.

$$\therefore A_V = \frac{V_{ce}}{V_{bc}} = A_I \times \frac{R_L}{Z_{in}}$$

$$A_V = (1 + h_{fe}) \frac{R_L}{h_{ie} + (1 + h_{fe}) R_L}$$

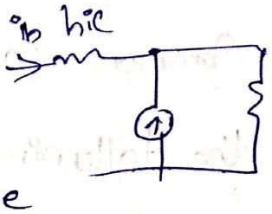
$Z_{in} >> h_i$
$\frac{h_{ie}}{Z_{ie}} << 1$

$$A_V = \frac{(1 + h_{fe}) R_L + h_{ie} - h_{ie}}{h_{ie} + (1 + h_{fe}) R_L} = 1 - \frac{h_{ie}}{(1 + h_{fe}) R_L}$$

$$\boxed{A_V \cong 1}$$

Input Impedance (Z_{in}) :- In CC amplifier input voltage is V_{bc} and i/p current is i_b

$$\therefore \boxed{Z_{in} = \frac{V_{bc}}{i_b}}$$



From i/p circuit

$$V_{bc} = i_b h_{ie} + V_{be}$$

$$V_{bc} = h_{ie} i_b + i_e R_L$$

$V_{bc} = h_{ie} i_b + i_b(1+h_{fe})R_L$

$$\frac{V_{bc}}{i_b} = \frac{h_{ie}}{\cancel{(1+h_{fe})}R_L} + (1+h_{fe})R_L$$

$$\boxed{Z_{in} = \frac{h_{ie} + (1+h_{fe})R_L}{\cancel{(1+h_{fe})R_L}}}$$

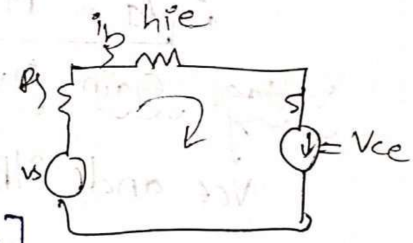
Output Impedance (Z_o): In CC amplifier, o/p voltage is V_{ce} and O/p current is i_e

$$\therefore Z_o = \frac{V_{ce}}{i_e}$$

$\because V_s = 0$ (or) $V_{bc} = 0$. $R_L = \infty$.

From i/p circuit:

$V_s = R_s i_b + h_{ie} i_b + V_{ce}$. | KVL to i/p loop

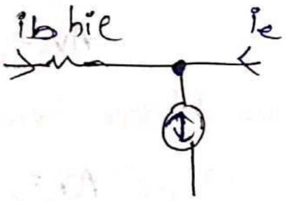


put $V_s = 0$

$V_{ce} = -[R_s i_b] - h_{ie} i_b$.

$V_{ce} = -[i_b(R_s + h_{ie})]$

From o/p circuit:



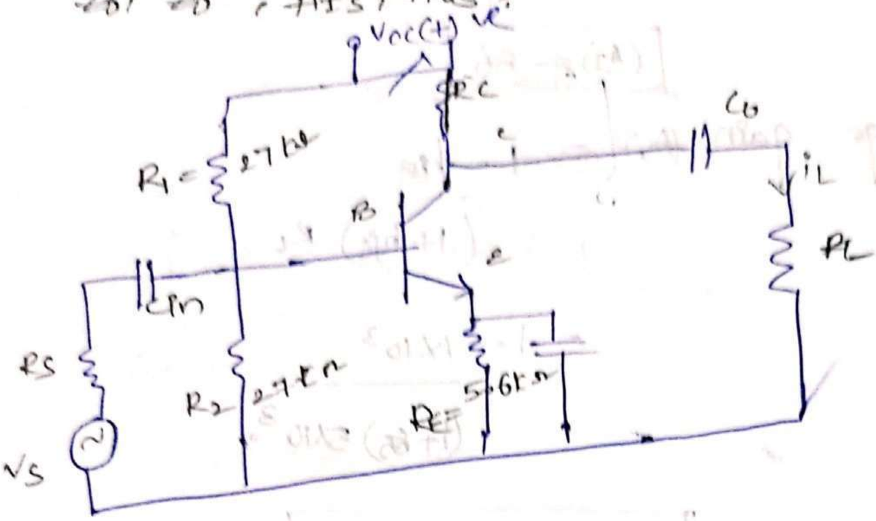
$i_E = i_b(1+h_{fe})$

$$Z_o = \frac{-V_{ce}}{i_e} = \frac{i_b(R_s + h_{ie})}{i_b(1+h_{fe})}$$

$$Z_o = \frac{R_s + h_{ie}}{(1+h_{fe})}$$

Common Collector Amplifier (emitter follower) is considered as the following components, $R_1 = 27k\Omega$, $R_2 = 27k\Omega$, $R_e = 5.6k\Omega$, $R_L = 47k\Omega$, $R_s = 400\Omega$.

The transistor parameters are hie = 1kΩ, hfe = 85 and hoe = 2μA/V. Calculate A_I, Z_{in}, Z_{in}', A_V, Z_o, Z_o', A_{IS}, A_{VS}?



$$R_L = R_E \parallel R_L$$

$$= 5.6k\Omega \parallel 47k\Omega$$

$$= \frac{(5.6 \times 47) \times 10^6}{(5.6+47) \times 10^3}.$$

$$\boxed{R_L = 5.003k\Omega}$$

The condition is $h_{oe}R_L = 2 \times 10^{-6} \times 5.003 \times 10^{3}$

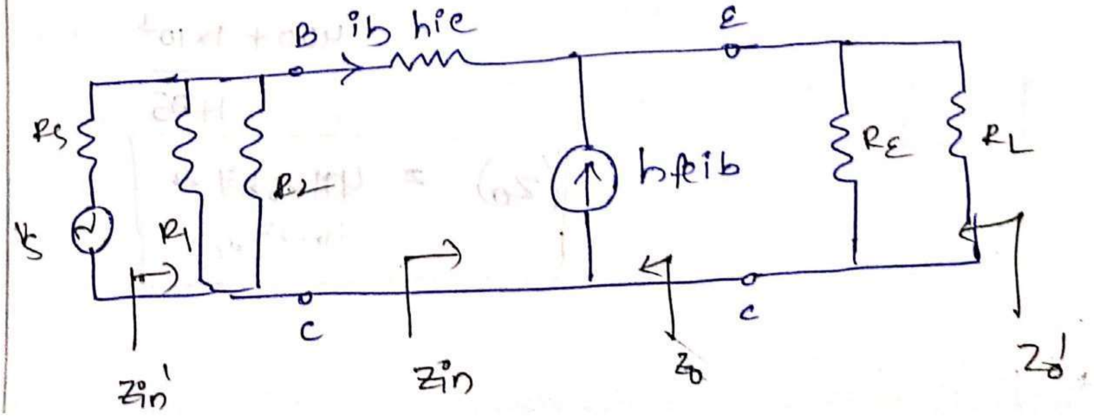
$$= 10.003 \times 10^{-3}$$

$$= 0.010$$

$$\boxed{h_{oe}R_L = 0.01 < 1}$$ so simplified

if $h_{oe}R_L > 1$ then Exact.

Draw Equivalent circuit:



current gain $(A_I) = 1 + h_{fe}$

$= 1 + 85$

$$\boxed{(A_I) = 86}$$

voltage gain $(A_V) = 1 - \frac{h_{ie}}{(1+h_{fe}) R_L}$

$= 1 - \frac{1 \times 10^3}{(1+85) 5 \times 10^3}$

$$\boxed{A_V = 0.9976}$$

Input Impedance $(Z_{in}) = h_{ie} + (1+h_{fe}) R_L$

$= 1 \times 10^3 + (1+85) 5 \times 10^3$

$$\boxed{Z_{in} = 431 K\Omega}$$

$Z_{in}' = R_1 || R_2 || Z_{in}$

$= \frac{1}{27} + \frac{1}{27} + \frac{1}{431 \times 10^3}$

$$\boxed{Z_{in}' = 13.499 K\Omega}$$

output Impedance $(Z_0) = \frac{R_s + h_{ie}}{1 + h_{fe}}$

$= \frac{400 + 1 \times 10^3}{1+85}$

$$\boxed{(Z_0) = \text{[illegible]}\ \Omega \quad 16.27\ \Omega}$$

$Z_0' = Z_0 \,||\, R_L \,||\, R_E$

$= Z_0 \,||\, R_L$

$= \frac{16.27 \times 5\times10^3}{16.27+5\times10^3}$

$\boxed{Z_0' = 16.217\ \Omega}$

$A_{VS} = \frac{V_{ce}}{V_S}$

$= \frac{V_{ce}}{V_S} \times \frac{V_{be}}{V_S}$

$A_{VS} = A_V \times \frac{Z_{in}'}{Z_{in}'+R_S}$

$= 0.997 \times \frac{13.499\times10^3}{13.499\times10^3+400}$

= ~~00.0002499~~ $= \boxed{0.9683.}$

$A_{IS} = \frac{R_E}{R_E+R_L} \times A_I \times \frac{R_S}{R_S+Z_{in}}$ 47kΩ

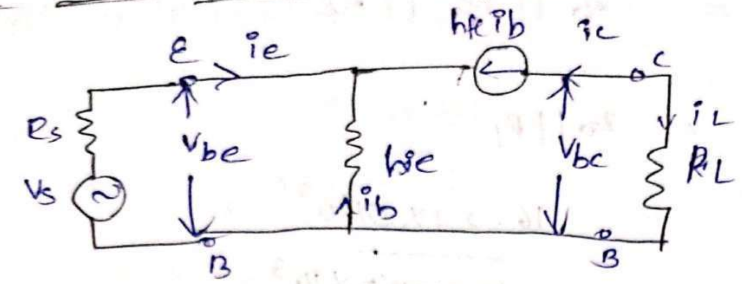
$= \frac{5.6\times10^3}{5.6\times10^3+47\times10^3} * 86 * \frac{400}{400+13.499\times10^3}$

$\boxed{A_{IS} = 0.26349}$

Analysis of CB using simplified Model.

→ In CB amplifier, the source voltage (V_s) is connected b/n emitter to base terminal and load resistor (R_L) is connected b/n collector to base terminal.

From Generalised Model, Equivalent Circuit Shown below



As we know that a resistance (hie) is connected b/n Base to Emitter and a current source hfe ib is connected b/n collector to Emitter Terminal.

Current Gain (AI):- In CB amplifier, o/p current ic and i/p current is ie

$$\boxed{A_I = \frac{i_c}{i_e}}$$

From o/p circuit

$i_C = h_{fe} i_b$

$i_e = i_b(1 + h_{fe})$

$$A_I = \frac{h_{fe} i_b}{i_b(1+h_{fe})}$$

$$A_I = \frac{h_{fe}}{(1+h_{fe})}.$$

Voltage gain:(Av):- In CB amplifier, o/p voltage is v_{bc} and i/p voltage is V_{be}.

$$\therefore A_V = \frac{V_{bc}}{V_{be}} \quad (\text{or}) \quad A_I \times \frac{R_L}{Z_{in}}$$

$$A_V = \frac{V_{bc}}{V_{be}}$$

where $V_{bc} = i_c R_L$

$$A_V = \frac{h_{fe}}{(1+h_{fe})} \cdot \frac{R_L}{\frac{h_{ie}}{(1+h_{fe})}} \Rightarrow \frac{h_{fe} \cdot R_L}{h_{ie}}$$

Input Impedance (~~Zin~~) : In CB amplifier, i/p voltage is V_{be}, and i/p current is i_e.

$$\therefore \quad Z_{in} = \frac{V_{be}}{i_e}$$

From i/p circuit

$$V_{be} = h_{ie} i_b$$

$$i_e = (1 + h_{fe}) i_b$$

$$\therefore Z_{in} = \frac{h_{ie} \cancel{i_b}}{(1+h_{fe}) \cancel{i_b}}$$

$$Z_{in} = \frac{h_{ie}}{(1+h_{fe})}$$

Output Impedance (Z_0) : In CB amplifier, o/p voltage V_{cb} and o/p current i_c.

$$\therefore Z_0 = \frac{V_{bc}}{i_c}$$

~~**~~condition

$V_S = 0$ (or) $V_{be} = 0$

$R_L = \alpha$ o/p circuit = open

$= R_L \neq \alpha$

i/p circuit = short

so V_{be} = i/p v

$= 0$ //

$$V_{bc} = i_c R_L$$

$$\boxed{Z_0 = \frac{i_c R_L}{i_c} \quad \frac{\cancel{i_c} R_L}{\cancel{i_c}} = \alpha}$$

As $V_{be} = 0 \Rightarrow i_e = 0 \Rightarrow i_c = 0$

$$\therefore Z_0 = \frac{V_{bc}}{0} = \alpha$$

$$\boxed{Z_0 = \alpha}$$

Consider a CB amplifier as shown in figure. as the following components $R_S = 600\Omega$, $R_e = 5.6K\Omega$, $R_C = 5.6K\Omega$, $R_L = 39K\Omega$, The transistor parameters are $h_{ie} = 1K\Omega$, $h_{fe} = 85$; $h_{oe} = 2\mu A/V$ calculate A_I, Z_{in}, A_V, Z_0 of given amplifier?

The effective load

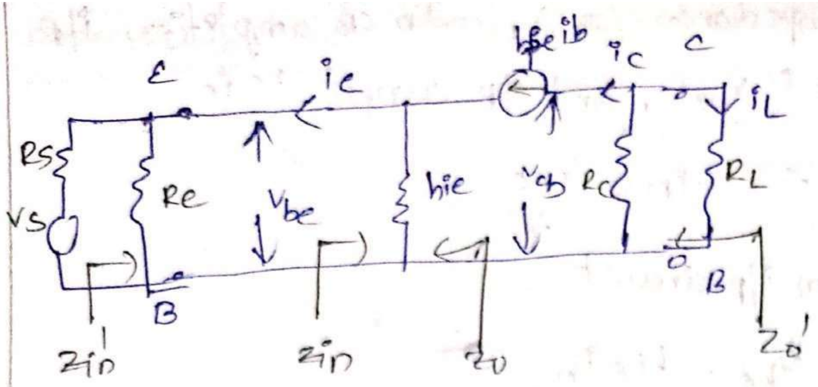
$$R_L = 5.6K\Omega \,||\, 39K\Omega$$

$$R_L = 4.89K\Omega$$

$$h_{oe} R_L = 2 \times 10^{-6} \times 4.89 \times 10^{3}$$

$$= 0.009 < 0.1$$

✓ Hence use simplified Model



Current gain $(A_I) = \frac{h_{fe}}{1+h_{fe}}$

$= \frac{85}{86}$

$(A_I) = 0.9883$

Input Impedance $(z_{in}) = \frac{h_{ie}}{1+h_{fe}}$

$$\boxed{(z_{in}) = 11.627\Omega}$$

Voltage gain $(A_V) = h_{fe} \cdot \frac{R_L}{h_{ie}}$

$= 85 \times \frac{\cancel{24}.891K\Omega}{1\times10^3}$

$$\boxed{(A_V) = 415.65}$$

Output Impedance $(Z_0) = \frac{i_c/R_L}{i_c}$ | $V_s = V_{be} = 0$, $R_L = \alpha$

$$\boxed{Z_0 = \alpha}$$

$z_{in}' = R_E \| z_{in}$

$= \frac{5.6\times10^3 \times 11.627}{5.6\times10^3 + 11.627}$

$$\boxed{z_{in}' = 11.602\Omega}$$

overall o/p Impedance (Z_o') $= R_C \,||\, R_L \,||\, Z_o$

$$= 4.89k\Omega \,||\, \frac{1}{\alpha}$$

$$= \left(\frac{1}{4.89k\Omega}\right)^{-1}$$

$$\boxed{Z_o' = 4.89\times10^{-13}\,\Omega}$$

$$A_{IS} = \frac{R_E}{R_E+R_L}\times A_I\times\frac{R_s}{R_s+Z_{in}}$$

$$\boxed{A_{IS} = 0.1217}$$

$$A_{VS} = \boxed{A_V\times\frac{Z_{in}'}{Z_{in}'+R_s}} \Rightarrow \frac{V_{cc}}{V_s} = \frac{V_{cc}}{V_s}\times\frac{V_{be}}{V_s}$$

$$= 415.65\times\frac{11.602}{11.602+600}$$

$$\boxed{A_{VS} = 7.8848}$$

Analysis of CE Amplifier with R_E Resistor: (or) unbypassed Resistor:

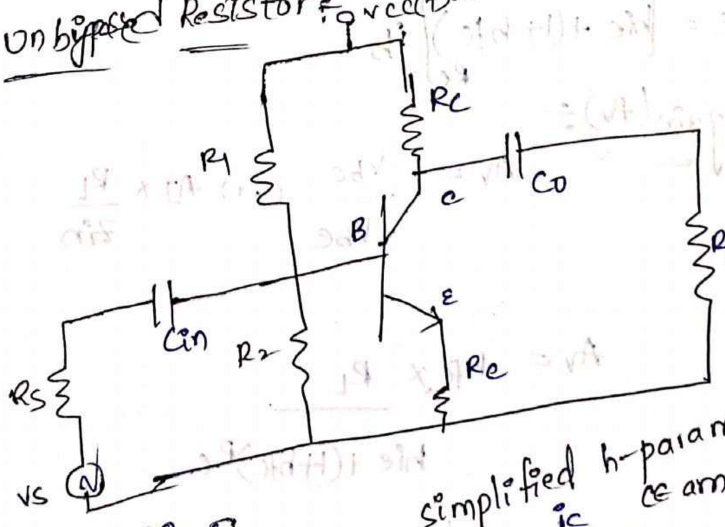
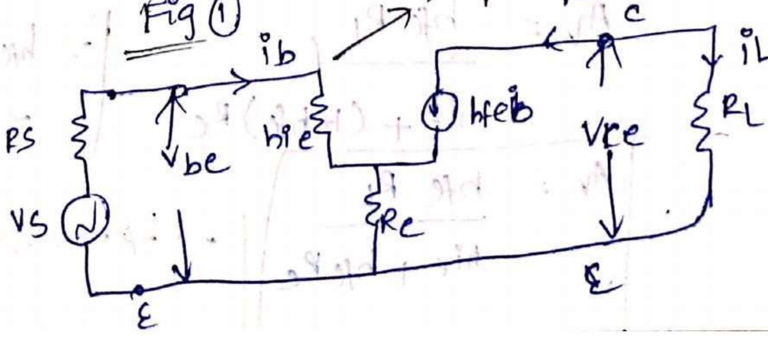


Fig ①

simplified h-parameter model of CE amplifier with "Re"



Current gain:- (A_I) In CE amplifier, o/p current is i_c

and i/p current is i_B

$$\therefore A_I = \frac{i_c}{i_b}$$

$$= \frac{h_{fe} i_b}{i_b}$$

$$A_I = h_{fe}$$

Input Impedance (Z_{in}):-

$$(Z_{in}) = \frac{V_{be}}{i_b}$$

From i/p circuit:-

$V_{be} = h_{ie} i_b + R_e i_e$ $\Rightarrow$ $Z_{in} = \frac{(1+h_{fe}) i_b + h_{ie} i_b}{i_b}$

$V_{be} = h_{ie} i_b + '$

$$\boxed{Z_{in} = h_{ie} + (1+h_{fe}) R_e}$$

$i_e = i_b + i_c$

$= i_b + h_{fe} i_b$

$i_e = i_b(1+h_{fe})$

$V_{be} = h_{ie} i_b + i_b(1+h_{fe}) R_e$

$V_{be} = [h_{ie} + (1+h_{fe}) R_e] i_b$

Voltage gain (A_V):- $A_V = \frac{V_{bc}}{V_{be}}$ (or) $A_I \times \frac{R_L}{Z_{in}}$

$$A_V = h_{fe} \times \frac{R_L}{h_{ie} + (1+h_{fe}) R_e}$$

$$A_V = \frac{h_{fe} R_L}{h_{ie} + (1+h_{fe}) R_e}$$ $\therefore h_{fe} >> 1$, $\approx h_{fe}$

$$\boxed{A_V = \frac{h_{fe} R_L}{h_{ie} + h_{fe} R_e}}$$ $\therefore h_{fe} R_e >> h_{ie}$

$$A_V = \frac{h_{fe} R_L}{h_{fe} R_e}$$

$h_{fe}R_e >> h_{ie}$

$h_{ie} + h_{fe}R_e \approx h_{fe}r_e$

$$\boxed{A_V = \frac{R_L}{R_e}}$$

output Impedance (Z_0) :-

$$Z_0 = \frac{V_{ce}}{i_c}$$

$V_S = V_{be} = 0$

$R_L = \alpha$

$V_{be} = 0 \Rightarrow i_b = 0$

$i_c = 0$

$$Z_0 = \frac{V_{ce}}{0}$$

$$\boxed{Z_0 = \alpha}$$

SUMMARY OF BJT AMPLIFIER

Parameter	Amplifier with Exact Model.			Amplifier with simplified Model (Approximat Model)			CE with Re
	CE	CC	CB	CE	CC	CB	
Current gain (AI)	$\frac{h_{fe}}{(1+h_{oe}R_L)}$	$\frac{-h_{fc}}{(h_{oc}R_L+1)}$	$\frac{-h_{fb}}{(1+h_{ob}R_L)}$	h_{fe}	$1+h_{fe}$	$\frac{h_{fe}}{(1+h_{fe})}$	h_{fe}
Input Impedance (Zin)	$h_{ie}-\frac{h_{fe}h_{re}}{(h_{oe}+1/R_L)}$	$h_{ic}-\frac{h_{rc}h_{fc}}{h_{oc}+\frac{1}{R_L}}$	$h_{ib}-\frac{h_{rb}h_{fb}}{h_{ob}+\frac{1}{R_L}}$	h_{ie}	$h_{ie}+(1+h_{fe})R_L$	$\frac{h_{ie}}{(1+h_{fe})}$	$h_{ie}+$ $(1+h_{fe})$
Voltage gain (AV)	$\frac{-h_{fe}}{(h_{oe}+\frac{1}{R_L})}\cdot\frac{1}{Z_{in}}$	$\frac{h_{fc}}{(h_{oc}+\frac{1}{R_L})}\cdot\frac{1}{Z_{in}}$	$\frac{h_{fb}}{(h_{ob}+\frac{1}{R_L})}\cdot\frac{1}{Z_{in}}$	$\frac{-h_{fe}R_L}{h_{ie}}$	$\approx 1\Big[\Big(1-\frac{h_{ie}}{Z_{in}}\Big]$	$\frac{h_{fe}R_L}{h_{ie}}$	$\frac{R_L}{R_e}$
Output Impedance (Zo)	$\frac{h_{re}}{h_{ie}h_{oe}-h_{fe}h_{re}}$	$\frac{h_{ic}}{h_{ic}h_{oc}-h_{fc}h_{rc}}$	$\frac{h_{ib}}{h_{ib}h_{ob}-h_{fb}h_{rb}}$	α	$\frac{R_s+h_{ie}}{(1+h_{fe})}$	α	α

Comparision of BJT Amplifiers.

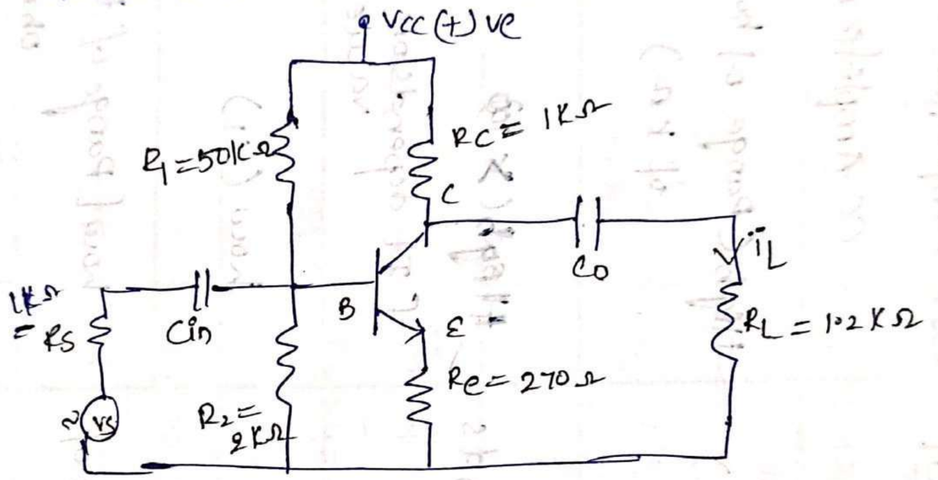
Parameter	CE Amplifier	CC Amplifier	CB Amplifier.
Input Impedance (Zin)	Medium (range of kΩ)	High (Range of hundreds of kΩ)	Low [Range of tens of ohm's]
current gain (AI)	High (>100) It depends on hfe value.	~~High~~ (> 100 [It depends on hfe value]	Low ~~High~~ (~~<100~~) Low (<1)
Voltage gain (Av)	High (>100)	Low (<1)	High (>100).
Output Impedance (Zo)	High (Range of tens of kΩ)	Low [Range of tens of ohm]	High (Range of tens of kΩ).

Consider a single stage CE amplifier with unbypassed emitter Resistance as the following components, $R_1 = 50K\Omega$, $R_2 = 2K\Omega$, $R_C = 1K\Omega$, $R_e = 270\Omega$ and $R_L = 1.2K\Omega$. Find A_I, A_V, Z_{in}, Z_o? Use Typical values of h-parameters? , $R_S = 1K\Omega$)

For CE

$h_{ie} = 1.1K\Omega$, $h_{fe} = 50$

$h_{re} = 2.5\times10^{-4}$, $h_{oe} = 25\mu A/V$.



Current gain $(A_I) = h_{fe}$

$(A_I) = h_{fe} = 50$

Input Impedance $(Z_{in}) = h_{ie} + (1+h_{fe})R_e$

$= 1.1\times10^{3} + (1+50)$ ~~[illegible]~~ 270 Ω

$(Z_{in}) =$ ~~9.947~~ KΩ

14.87 KΩ

$R_L' = R_C \parallel R_L$

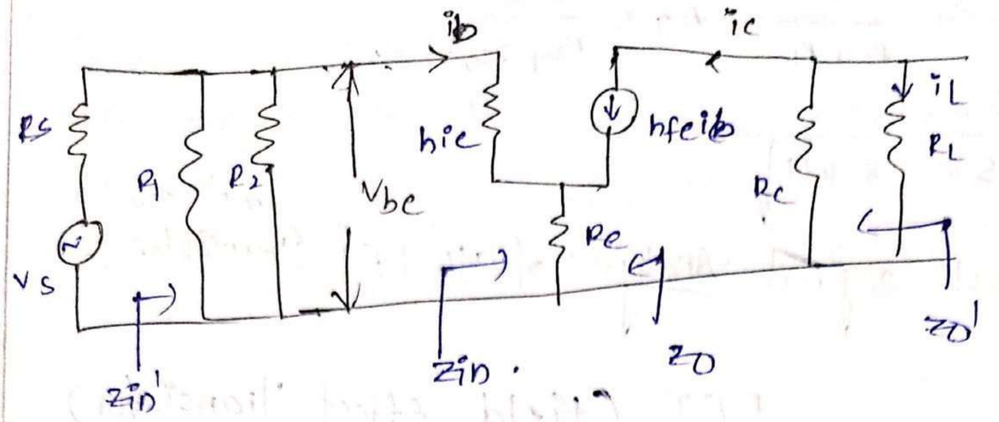
$= 1\times10^{3} \parallel 1.2 K\Omega$

$R_L' = 545.45\,\Omega$

$h_{oe}R_L' = 25\times10^{-6}\times545.45$

$= 0.013 < 0.1$

Hence use simplified Model.



Voltage gain $(A_v) = \frac{R_L}{R_e}$

$= \frac{545.45}{270}$

$\boxed{A_V = 2.0201}$

Overall i/p Impedance $(Z_{in})' = R_1 \,||\, R_2 \,||\, Z_{in}$

$= 1702.85$

$\boxed{Z_{in}' = 1.702\ K\Omega}$

output Impedance $(Z_0) = \alpha$

overall output Impedance $(Z_0') = R_L \,||\, Z_0$

$= \frac{1}{545.45} + \frac{1}{0}$

$= \left(\frac{1}{545.45}\right)$

$\boxed{(Z_0') = 545.45\Omega}$

$A_{vs} = A_V \times \frac{Z_{in}'}{Z_{in}' + R_S}$

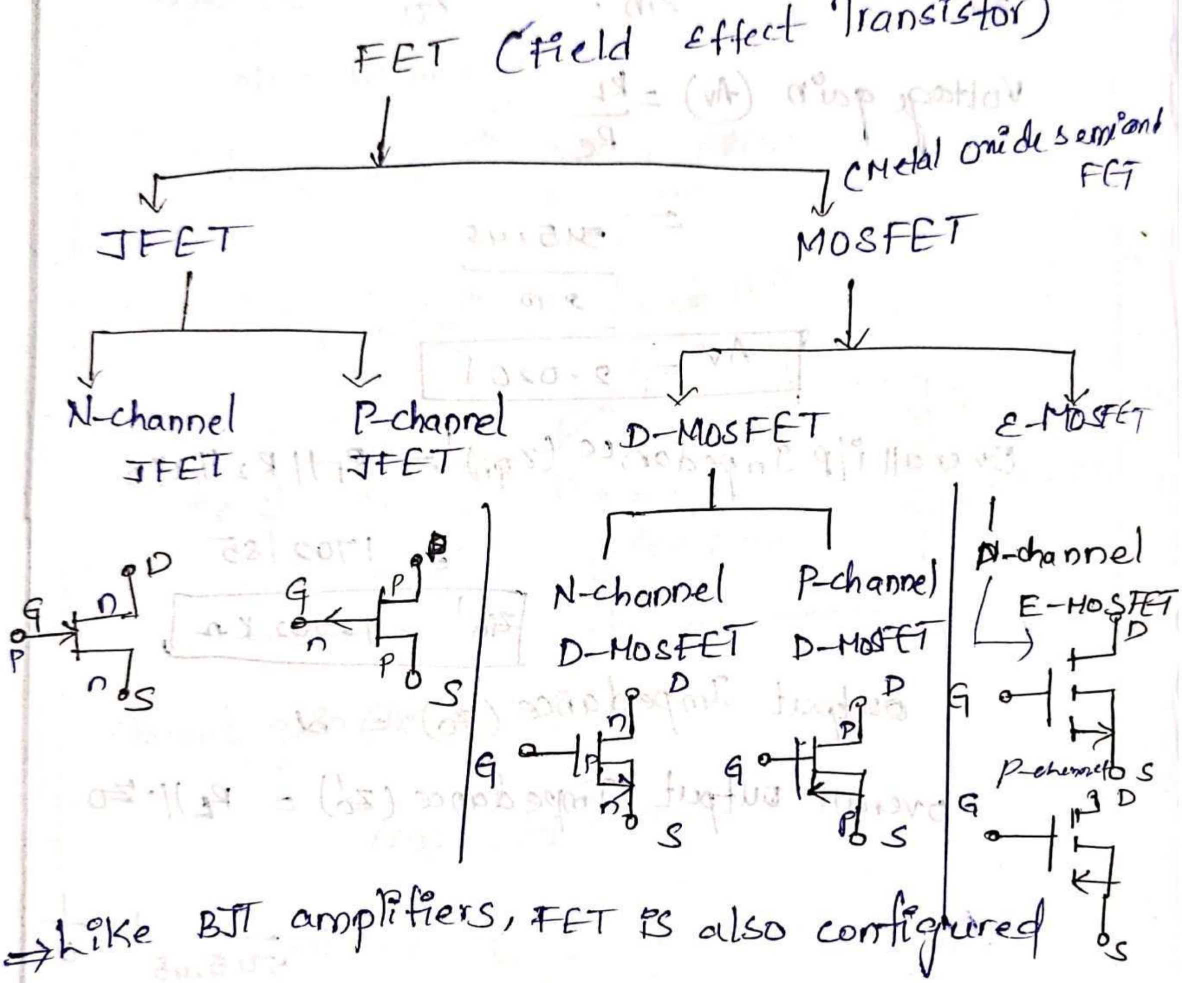
$= \frac{2.020 \times 1.702 \times 10^3}{1.702 \times 10^3 + 1 \times 10^3}$

$\boxed{A_{vs} = 1.272}$

$$A_{IS} = \frac{R_C}{R_C + R_L} \times A_I \times \frac{R_S}{R_S + Z_{in}'}$$

$$\boxed{A_{IS} = 8.411}$$

Small signal Analysis of MOSFET Amplifier (Transistor):



⇒ Like BJT amplifiers, FET is also configured into three configurations such as 1. common-source, 2. common drain and 3. common gate (source).

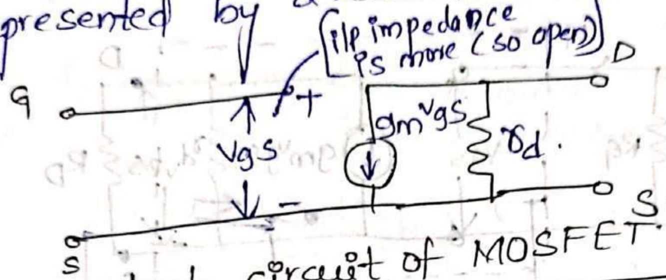
⇒ The AC analysis of MOSFET requires the small signal AC Model which can be derived from the operation of MOSFET.

1) A major component of the AC Model will reflect the AC voltage is applied to the i/p will control the level of output current.

1) It can be represented as by the voltage source across the inputs and a current source across the output terminals.

2) The current source as its arrow pointing down to establish a 180° phase shift b/n input and output.

3) As we know the input impedance of MOSFET is very high and it can be represented as open ckts between the input terminals, and output impedance is represented by a resistance r_d.



AC equivalent circuit of MOSFET

where g_m is called $\boxed{\text{transconductance.}}$

⇒ It is the ratio of o/p current to i/p voltage.

$$g_m = \frac{i_d}{V_{gs}} \times$$ ~~deps~~

$$g_m = \frac{i_d}{V_{gs}}$$

$$\frac{1}{y_{os}} = r_d$$

y_{os} is called output admittance.

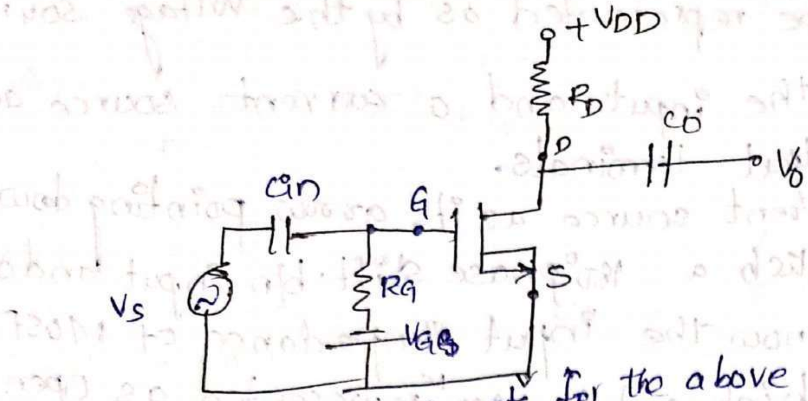
$$\boxed{g_m = g_{m0}\left[1 - \frac{V_{gs}}{V_p}\right]}$$

where $g_{m0} = \frac{2 I_{DSS}}{|V_p|}$ (saturation current of drain (pinchoff voltage).

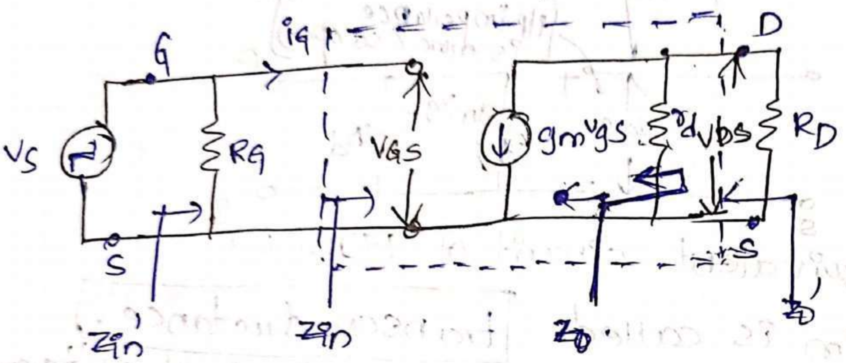
Analysis of Common Source Amplifier:

As we know, in common source, the input voltage is applied b/n gate terminal to source terminal and the output voltage is taken across drain terminal to source terminal.

→ The below figure shows CS amplifier with fixed bias.



The AC equivalent circuit for the above CS amplifier circuit is shown in below fig:



Input Impedance (Zin): In CS amplifier, input voltage is VGS and i/p current is ig.

$$\therefore \boxed{Z_{in} = \frac{V_{gs}}{i_g}}$$

From input circuit, i/p terminals are open circuited.

i.e., which indicates $\boxed{i_g = 0.}$

$$\therefore Z_{in} = \frac{V_{gs}}{0}$$

$$\boxed{Z_{in} = \alpha}$$

overall i/p Impedance: $Z_{in}' = R_g \parallel Z_{in}$

$$= R_g \parallel \alpha$$

$$\boxed{Z_{in}' = R_g}$$

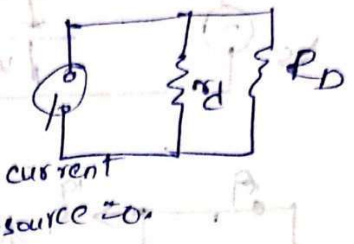
output impedance (Z_o): In CS amplifier, output voltage is V_{DS} and o/p current is i_D.

$$\therefore Z_o = \frac{V_{DS}}{i_D}. \quad \Big| \; V_{GS} = 0.$$

From o/p circuit:

$$V_{GS} = 0 \Leftrightarrow gm\,(V_{GS}) = 0$$

$$\therefore \boxed{Z_o = r_d}$$



overall o/p Impedance (Z_o'):

$$(Z_o') = Z_o \,||\, R_D$$

$$\boxed{Z_o' = r_d \,||\, R_D}$$

Voltage gain (A_V): In CS amplifier, o/p voltage is V_{DS} and i/p voltage is V_{GS}.

$$\boxed{A_V = \frac{V_{DS}}{V_{GS}}}$$

From o/p circuit:

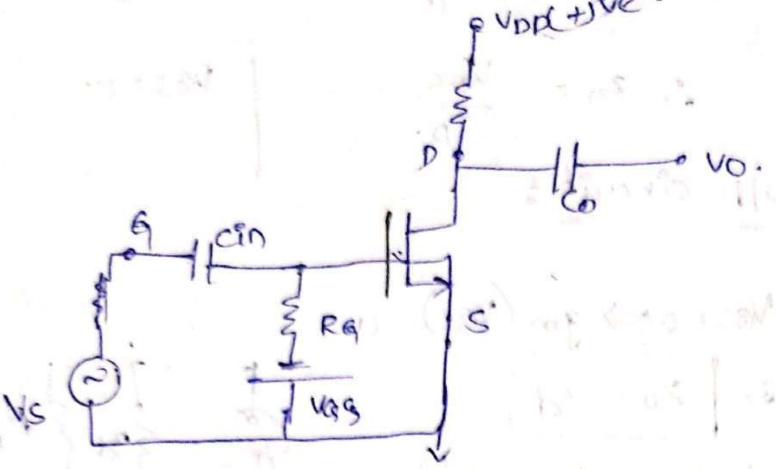
$$V_{DS} = -g_m v_{gs}\,(r_d \,||\, R_D)$$

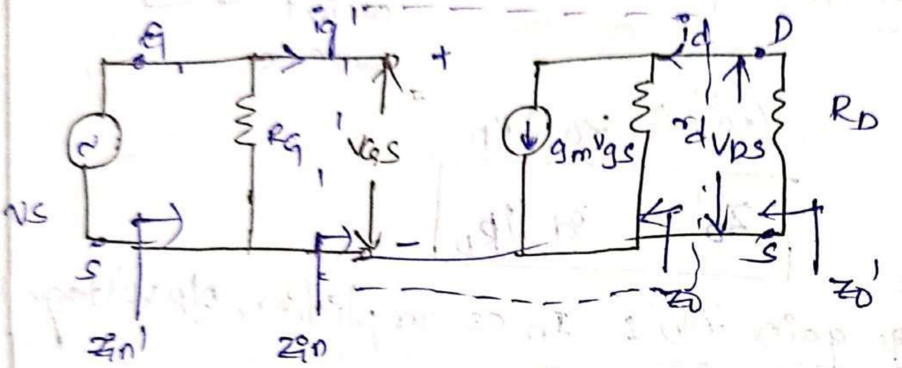
$$A_V = \frac{-g_m \cancel{v_{gs}}\,(r_d \,||\, R_D)}{\cancel{v_{gs}}}$$

$$\boxed{A_V = -g_m(r_d \,||\, R_D).}$$

The fixed bias configuration of CS amplifier as an operating point defined by $V_{GSQ} = -2V$ $I_{DQ} = 5.625$ mAmp, with $I_{DSS} = 10$ mA and $V_P = -8V$ The biasing resistor values are $R_G = 1\,M\Omega$, $R_D = 2K\Omega$. The parameter $Y_{os} = 40\mu$Seimen.
↳ output admittance.

Calaulate g_m, r_d, Z_{in}, Z_{in}', Z_o, Z_o', Av(with and without r_d)?





① $I_D = I_{DSS}\left[1-\frac{V_{GS}}{V_p}\right]^2$ ✓

$= 10\times10^{-3}\left[1-\left(\frac{-2}{-8}\right)\right]^2$ ✓

$= 10\times10^{-3}\left[1-1/4\right]^2$ no need

$= 10\times10^{-3}\left[3/4\right]^2$

$= 10\times10^{-3}\left[\frac{9}{16}\right] = 0.005625$

$I_D = 5.625\ \mu\text{Amp}$

$g_{m0} = \frac{2 I_{DSS}}{|V_p|} = \frac{2\times10\times10^{-3}}{84} = \boxed{2.5\text{m seimen}}$

$g_m = g_{m0}\left[1-\frac{V_{GS}}{V_p}\right] = 2.5\times10^{-3}\left[1-\left(\frac{-2}{-8}\right)\right] =$

$= \boxed{1.87\text{m seimen,}}$

$$r_d = \frac{1}{Y_{os}} = \frac{1}{40\times10^{-6}} = 25000\cdot\frac{1}{\frac{I}{V}} = 25k\Omega$$

$$\boxed{r_d = 25k\Omega}$$

$$\boxed{Z_{in} = \alpha}$$

$$Z_{in}' = Z_{in} \,||\, R_g$$

$$= \alpha \,||\, R_g$$

$$Z_{in}' = 1M\Omega$$

$$Z_o = r_d$$

$$Z_o' = r_d \,||\, R_D$$

$$= 25k\Omega \,||\, 2k\Omega$$

$$\boxed{Z_o' = 1.85k\Omega}$$

$$A_V(\text{with } r_d) = -g_m(r_d \,||\, R_D)$$

$$= -1.87\times10^{-3}[25k\Omega \,||\, 2.0k\Omega]$$

$$= -1.87\times10^{-3}[1.85\times10^{3}]$$

$$\boxed{A_V = -3.46}$$

$$A_V(\text{without } r_d) = -g_m(R_D)$$

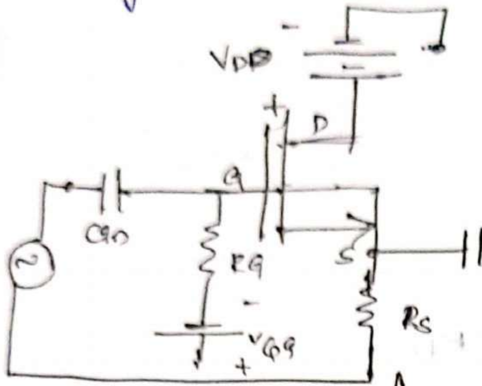
$$= -1.87\times10^{-3}[2\times10^{3}]$$

$$\boxed{A_V(\text{without } r_d) = -3.74}$$

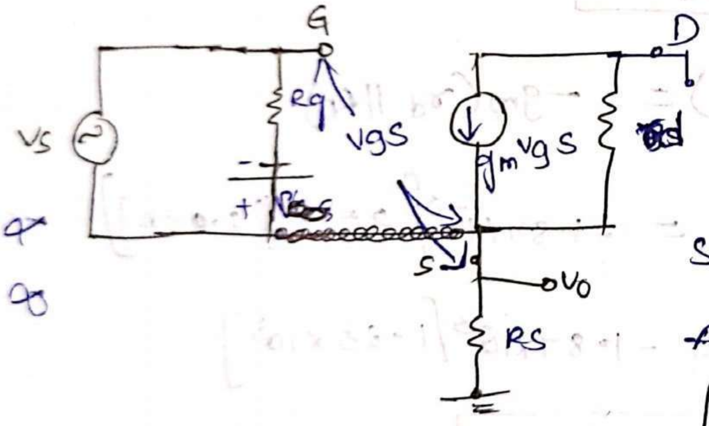
Analysis of CD Amplifier (or) ~~Gnai~~ Source follower:

→ In CD amplifier, the $\overset{input}{(source)}$ voltage is applied b/n gate and Drain terminal and output voltage is taken b/n source and drain terminal.

→ The below figure shows the CD amplifier with fixed bia

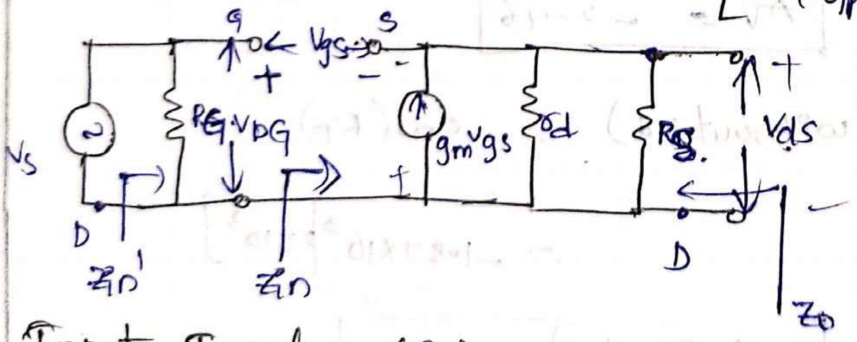


AC equivalent circuit for above fig shows below



→ It is difficult to analyse so again equivalent AC circuit.

[As i/p circuit at left & o/p circuit at Right



Input Impedance (Zin):

$(Z_{in}) = \frac{V_{gd}}{i_g}$ From equivalent i/p circuit the i/p terminals is open circu

i.e. $i_g = 0$.

$\boxed{Z_{in} = \alpha}$

Overall input Impedance (Z_{in}'):

$$Z_{in}' = Z_{in} \,||\, R_g \Rightarrow \infty \,||\, R_g$$

$$\boxed{Z_{in}' = R_g}$$

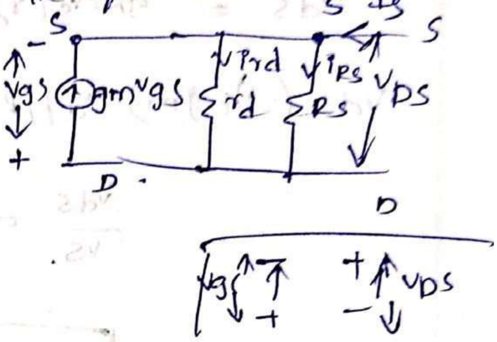
Output Impedance (Z_o):

$$Z_o = \frac{V_{DS}}{i_s}$$

$$\boxed{Z_o = \frac{V_{DS}}{i_S}}$$

$V_S = 0$

The equivalent circuit becomes



(Voltage gain (with r_d)):

$$A_V = \frac{V_{DS}}{V_{dg}}$$

Apply KCL at Node S

$$g_m V_{gs} + I_S = I_{rd} + I_{RS}$$

$$I_S = I_{rd} + I_{RS} - g_m V_{gs} \quad \text{(opposite}$$

$$I_S = \frac{V_{ds}}{r_d} + \frac{V_{ds}}{r_S} - g_m(-V_{ds})$$

$$\boxed{I_S = V_{ds}\left[\frac{1}{r_d} + \frac{1}{r_S} + g_m\right]}$$

$$\therefore Z_o = \frac{V_{DS}}{V_{ds}\left[\frac{1}{r_d} + \frac{1}{R_S} + g_m\right]}$$

normal

R_s at o/p

$$\boxed{Z_o = \frac{1}{\frac{1}{r_d} + \frac{1}{R_S} + g_m}} \approx r_d \,||\, R_S \,||\, \frac{1}{g_m}$$

Voltage gain (A_V): (with or without r_d)

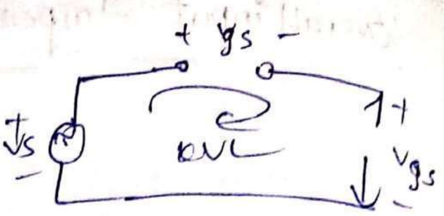
$$A_V = \frac{V_{DS}}{V_{DG}}.$$

$$A_V = \frac{V_{DS}}{V_{DG}} = \frac{V_{DS}}{V_S}.$$

$$V_{DS} = +g_m V_{gs} \cancel{(}(r_d \,||\, R_S)$$

$$V_{DS} = g_m V_{gs}(r_d \,||\, R_S)$$

Apply KVL to entire circuit



$$V_s - V_{gs} - V_{ds} = 0$$

$$\boxed{V_{gs} = V_s - V_{ds}}$$

$$V_{ds} = g_m(V_s - V_{ds})(r_d || R_s)$$

$$V_{ds} = g_m V_s(r_d || R_s) - g_m V_{ds}(r_d || R_s)$$

$$V_{ds}(1+g_m) r_d || R_s = g_m V_s(r_d || R_s)$$

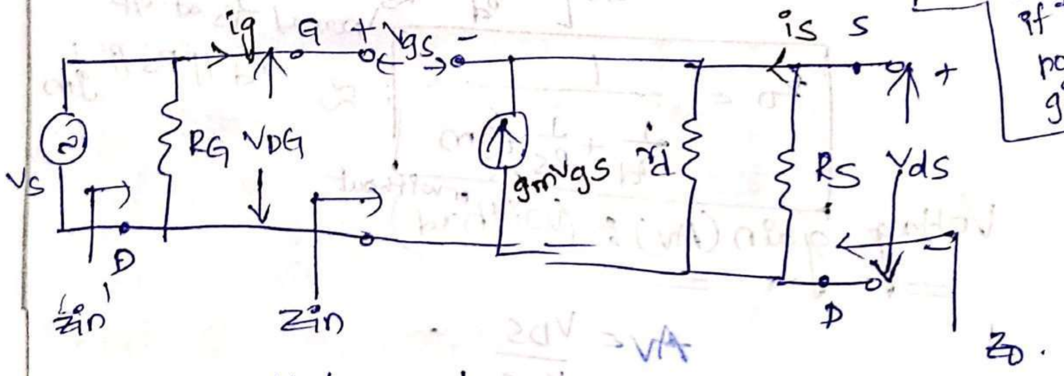
$$\frac{V_{ds}}{V_s} = \frac{g_m(r_d || R_s)}{(1+g_m)(r_d || R_s)}$$

$$\boxed{A_V = \frac{g_m(r_d || R_s)}{1+g_m(r_d || R_s)}}$$

Resistance connected at source tm

The DC Analysis of the source follower [CD amplifier] will results in $V_{GSQ} = -2.86V$, $I_{DQ} = 4.56mA$ with $I_{DSS} = 16mA$. $V_p = -4V$ with $R_g = 1M\Omega$ $R_S = 2.2K\Omega$ The parameter $Y_{os} = 25\mu A/v$ (or) 25×10^{-6} seimen. calculate $g_m, r_d, Z_{in}, Z_o, A_V$ (with and with r_d)?

If $g_{mo} = 2mse$ we should take if they not given



$$Z_{in} = \frac{V_{gd}}{i_g} \quad \Big| \quad i_g = 0$$

$$Z_{in} = \frac{V_{gd}}{0}$$

$$\boxed{Z_{in} = \alpha}$$

$$g_{mo} = \frac{2 I_{DSS}}{|V_P|} = \frac{2\times \overset{8}{\cancel{16}}\times10^{-3}}{\underset{2}{\cancel{4V}}} = \boxed{8\,\text{m seimen}}$$

$$g_m = g_{mo}\left[1-\frac{V_{GS}}{V_P}\right] = 8\times10^{-3}\left[1-\frac{2.86}{4}\right] = 8\times10^{-3}\left[1-\frac{2.}{4}\right.$$

$$\simeq 0.002280$$

$$\boxed{= 2.28\,\text{m seim}}$$

$$r_d = \frac{1}{Y_{OS}} = \frac{1}{25\times10^{-6}} = 40\,K\Omega$$

$$\boxed{Z_{in}' = R_g = R_g = 1\,M\Omega}$$

$$Z_0 = \frac{1}{\frac{1}{r_d}+\frac{1}{R_S}+g_m} = 362.378\,\Omega$$

$$= \boxed{362.378\,\Omega}$$

$$A_V = \frac{g_m\left[r_d \| R_S\right]}{1+g_m(r_d\|R_S)}$$

$$A_V = \frac{2.28\times10^{-3}\left[\frac{40\times10^3\times2.2\times10^3}{\left[40\times10^3+2.2\times10^3\right]}\right]}{1+2.28\times10^{-3}\left[\frac{40\times10^3\times2.2\times10^3}{40\times10^3+2.2\times10^3}\right]}.$$

$$\boxed{A_V = 0.8262}$$

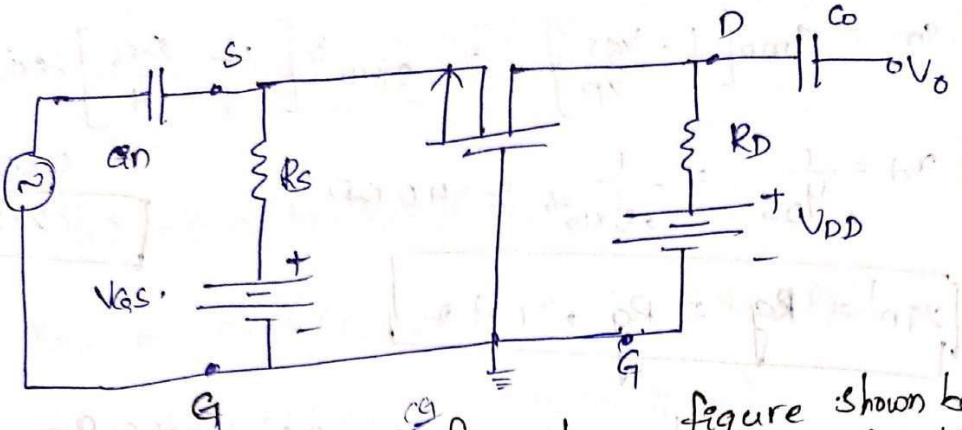
$$A_V\,(\text{without } r_d) = \frac{g_m(R_S)}{1+g_m(R_S)} = \frac{2.28\times10^{-3}\times2.2\times10^3}{1+2.28\times10^{-3}\times2.2\times10^3}.$$

$$\boxed{A_V = 0.8337}$$

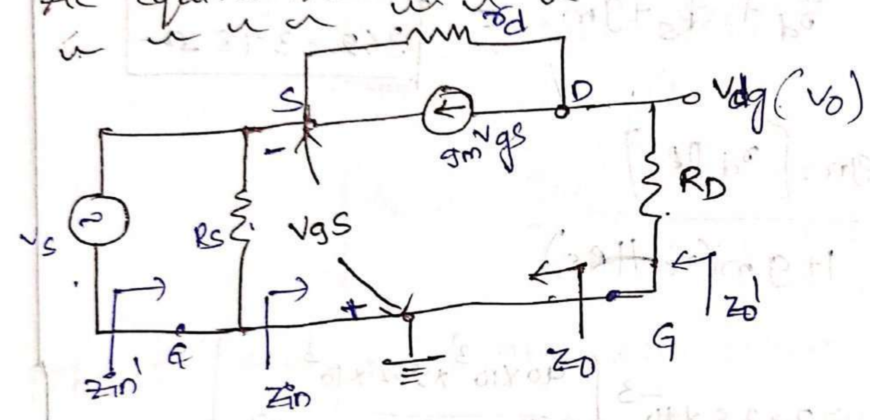
Analysis of common gate (CG) amplifier :-

In CG amplifier, the input voltage is applied b/n source and gate terminal and output voltage is taken across drain and gate terminal.

The below figure shows the common gate amplifier with fined bias.



AC equivalent circuit for above figure shown below:-

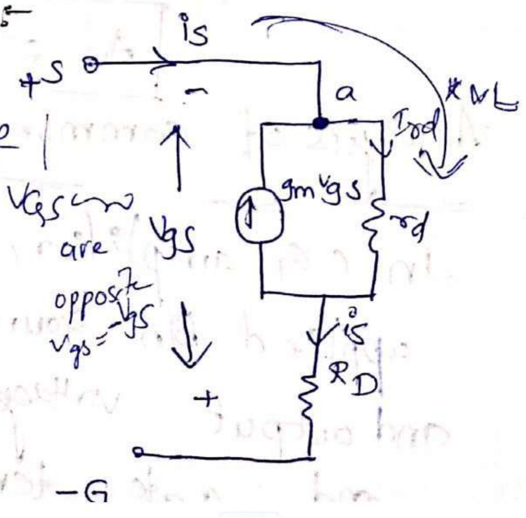


Input Impedance (Zin):- In CG amplifier, input voltage is Vgs and i/p current is Is, Then

$$Z_{in} = \frac{V_{gs}}{I_s}$$

$$Z_{in} = \frac{V_{gs}}{I_s}$$

Redraw the equivalent circuit as shown in figure to find Input Impedance:-



Apply KVL to o/p perimeter of networks.

$$V_{gs} - V_{rd} - V_{RD} = 0$$

$$V_{gs} = V_{rd} + V_{RD}$$

$$V_{rd} = V_{gs} - V_{RD}.$$

$$\boxed{I_{rd} = \frac{V_{gs} - V_{RD}}{r_d}} = \frac{V_{gs} - I_s R_D}{r_d}$$

Apply KCL at node "a".

$$I_s + g_m V_{gs} = I_{rd}$$

$$I_s = I_{rd} - g_m V_{gs}$$

$$= \frac{V_{gs} - V_{RD}}{r_d} - g_m(-V_{gs})$$

$$I_s = \frac{V_{gs}}{r_d} - \frac{V_{RD}}{r_d} + g_m(V_{gs})$$

$$I_s = \frac{V_{gs}}{r_d} - \frac{I_s R_D}{r_d} + g_m V_{gs}.$$

$$I_s + \frac{I_s R_D}{r_d} = V_{gs}\left[\frac{1}{r_d} + g_m\right]$$

$$I_s\left[1 + \frac{R_D}{r_d}\right] = V_{gs}\left[\frac{1}{r_d} + g_m\right]$$

$$\frac{V_{gs}}{I_s} = \frac{\left(1 + \frac{R_D}{r_d}\right)}{\left(\frac{1}{r_d} + g_m\right)} = \frac{r_d + R_D}{1 + g_m r_d}$$

$$\boxed{Z_{in} = \frac{r_d + R_D}{1 + g_m r_d}}$$

Overall i/p Impedance:

$$\boxed{Z_{in}' = Z_{in} \,||\, R_S.}$$

Output Impedance (Z_0):- In CG amplifier, output voltage is V_{dg} and o/p current is I_D.

$$\therefore Z_0 = \frac{V_{dg}}{I_D}.$$

By keeping i/p voltage as '0'

$V_{gs} = 0$
(or)
$V_s = 0$.

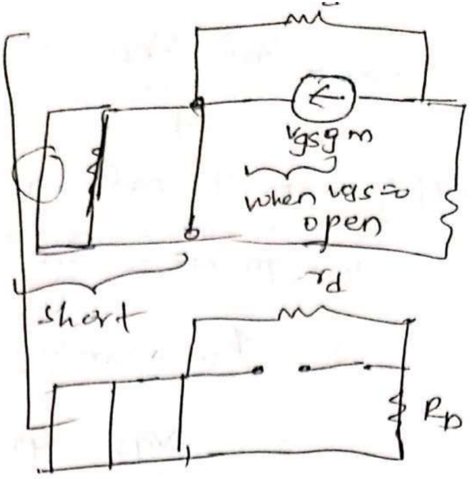
With $V_{gs} = 0$ | $V_s = 0$ i/p circuit becomes short

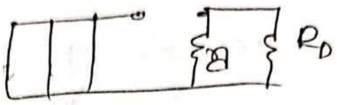
So, R_s becomes short (≈ 0) and when $V_{gs} = 0$ then current source is open circuit. Then r_d is connected b/n D and source (ground),

$$\boxed{Z_0 = r_d}$$

$$\therefore Z_0' = R_D \,||\, Z_0$$

$$\boxed{Z_0' = R_D \,||\, r_d}$$





Voltage gain (A_V):

In CG amplifier, o/p voltage is V_{dg} and i/p voltage is V_{gs} (or) V_s.

$$\therefore A_V = \frac{V_{dg}}{V_{gs}}$$

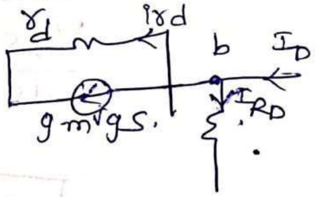
From Equivalent circuit,

$$V_{in} \text{ (or) } V_s = -V_{gs}$$

$$V_{dg} \text{ (or) } V_o = I_D R_D.$$

The voltage across r_d $(V_{rd}) = V_o - V_{in}$

$$I_{rd} = \frac{V_o - V_{in}}{r_d}$$



Apply KCL at Node 'B'

[By neglecting (I_{RD})]

$$I_D = g_m V_{gs} + I_{rd}$$

$$I_D = \frac{V_o - V_{in}}{r_d} + g_m V_{gs}$$

$$I_D = \frac{(V_o + V_{gs})}{r_d} + g_m V_{gs}$$

sub I_D in V_o then

$$V_{dg} \text{ (or) } V_o = \left[\frac{V_o + V_{gs}}{r_d} + g_m V_{gs}\right] R_D$$

$$V_{dg} = V_o = \frac{R_D (V_o + V_{gs})}{r_d} + g_m V_{gs} R_D$$

$$V_{dg} = V_0 \Rightarrow \frac{R_D \overset{v_{dg}}{V_0}}{r_d} + \frac{V_{gs} R_D}{r_d} + g_m V_{gs} R_D$$

$$V_{dg} - \frac{R_D V_{dg}}{r_d} = \frac{V_{gs} R_D}{r_d} + g_m V_{gs} R_D$$

$$V_{gd}\left[1 - \frac{R_D}{r_d}\right] = V_{gs}\left[\frac{R_D}{r_d} + g_m R_D\right]$$

$$\frac{V_{dg}}{V_{gs}} = \frac{\left[\frac{R_D}{r_d} + g_m R_D\right]}{\left[1 - \frac{R_D}{r_d}\right]}$$

$$\boxed{A_V = \frac{R_D + g_m r_d R_D}{r_d - R_D}}$$

The DC Analysis of CG amplifier, $V_{gs} = -2.2V$ and $I_{DQ} = 2.03mA$, with $I_{DSS} = 10mA$ and $V_p = -4V$ and $Y_{os} = 50\mu A/V$. Calculate g_m, r_d, Z_{in}, Z_{in}', Z_0, Z_0', A_V? with and without (r_d)?. $R_S = 1.1 K\Omega$, $R_D = 3.6 K\Omega$?

$$g_{m0} = \frac{2|I_{DSS}|}{|V_P|} = \frac{2|10 \times 10^{-3}|}{4} = 0.0050 = \boxed{5 \text{ mseimen}}$$

$$g_m = g_{m0}\left[1 - \frac{V_{gs}}{V_P}\right] = 5 \times 10^{-3}\left[1 - \left(\frac{2.2}{4}\right)\right] = 0.00225 = \boxed{2.25 \text{ msei}}$$

$$r_d = \frac{1}{Y_{OS}} = 20000 = \boxed{20 K\Omega}$$

$$Z_{in} = \frac{r_d + R_D}{1 + g_m r_d} = 513.0434\ \Omega = \frac{20k\Omega + 3.6k}{1 + 2.25 mS(20 KS}$$

$$Z_{in}' = Z_{in} \| R_S = \boxed{349.845\ \Omega}$$

$$Z_0 = r_d = \underline{\underline{20 K\Omega}}$$

$$Z_0' = R_D \| r_d = 3050.84 = \boxed{3.050 K\Omega}$$

0.00

$$(A_V \text{ with } r_d) \div \left[\frac{R_D + g_m r_d R_D}{r_d - R_D}\right]$$

$$= \frac{3.6 \times 10^{3} + 2.25 \times 10^{-3} \times 3.6 K\Omega \times 20 K\Omega}{2.25 \times 10^{-3} - 3.6 K\Omega}$$

$$A_V = \frac{165.6 \times 10^{3}}{-3599.77} = -0.04600$$

$$= \boxed{-46}$$

$$(A_V \text{ without } r_D) \div \left[\frac{R_D + g_m R_D}{1 - R_D}\right]$$

$$\boxed{A_V = -1.00225}$$

Verified

9/4/22

UNIT - II

Differential and Multistage Amplifiers:

(2M) **Multistage Amplifier:-** Amplification is carried out at more than one stage is called multistage amplifier.

(or)

Transistors circuit ~~have~~ two (or) more than two transistors is called multistage amplifier.

why Multistage Amplifier:-

(XV) Imp The o/p of a single stage amplifier is usually insufficient to drive an as a output devices.

→ The gain of a single stage amplifier is insufficient for particular purposes, then additional amplification over two (or) more stages is required.

→ To achieve this, the o/p of each amplifier stage is coupled to the next stage.

→ The resulting system is called as multistage amplifier.

(or)

→ Transistor circuit containing more than one stage of amplifier is known as "multistage amplifier"

2M (XX) **Purpose of coupling device:-**

→ The purpose of coupling device is to transfer the ac signal o/p from one stage to i/p of next stage and it isolate the DC conditions from one stage to next stage.

→ In multistage amplifier, a no. of single stage amplifiers are connected in Cascade arrangement.

→ (ie) The o/p of one stage is connected as an input for the next stage with suitable coupling device, called as passive elements [L, R, C, Transformer]

(XXX) Imp **Need for Cascading / Multistaging:-**

→ Many times, the primary requirements of the

(AW) of the amplifier cannot be achieved with single stage amplifier then go for cascading in the following cases:-

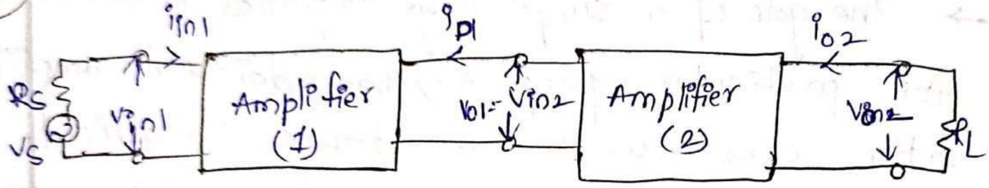
1) When the amplification of single stage is not sufficient.

2) When the input ~~and~~ o/p impedances are of not correct magnitude.

3) When the voltage gain of single stage amplifier can vary (unstable) →  (instability).

Pv & Av

(2M) (**) Consider a Multistage amplifier shown in fig:-



In the above figure, $V_{in1} = V_S$ input of 1st stage.

V_{o1} is o/p of stage-1. ; V_{o2} is o/p of stage-2.

V_{in2} i/p of stage-2

→ We know that voltage gain (A_V):- the Ratio of o/p voltage to i/p voltage.

{ Av & Pv asked for 2M so write from diagram.
{ Av & Pv in dB

$$A_V = \frac{V_{o2}}{V_S} = \frac{V_o}{V_{in}}$$

For above circuit $\boxed{A_V = \frac{V_{o2}}{V_{in1}}}$

$$A_V = \frac{V_{o2}}{V_{in2}} \times \frac{V_{in2}}{V_{in1}}$$

$$\Rightarrow A_V = \frac{V_{o2}}{V_{in2}} \times \frac{V_{o1}}{V_{in1}} \quad \Big| \because V_{in2} = V_{o1}$$

$$A_V = A_{V2} \times A_{V1}$$

overall voltage gain $\boxed{A_V = A_{V1} \times A_{V2} \times A_{V3} \times \cdots\cdots, A_{Vn}}$

voltage gain is the product of individual (~~voltage gains~~ stages.

Illy:-

Power gain (P_V) :- It is the ratio of o/p power to i/p power.

$$P_V = \frac{P_o}{P_{in}} = \frac{V_o I_o}{V_{in} I_{in}}$$

$$\boxed{P_V = P_{V1} * P_{V2} * \cdots * P_{Vn}}$$

The overall power gain is the product of powers of individual stages.

→ The voltage gain in dB can be expressed as.

$$\boxed{A_V(dB) = 20\log(A_V)} = 20\log(A_{V1}) \times 20\log(A_{V2}) * \cdots \times 20\log(A_{Vn})$$

The overall voltage gain in (dB) for Multistage amplifiers

$$\boxed{A_V(dB) = 20\log(A_{V1}) + 20\log(A_{V2}) + 20\log(A_{V3}) + \cdots + 20\log(A_{Vn})}$$

From above eqn:-

→ The overall gain in (dB) is sum of voltage gains in (dB) of individual stages.

Illy

$$P_V(dB) = 20\log(P_{V1}) * 20\log(P_{V2}) * 20\log(P_{V3}) * \cdots * 20\log(P_{Vn})$$

$$\boxed{P_V(dB) = 20\log(P_{V1}) + 20\log(P_{V2}) + \cdots + 20\log(P_{Vn})}$$

Classification of Multistage Amplifiers :-

① Based on type of Configurations :-

a) CE - CE amplifier ⎤ Cascade amplifier
b) CE - CC amplifier ⎦
c) CE - CB amplifier (or) cascode amplifier.
4) CC - CC amplifier (or) Darlington amplifier.

② Based on type of coupling method :-

a) RC coupled amplifier.
b) Transformer Coupled amplifier.
c) Direct coupled amplifier.

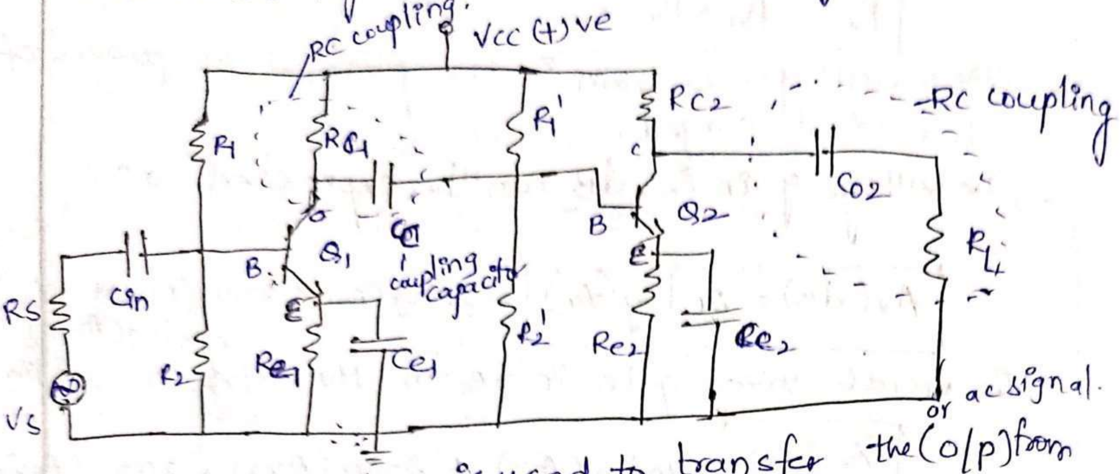
4M

Two stage RC coupled amplifier:

This is the most popular type of coupling because it is cheap and provides excellent audio amplification fedility over a wide range of frequencies.

→ It is usually used for voltage amplification.

→ The below figure shows the two stage RC coupled amplifier.



→ Coupling capacitor is used to transfer the (o/p) form one stage to next stage.

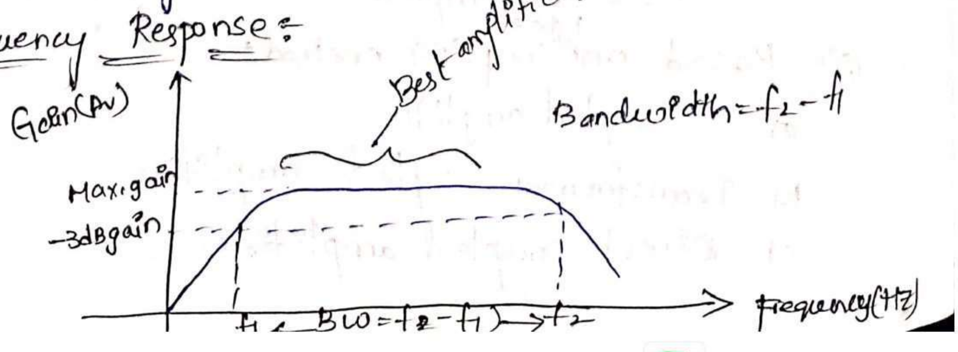
→ In above fig, transister is configured as CE-CE with voltage divider bias. Hence it is also called two stage $\boxed{\text{CE - CE}}$ cascade amplifier.

→ When an AC i/p signal is applied to the base of the first transistor it appears in the amplified form across its collector Resistor (RC1).

→ The amplified signal across (RC1) is given to base of next stage through coupling capacitor (Cc)

→ Then the second stage, thus further amplification of the signal. In this way the cascaded stages amplify the signal and the overall gain is considerably increases.

Frequency Response:



The above fig (Frequency Response) shows the frequency response of a two-stage RC coupled amplifier.

From fig, it is clear that at low frequencies the gain of the amplifier increases and at high frequencies the gain of the amplifier decreases whereas at mid-frequencies gain of the amplifier is constant.

→ From graph, we can say that two stage RC coupled amplifier provides excellent frequency response over a mid frequencies.

Frequency Response:-

2M **Advantages of RC coupled:-**

→ It has excellent frequency response over audio frequency Range [20HZ–20KHZ]

→ It has easiest (easy to construct) and low cost, since Resistors & capacitors are cheap. circuit weight less.

→ The circuit is very compact (less) as the modern resistors and capacitors are small and light weight.

2M **Disadvantages:-**

→ It has low voltage and power gain. (≈1000gain) because of loading effect.

→ It has poor impedance matching, due to resistors.

→ This circuit has tendency to become noisy with aging.

2M **Applications:-**

→ Widely used as Voltage amplifiers.

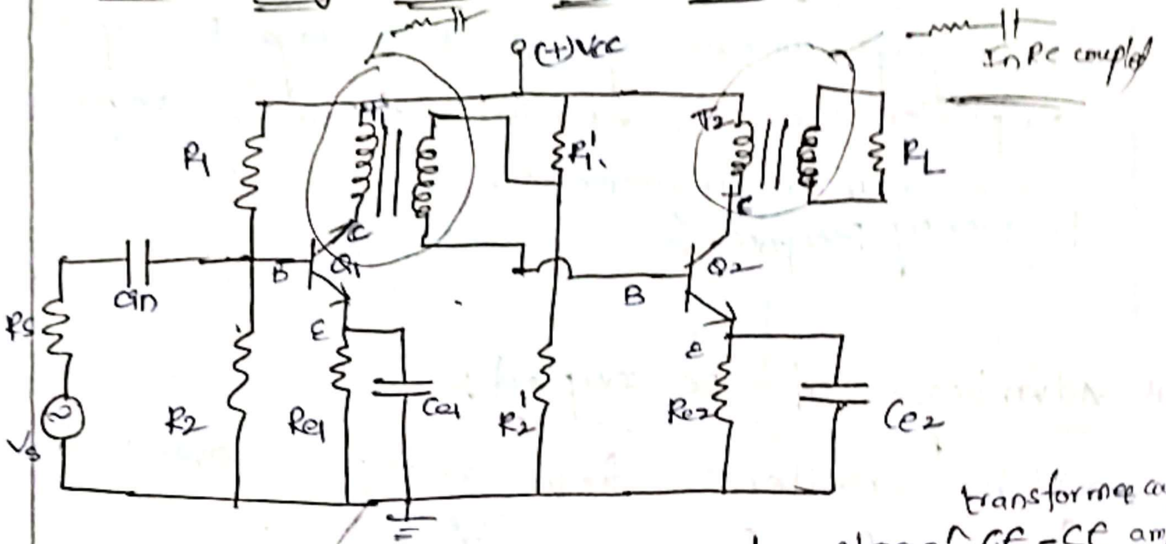
→ This are generally used in last stage of amplification.

Drawback (low voltage & power gain) overcome through transformer.

Transformer Coupled amplifier :-

Drawback of Rc coupled amplifier [low voltage gain and poor impedance matching] are overcome with the help of transformer coupled amplifier

The below fig. shows two stage transformer coupled amplifier :-



→ The above figure shows the two stage transformer coupled CE-CE amplifier where Collector resistor Rc is replaced with primary of the transformer and its secondary is connected to the base of the next (second) stage

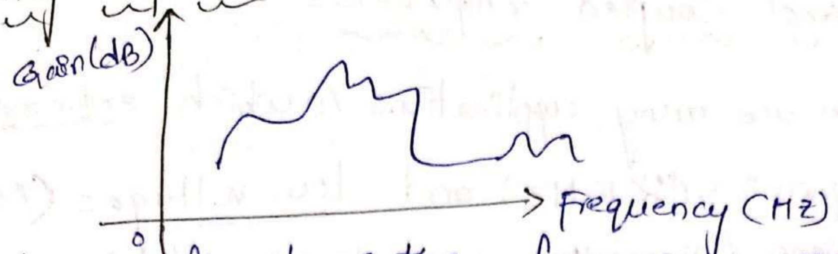
Operation :-

When an AC signal is applied to base of the first transistor it appears in amplified form across primary of the coupling transformer.

→ The voltage developed across primary is transferred to the input of the next stage by the transformer secondary.

→ In second stage, it is further amplified and appears across primary of second transformer (T_2) and to the load connected to the secondary.

Frequency Response :-



The above fig. shows the frequency response of transformer coupled amplifier.

→ It is clear that, frequency response is poor (i.e.) gain is not constant, gain is only constant over a small range of frequencies).

→ It is due to transformer losses such as capacitance leakage inductance and interwinding capacitance

Advantages :- (2M)

1) It provides an excellent impedance matching due to transformer

2) It provides high voltage and power gains.

3) No signal loss in collector / base resistors.

Disadvantages :- (2M)

1) It has poor frequency response.

2) The coupling transformers are bulky and expensive.

③ It ~~has~~ (provides) frequency distortions.

Applications :- (2M)

1) Used for impedance matching.

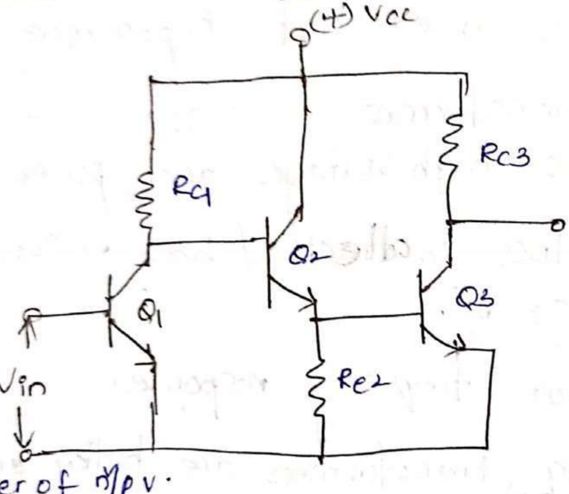
2) Used in Radio & TV receivers, to amplify RF (Radio Frequency 20KHz - 200KHz) signals

Direct Coupled Amplifiers:

There are many applications in which extremely low frequencies (i.e. <10HZ) and low voltages (i.e.) in order of nano / picovolts) are to be amplified with the help of direct coupled amplifier

→ Ex: The signals such as ECG [Electro cardiography] (or) photoelectric (or) thermoelectric , EEG, EMG] signals are having small amplitudes and low frequency signals.

→ These can be amplify with direct coupled amplifier as shown in below fig:-



The fig. is direct coupled amplifier with CE+CC+CE amplifier

operation is similar to Transformer.

Here weak signal is applied to i/p of Q1 and it is

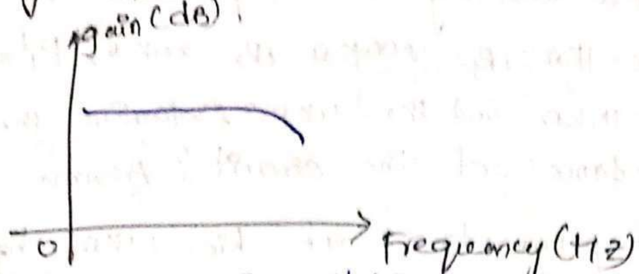
(Frequency Response:)

amplified and the o/p voltage is taken across Rc1.

→ The o/p voltage at Rc1 is directly connected to base of Q2 and it further amplifies and --so on.

→ The o/p voltage at Re2 is connected to base of Q3 and further amplifies then the o/p voltage is taken across Rc3.

Frequency Response:-



At low frequencies gain in (dB) is constant.

Advantages:-

1) The circuit arrangement is simple because of Minimum resistors.
2) The circuit cost is low because of abcence of expensive coupling devices.

Disadvantages:-

1) It cannot be used for amplification of high frequencies.
2) The operating point is shifting from one point to another, due to direct coupling.

Here I_C value disturbs the base voltage of Q_2 because of no capacitor

Applications:-

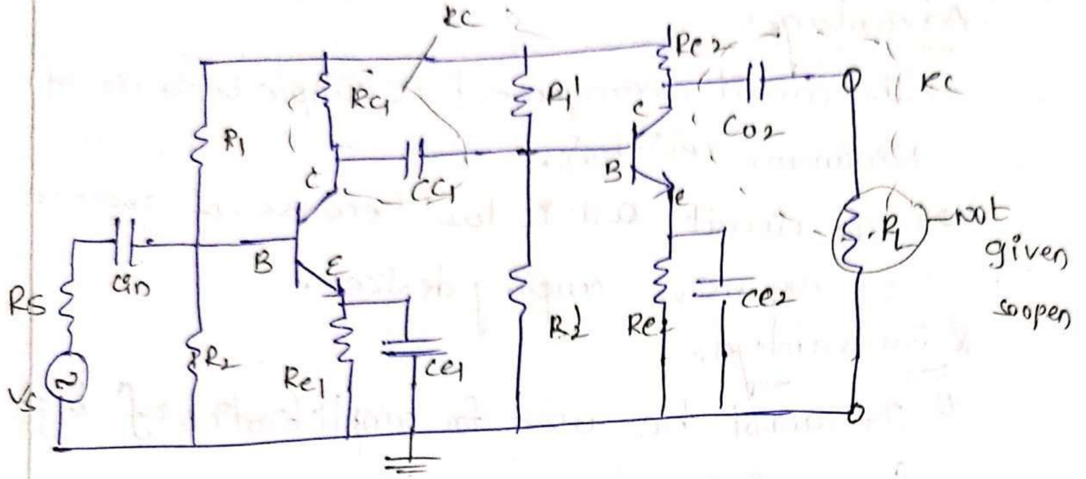
→ It can be used for low voltages and low frequencies.

→ It is mainly used in intial stages in multistage amplifiers.

Analysis of CE-CE Amplifier:-

Note:- In analysis of multistage amplifiers, first we should analyse last stage then go for preceeding stages; because the i/p impedance of last stage will acts as a load resistor for the preceeding stage.

Consider a two stage RC coupled CE-CE amplifier with $R_S = 1K\Omega$, $R_1 = 200K\Omega$, $R_2 = 20K\Omega$, $R_1' = 47K\Omega$ $R_2' = 4.7K\Omega$ $R_{C1} = 15K\Omega$ and $R_{C2} = 4K\Omega$? Determine the gain's & impedances of the circuit? Assume the typical values of h-parameters are $h_{ie} = 1.1K\Omega$, $h_{fe} = 50$, $h_{re} = 2.4\times10^{-4}$, $h_{oe} = 25\,\mu A/V$?



$\therefore R_L = R_{C2}$

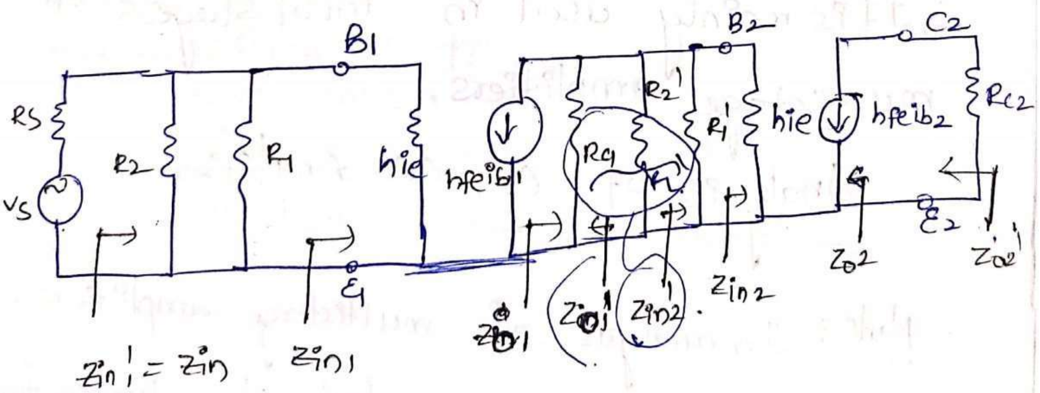
$R_L = 4K\Omega$

$h_{oe}R_L = 25\times10^{-6}\times4\times10^{3}$

$= 100\times10^{-3}$

$= 0.1 < 0.1$

Hence use simplified Model.



Analysis of stage-2 [CE]

$A_{i2} = h_{fe} = 50$

$$\boxed{Z_{in2} = h_{ie} = 1.1K\Omega}$$

3) $Z_{in2}' = R_1' || R_2' || Z_{in2} = 47k\Omega || 4.7k\Omega || 1.1k\Omega$

$= \boxed{874.78\,\Omega}$

4) $A_{V2} = \frac{A_{I2} \times R_L}{Z_{in2}} = \frac{50 \times 4k\Omega}{1.1k\Omega} = 1\boxed{81.81}$

5) $\boxed{Z_{o2} = \alpha}$

6) $\boxed{Z_{o2}'} = Z_{o2} || R_{C2} = 4k\Omega || \alpha = \boxed{4k\Omega}$

Analysis of stage-1 [CE]:-

Load resistance $R_{L1} = Z_{in2}' || R_{C1}$

$= 874.78 || 15k\Omega$

$\boxed{R_{L1} = 826\,\Omega}$

condition is $h_{oe} \times R_{L1} = 826 \times 25 \times 10^{-6}$

$= 0.02 < 0.1$

Hence use simplified Model.

$A_{I1} = h_{fe} = 50$

$Z_{in1} = h_{ie} = 1.1k\Omega$

$Z_{in1}' = R_1 || R_2 || Z_{in1} = 200k\Omega || 20k\Omega || 1.1k\Omega$

$= 1037\,\Omega$

$\boxed{A_{V1}} = \frac{A_{I1} \times R_{L1}}{Z_{in1}} = \frac{50 \times 826}{1.1k\Omega} = \boxed{37.54}$

$Z_{o1} = \alpha$

$\boxed{Z_{o1}'} = R_{L1} || Z_{o1} = 826 || \alpha = \boxed{826\,\Omega}$

$A_{VS} = R_S$

For overall Amplifier:-

$A_I = A_{I1} \times A_{I2} = 50 \times 50 = 2500$

$A_V = A_{V1} = 181.81 \times 37.54 = 6825$

$Z_{in} = Z_{in1}' = 1037\,\Omega$

$Z_o = Z_{o2}' = 4k\Omega$

with Rs ÷ $A_{VS} = \dfrac{\cancel{B}\, Z_{in1}'}{Z_{in1}' + R_s \cancel{\phi}} \times A_V$

{ In case if particularly they ask do this

$$A_{VS} = \frac{1037}{1037 + 1K\Omega} = 0.509 \times 6825$$

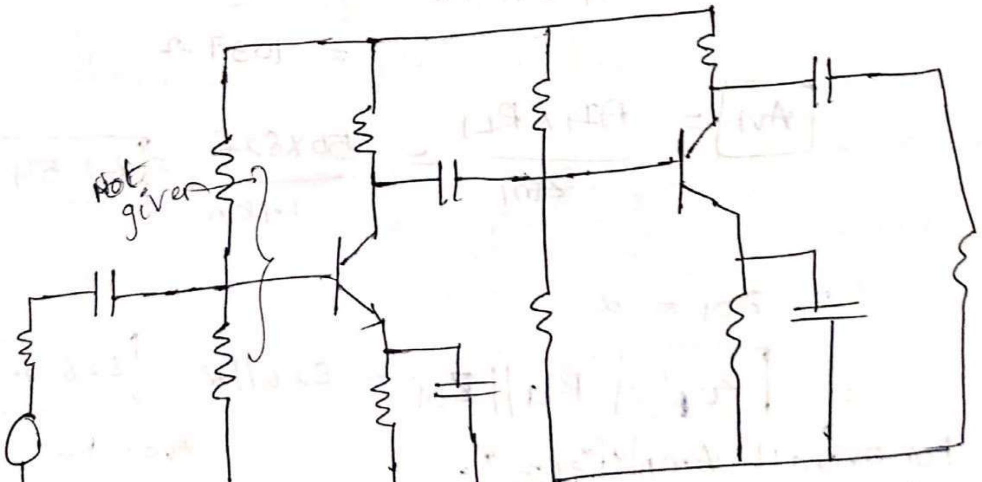
$$\boxed{A_{VS} = 3474.48}$$

with Rs ÷ $A_{IS} = \dfrac{R_s}{Z_{in1}' + R_s} \times A_I$

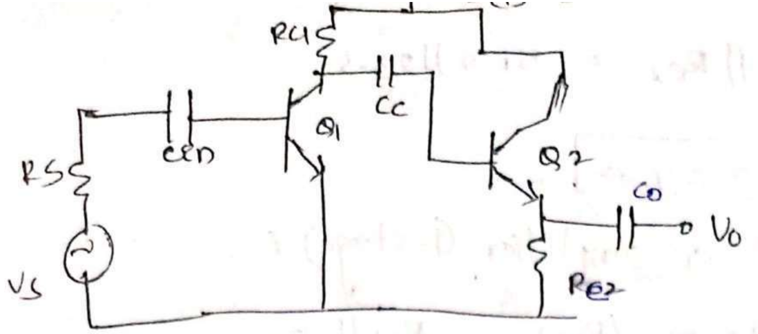
$$A_{IS} = \frac{I_L}{I_S} = \frac{I_L}{I_{C2}} \times \underbrace{\frac{I_{C2}}{I_{B2}}}_{A_{I2}} \times \underbrace{\frac{I_{C1}}{I_{B1}}}_{A_{I1}} \times \frac{I_{B1}}{I_S}.$$

$$\boxed{A_{IS} = 1227.29}$$

Consider a two stage RC coupled ~~CE~~-CC amplifier with $R_s = 1K\Omega$, $R_{C1} = 10K\Omega$, $R_{E2} = 5K\Omega$. Assume Transistor parameters are its typical values. Calculate Voltage gain, Current gain, Zin and Zo of the amplifier?



This is RC coupled circuit but given parameters are only 3 resistors.



For CE

h-parameters

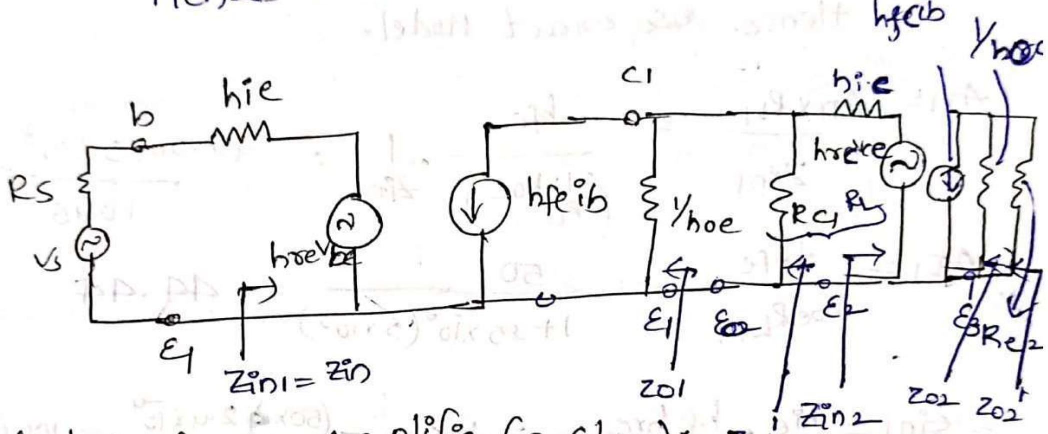
$h_{ie} = 1.1 k\Omega$, $h_{fe} = 50$, $h_{re} = 2.4 \times 10^{-4}$ $h_{oe} = 25 \times 10^{-6} A/$

$h_{ic} = 1.2 k\Omega$, $h_{fc} = -51$ $h_{rc} = 1$ $h_{oc} = 25 \times 10^{-6} A/$

condition is $h_{oe} R_{e2} = 25 \times 10^{-6} \times 5 \times 10^{3}$

$$= \boxed{0.125 > 0.1}$$

Hence use exact model



Analysis of CC Amplifier (2-Stage):-

$$A_{I2} = \frac{-h_{fC}}{h_{oc}R_L + 1} = 45.33 = \frac{51}{1 + 25\times10^{-6}\times5\times10^{3}}$$

$$Z_{in2} = h_{ie} - \frac{h_{fc}h_{re}}{h_{oc} + 1/R_L} \Rightarrow 1.2k - \frac{(51)(1)}{25\times10^{-6} + \frac{1}{5\times10^{3}}} =$$

$$Z_{in2} = 227.866 k\Omega$$

$$A_{V2} = \frac{A_{I2} \times R_L}{Z_{in2}} = \frac{45.33 \times 5 \times 10^{3}}{227.86 \times 10^{3}} = 0.994$$

$$Z_{O2} = \frac{h_{ic}}{h_{ic}h_{oc} - h_{fc}h_{rc}} = \frac{1.2 k\Omega}{1.2\times10^{3}\, 25\times10^{-6} - (-51)(1)}$$

$$Z_{O2} = 23.515\ \Omega$$

$Z_{o2}' = Z_{o2} \,||\, R_{e2} = 5k\Omega \,||\, 23.5$

$$\boxed{Z_{o2}' = 23.39\,\Omega}$$

Analysis of CE amplifier (1-stage) :-

Load resistance $(R_{L1}) = R_{c1} \,||\, Z_{in2}$

$= 10k\Omega \,||\, 227.88k\Omega$

$= 9.57k\Omega$

The condition is $h_{oe}R_{L1} = 9.57k\Omega \times 25\times10^{-6}$

$= 0.237 > 0.1$

Hence use exact Model.

$$A_{V1} = \frac{A_{I1}\times R_{L1}}{Z_{in1}} = \frac{-h_{fe}}{\left(\frac{1}{R_L}+h_{oe}\right)} \cdot \frac{1}{Z_{in}} = \frac{44.44\times5\times10^{3}}{1046} = 212.42$$

$$A_{I1} = \frac{+h_{fe}}{h_{oe}R_{L}+1} = \frac{50}{1+25\times10^{-6}(5\times10^{3})} = 44.44$$

$$Z_{in1} = h_{ie} - \frac{h_{fe}h_{re}}{h_{oe}+1/R_L} = 1.1k\Omega - \frac{(50\times)\,2.4\times10^{-4}}{25\times10^{-6}+1/5\times10^{3}} = 1046 = 1.046k\Omega$$

$$Z_{o1} = \frac{h_{ie}}{h_{ie}h_{oe}-h_{fe}h_{re}} = \frac{1.1\times10^{3}}{(1.1)\times10^{3}(25\times10^{-6})-50\times2.4\times10^{-4}} = 70.967\,k\Omega$$

$$Z_{o1}' = Z_{o1} \,||\, R_{C1} = \frac{70.967\times10^{3}\times10\times10^{3}}{70.967\times10^{3}+10\times10^{3}} = 8764 = 8.764k\Omega$$

For Overall Amplifier :-

CC-CB Amplifier [Cascode Amplifier]

$A_I = A_{I1}\times A_{I2} = 2014.46$

$A_V = A_{V1}\times A_{V2} = 211.145$

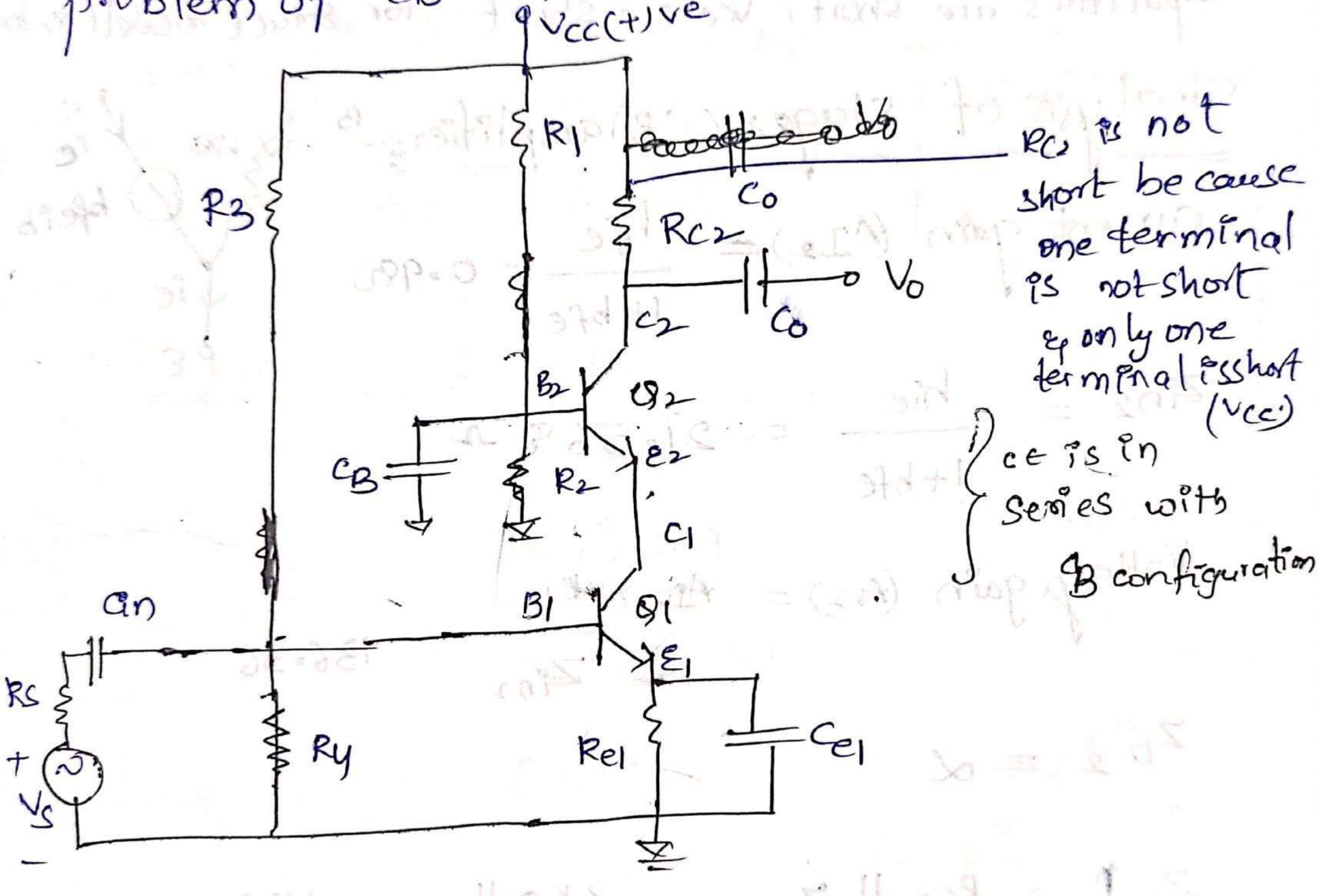
$Z_{in} = Z_{in1}' =$ (No resistors so no Z_{in1}'

$Z_o = Z_{o2}' = 23.39\,\Omega$

CE-CB Amplifier [Cascode Amplifier].

The cascade amplifier consists of CE amplifier in series with 'CB' amplifier as shown in below fig:

→ With this connection the low i/p impedance problem of CB can be eliminated.



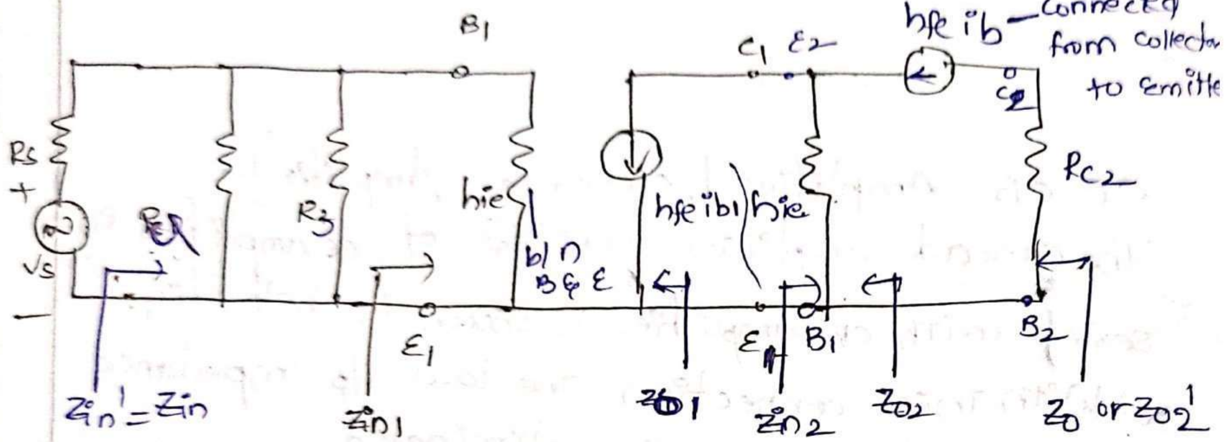
Rc2 is not short because one terminal is not short & only one terminal is short (Vcc)

CE is in series with CB configuration.

Consider a Cascode (CE-CB) amplifier with circuit parameters $R_S = 1K\Omega$, $R_3 = 200K\Omega$, $R_4 = 10K\Omega$ and $R_{C_2} = 3k\Omega$ (or) $R_L = 3K\Omega$ and the transistor parameters for both tansistors are $h_{ie} = 1.1K\Omega$, $h_{fe} = 50$. Calculate i/ Z_{in}, A_I, A_V and Z_o of the amplifier.

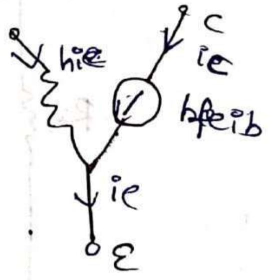
From given data, we can use $\boxed{\text{simplified model}}$ using as shown in below figure

There is no need with $R_1 \| R_2$, R_{e_1} because they are ground & R_{e} is short due to c_{e_1}.



capacitors are short, Vcc are short for Exact model (in before fig)

Analysis of stage 2 (CB) amplifier:



$$\text{current gain } (A_{I_2}) = \frac{h_{fe}}{1+h_{fe}} = 0.980$$

$$Z_{in_2} = \frac{h_{ie}}{1+h_{fe}} = 21.568\,\Omega$$

$$\text{Voltage gain } (A_{V_2}) = A_{I_2} \times \frac{R_L}{Z_{in_2}} = 136.36$$

$$Z_{o_2} = \alpha$$

$$Z_{o_2}' = R_{C_2} \| Z_{o_2} = 3K\Omega \| \alpha = 3K\Omega$$

$$Z_o = Z_{o_2}' = 3K\Omega$$

Analysis of CE (1st stage) :-

$A_{I1} = h_{fe} = 50$

~~hfe~~ $Z_{in} = h_{ie} = 1.1k\Omega = Z_{in1}$

$A_V = -h_{fe} \times \frac{R_{L1}}{Z_{in1}}$ $R_{L1} = Z_{in2}$ $= 0.98$ (or) $A_{I1} \times \frac{R_{L1}}{Z_{in1}}$ $= Z_{ir}$

$A_{V1} = 0.98$

$Z_{o1}' = Z_{o1} || R_L$

Z_{o1}

$= \Omega || 21.56$

$Z_{o1}' = 21.56\Omega$

$= R_3 || R_4 || Z_{in1}'$

$Z_{in1}' = 200k\Omega || 10k\Omega || 1.1$

$= 986.10\ \Omega$

Overall Amplifier :-

$A_I = A_{I1} \times A_{I2} = 50 \times 0.98 = 49$

$A_V = A_{V1} \times A_{V2} = 136.36 \times 0.98 = 133.6$

$Z_{in} = Z_{in1}' = 986.10\Omega$

$Z_o = Z_{o2}' = 3k\Omega$

with Rs :- $A_{VS} = \frac{Z_{in1}'}{Z_{in1}' + R_S} \times A_V$

$A_{VS} = 66.34.$

MOS CASCODE

C

with Rs :- $A_{IS} = \frac{R_S}{Z_{in1}' + R_S} \times A_I$

$= \frac{1 \times 10^3 \times 49}{986.10 + 1 \times 10^3}$

$= 24.67$

0.001354

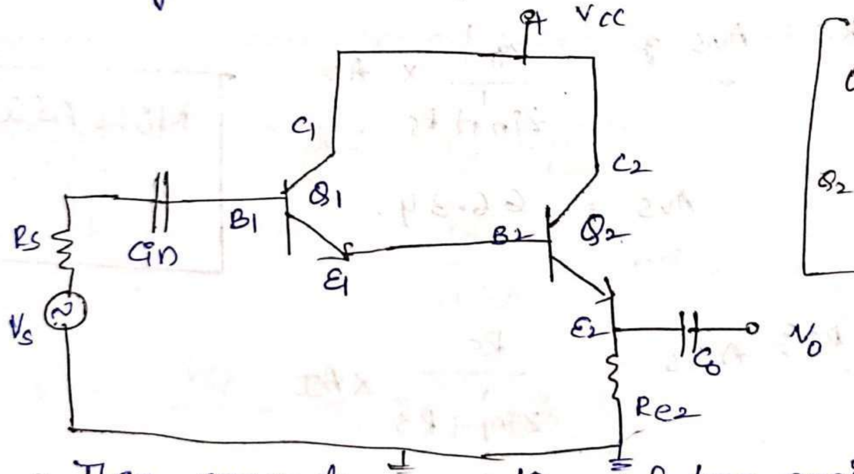
(CC - CC) [Darlington Amplifier]. (or) Two Stage Emitter follower:

We know that out of three configurations (CE, CB, CC) common collector (CC) (or) Emitter follower bias circuit has high i/p impedance [i.e., typically (200-500)kΩ]

→ A single stage Emitter follower circuit can give input impedance upto (500kΩ). However the i/p impedance by considering biasing resistors is considerably decreases, because $\boxed{Z_{in}' = R_1 || R_2 || Z_{in}}$

→ To keep the i/p impedance of the circuit $< R_2$ has high, by direct coupling of (CC-CC) amplifier.

→ The below fig. shows the Direct coupling of a two stage CC-CC amplifier.



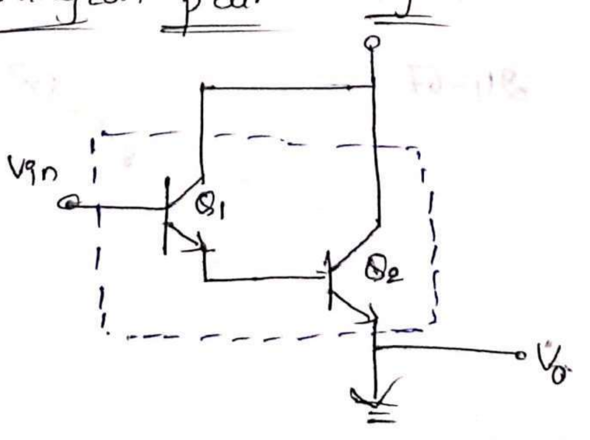
Q1 → i/p = B1
o/p = E

Q2 → i/p - B2
o/p = E2

→ This cascade connection of two emitter followers is also called Darlington amplifier

In single stage due to resistors i/p impedance dec so we use darlington

(QA) Darlington pair Diagram:



Analysis of stage-2 (CC) Amplifier:-

Assume that load resistor ~~of~~ second stage (2) ($R_{L2} = R_{e2}$) will satisfy the condition $h_{oe} R_{L2} \approx h_{oe} R_{e2} < 0.1$ Hence use simplified Model.

$$\boxed{\begin{aligned} A_{I2} &= 1 + h_{fe} \\ Z_{in2} &= h_{ic} + (1+h_{fe}) R_{e2} \\ A_{V2} &= \frac{A_{I2} R_{L2}}{Z_{in2}} \\ Z_{o2} &= \frac{R_s + h_{ie}}{1+h_{fe}} \end{aligned}}$$

(or) CC interms of CE $A_{V2} = 1 - \frac{h_{ie}}{Z_{in2}}$

$R_s = Z_{in2}$

Analysis of stage-1 (CC) amplifier:-

The load resistance $R_{L1} = Z_{in2}$ (in range of 100 kΩ) Generally Z_{in} is high, usually it doesnot meet the requirement ie ($h_{oe} R_{L1} < 0.1$). Hence we have to use exact method for analysis of stage-1.

→ In some cases, if we know only CE parameter's then CC analysis can be done with following assumption.

$$\boxed{\begin{aligned} h_{fc} &= -(1+h_{fe}) & h_{oc} &= h_{oe} \; \& \\ h_{ic} &= h_{ie} & h_{rc} &= 1 \end{aligned}}$$

$h_{ie} = 1.1 k\Omega$ $h_{ic} = 1.21 k\Omega$

$h_{fe} = 50$

$h_{re} = 2.4 \times 10^{-4}$

$h_{oe} = 25 \mu A/V$

$h_{fc} = -51$

$h_{rc} = 1, h_{oc} = 25 \mu A$

From above assumptions;

$$A_{I1} = \frac{-h_{fc}}{1 + h_{oc} R_{L1}} = \frac{+(1+h_{fe})}{1 + h_{oe} R_{L1}}$$

$$Z_{in1} = h_{ic} - \frac{h_{rc} h_{fc}}{h_{oc} + 1/R_L} = h_{ie} + \frac{(1+h_{fe})}{h_{oe} + 1/R_L}$$

$$A_{V1} = \frac{h_{fc}}{h_{oc} + 1/R_L} \cdot \frac{1}{Z_{in}} = \frac{-(1+h_{fe})}{h_{oe} + 1/R_L} \cdot \frac{1}{Z_{in1}} \text{ (or) } \frac{A_{I1} R_{L1}}{Z_{in1}}$$

$$Z_{o1} = \frac{h_{ic}}{h_{ic} h_{oc} - h_{fe} h_{rc}} = \frac{h_{ie}}{h_{ie} h_{oe} + (1+h_{fe})}$$

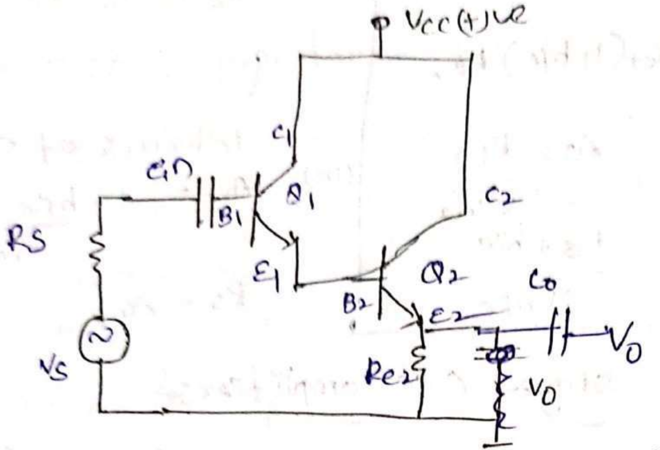
Consider Darlington (cc-cc) amplifier with

$R_S = 3K\Omega$ & $R_{e2} = R_L = 3K\Omega$,

The typical h-parameters for both transistors

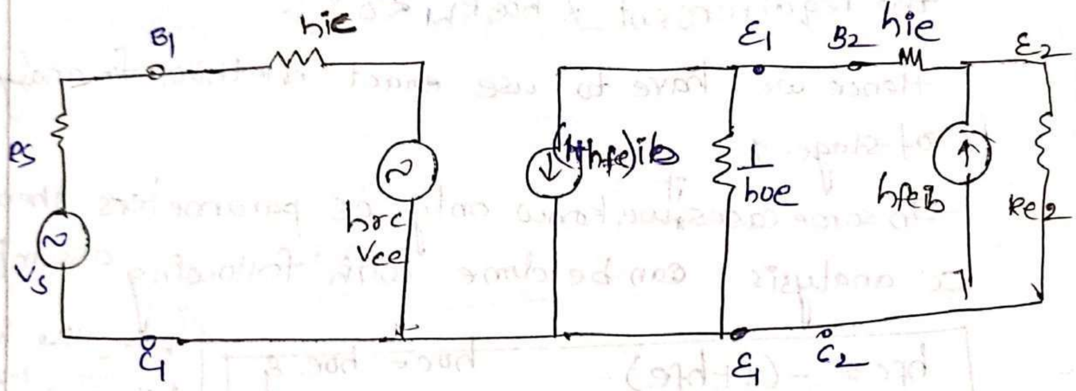
$h_{ie} = 1.1K\Omega$; $h_{fe} = 50$; $h_{oe} = 25\times10^{-6}\mho/V$

Calculate A_I, Z_{in}, A_V, Z_o of amplifier.



$h_{oe}R_{L1} = 25\times10^{-6}\times 3\times10^{3} = 75\times10^{-3} = 0.075<1$

Hence use simplified Model.



Analysis of stage 2 (cc) amplifier:-

$A_{I2} = 1+h_{fe}$ $\quad R_L = R_{e2} = 3K\Omega$

$A_{I2} = 1+50 = 51$

$Z_{in2} = h_{ie} + (1+h_{fe})\underbrace{R_L}_{R_{e2}}$

$Z_{in2} = \overset{1.1K\Omega}{\cancel{0}} + (1+50)3\times10^{3} = 154.1K\Omega$

$A_{V2} = A_{I2}\times\frac{R_{L2}}{Z_{in2}} = \frac{1-h_{fe}}{Z_{in2}} = 0.99$

$$Z_{o2} = \frac{R_s + h_{ie}}{1 + h_{fe}} = \frac{154.1 \times 10^3 + 1.1 \times 10^3}{51} = 3.043 k\Omega$$

$$Z_0 = Z_{o2}' = Z_{o2} \| R_L = 3.043 \times 10^3 \times 3k\Omega = 1.500 k\Omega$$

Analysis of stage-1 (CC) Amplifier.

using Exact Model. $R_{L1} = Z_{in2} = 154.1 k\Omega$

using as parameters.

$$A_{I1} = \frac{+h_{fc}}{(h_{oc}R_L + 1)} \textcircled{x} = +\left(\frac{1 + h_{fe}}{1 + h_{oe}R_{L1}}\right) = -10.51$$

$$Z_{in} = Z_{in1} = h_{ic} - \frac{h_{rc}h_{fc}}{h_{oc} + 1/R_L} = h_{ie} + \frac{(1 + h_{fe})}{h_{oe} + 1/R_{L1}} = 1.62 M\Omega$$

$$A_{V1} = \frac{h_{fc}}{h_{oc} + 1/R_L} \cdot \frac{1}{Z_{in1}} = A_{I1}\frac{R_{L1}}{Z_{in1}} = 0.99$$

$$Z_{o1} = \frac{h_{ic}}{h_{ic}h_{oc} - h_{fc}h_{rc}} = \frac{h_{ie}}{h_{ie}h_{oe} + (1 + h_{fe})}$$

$$Z_{o1} = 21.55 \Omega$$

Overall Amplifier:

$$A_I = A_{I1} \times A_{I2} = 536$$

$$A_V = A_{V1} \times A_{V2} = 0.98$$

$$Z_{in} = Z_{in1} = 1.62 M\Omega$$

$$Z_{o2}' = Z_0 = 1.5 k\Omega$$

Miller's Theorem:

In general the miller's theorem is used for converting any circuit having configuration in fig 1, into another configuration as shown in fig 2

$K = \frac{V_2}{V_1}$ gain

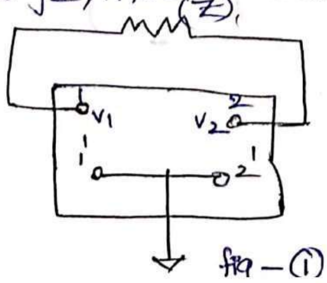


fig – ①

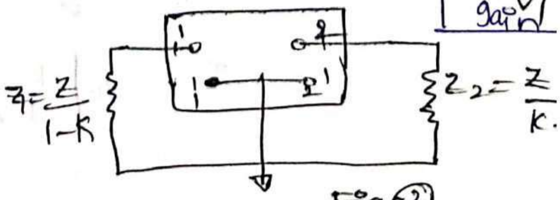


Fig ②

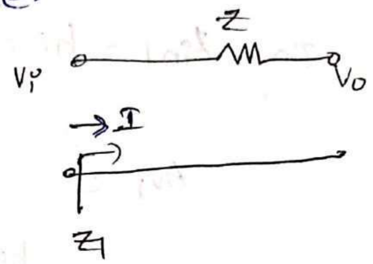
(**)

1) **Statement:-** "It states that "an impedance 'z' is connected b/n two nodes then it can be replaced by two separate impedances (Z_1 & Z_2) where Z_1 is connected b/n ~~node~~ node & ground and ground and 'Z_2' is connected b/n node & ground. and its magnitudes/values depends on i/p & o/p voltages. Ratio and given by $Z_1 = \frac{Z}{1-K}$ and $Z_2 = \frac{Z \cdot K}{K-1}$ where $K = \frac{V_2}{V_1}$ or $\frac{V_o}{V_{in}}$"

proof:- From above statement the effect of impedance 'z'

case i:- on the i/p side is the ratio of i/p voltage to i/p current (i) which flows from i/p to o/p side.

$$Z_1 = \frac{V_i}{I}$$



$$\text{where } I = \frac{V_i - V_o}{Z}$$

$$I = V_i\left[\frac{1 - V_o/V_i}{Z}\right]$$

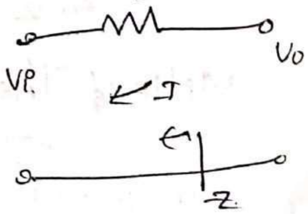
$$I = V_i\left[\frac{1-K}{Z}\right]$$

$$\text{Then } Z_1 = \frac{V_i}{V_i\left[\frac{1-K}{Z}\right]} = \frac{Z}{1-K}$$

$$\boxed{Z_1 = \frac{Z}{1-K}}$$ where 'K' is gain of amplifier $\left(\frac{V_2}{V_1}\right)$ or $\left(\frac{V_o}{V_i}\right)$

case ii:- From miller's theorem, the effect of impedance (Z) on o/p circuit is the ratio of o/p voltage (V_o) to the current (I) flows from o/p to i/p.

$$Z_2 = \frac{V_o}{I}$$



$$\text{where } I = \frac{V_o - V_i}{Z}$$

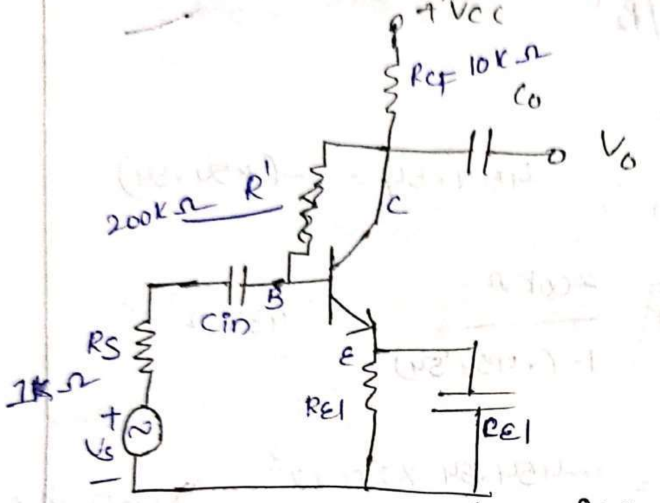
$$I = V_o\left[\frac{1 - V_i/V_o}{Z}\right] = V_o\left[\frac{1 - 1/K}{Z}\right]$$

$$I = V_o\left[\frac{K-1}{KZ}\right]$$

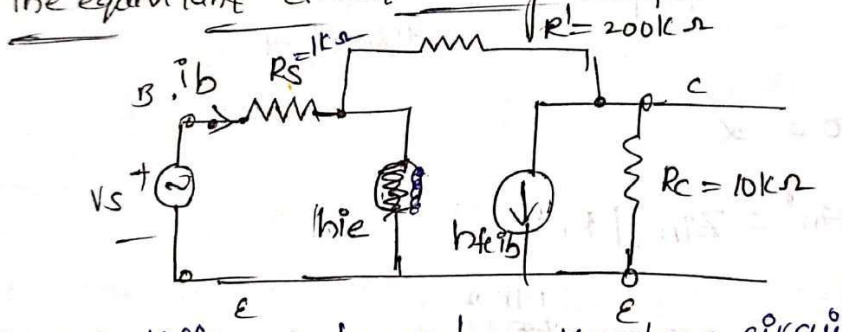
$$\therefore \quad Z_2 = \frac{V_0}{V_0\left[\frac{K-1}{KZ}\right]}$$

$$\boxed{Z_2 = K\left[\frac{Z}{K-1}\right]}$$

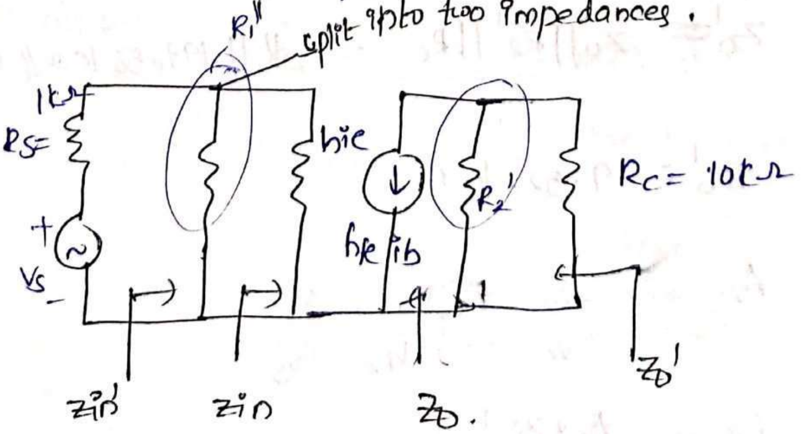
Consider a CE amplifier with collector-to Base biasing with $R_S = 1K\Omega$, $R_C = 10K\Omega$, and $R' = 200K\Omega$ The transistor parameters are $h_{ie} = 1.1k\Omega$ & $h_{fe} = 50$. calculate Zin, AI, Av, Zo & Avs, AIs ?



The equivalent circuit using simplified Model:-



It is difficult to analyse the above circuit, so by using millers theorem the above equivalent circuit can be simplified Model as shown below:-



Input Impedance :-

$R_1' = \frac{R'}{1-K}$; $R_2' = \frac{KR'}{K-1}$

$Z_{in} = h_{ie} = 1.1k\Omega$

$K = A_v = \frac{V_o}{V_i}$

$= 2001$

$A_I = h_{fe} = 50$

$Z_0 = \alpha$

$Z_0' = Z_0 || R_C || R_2'$

$K = A_v = \frac{A_I R_L'}{Z_{in}} = 454.54 = -(454.54)$

$R_1' = \frac{R'}{1-K} = \frac{200k\Omega}{1-(-454.54)} = 439\Omega$

$R_2' = \frac{KR'}{K-1} = \frac{-454.54 \times 200 \times 10^3}{-454.54-1} = 199.560k\Omega$

$Z_0 = \alpha$

$Z_{in}' = Z_{in} || R_1'$

$= \frac{439 \times 1.1k\Omega}{439 + 1.1k\Omega} = 313.76\Omega$

$Z_0' = Z_0 || R_2' || R_C = \alpha || 199.56 k\Omega // 10k\Omega$

$Z_0' = 9.522k\Omega.$

$A_{VS} = \frac{V_o}{V_s} = \frac{V_{ce}}{V_{be}} \frac{V_{be}}{V_s}$

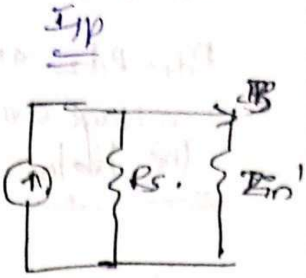
$A_{VS} = \frac{A_V \times Z_{in}'}{Z_{in}' + R_S} = -108.55$

$$A_{IS} = \frac{I_o}{I_s} = \frac{I_L}{I_c} \times \frac{I_c}{I_b} \times \frac{I_b}{I_s} \Rightarrow \boxed{\frac{-R_2'}{R_2'+R_c} \times A_I \times \frac{R_s}{R_s+Z_{in}}}$$

= ~~[illegible]~~

$$= \boxed{A_I \cdot \frac{R_s}{R_s+Z_{in}'}} \rightarrow \text{using this}$$

$\underline{I/p}$



$$\boxed{A_{IS} = -36.242}$$

$$A_{IS} = \frac{-199.56k\Omega}{199.56k\Omega + 10k\Omega} \times 50 \times \frac{1k\Omega}{1k\Omega + 313.76\Omega}$$

Differential Amplifiers :- /pair

→ This amplifier is most widely used building block in analog electronic circuit design.

Ex:- The i/p stage of every op-amp (operation amplifier) is differential amplifier, and also BJT differential amplifier is the basis of very high speed logic circuit family.

→ This amplifiers are used most widely because of these two reasons.

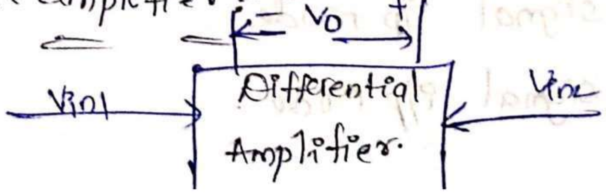
1) The performance of the differential amplifier depends critically on the matching b/n two sides of the circuit.

2) This amplifiers utilise more components than single ended circuits.

→ Differential Amplifier :- It is defined as its output is the difference b/n the two i/p signals.

i.e) $\boxed{V_o = V_{in2} - V_{in1} \quad (\text{or}) \quad V_o = V_{in1} - V_{in2}}$

The below fig shows the simple block diagram of differential amplifier :-



$V_0 = A_d (V_{in2} - V_{in1}) = A_d V_{id}$ where $V_{id} = V_{in2} - V_{in1}$

Where $A_d \rightarrow$ differential gain

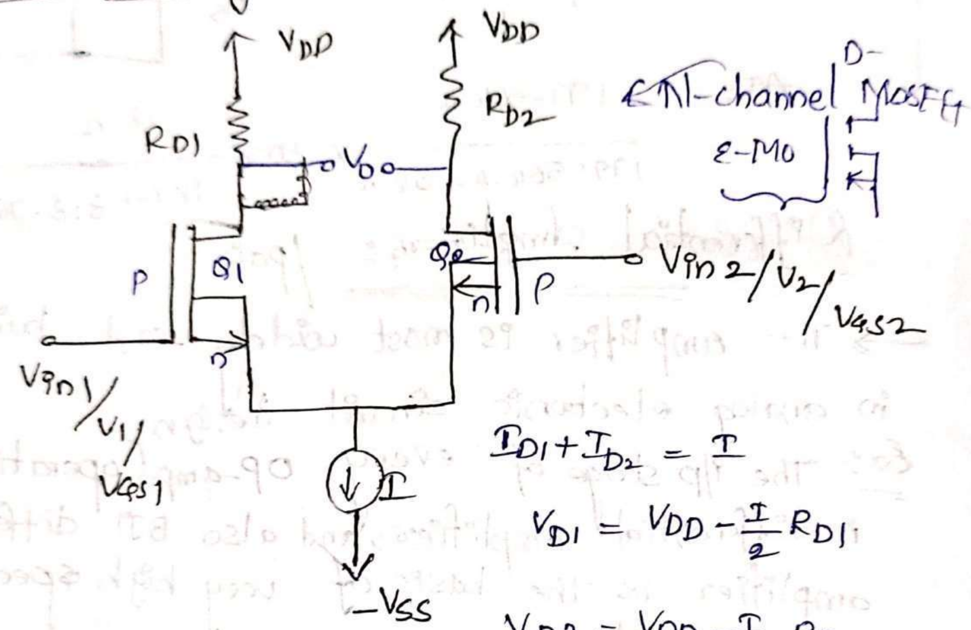
MOS Differential Amplifier:-

Q_1, Q_2 are two mosfets (2)

R_{d1}, R_{d2} are resistors (2), current source (1)

2- voltage sources for biasing.

The below fig shows the MOSFET differential (n-channel) Amplifier



$I_{D1} + I_{D2} = I$

$V_{D1} = V_{DD} - \frac{I}{2} R_{D1}$

$V_{D2} = V_{DD} - \frac{I}{2} R_{D2}$

$V_0 = V_{D2} - V_{D1}$ (or) $V_{D1} - V_{D2}$ (or) $V_{GS1} - V_{GS2}$

The above circuit work as an differential amplifier with the following conditions are satified.

→ Both transistors (Q_1 & Q_2) are identical [Both-n or Both-p]

Drain of Q_1 transistor.

→ $I_{D1} + I_{D2} = I$

$V_{D1} = V_{DD} - \frac{I}{2} R_{D1}$ & $V_{D2} = V_{DD} - \frac{I}{2} R_{D2}$.

$V_0 = V_{D2} - V_{D1}$ (or) $V_{D1} - V_{D2}$ (or) $V_{GS1} - V_{GS2}$

$V_{ID} = V_{GS1} - V_{GS2}$ (or) $V_1 - V_2$, or $(V_2 - V_1)$ (or) $V_{GS2} - V_{GS1}$

Differential amplifier operates on 4 modes:-

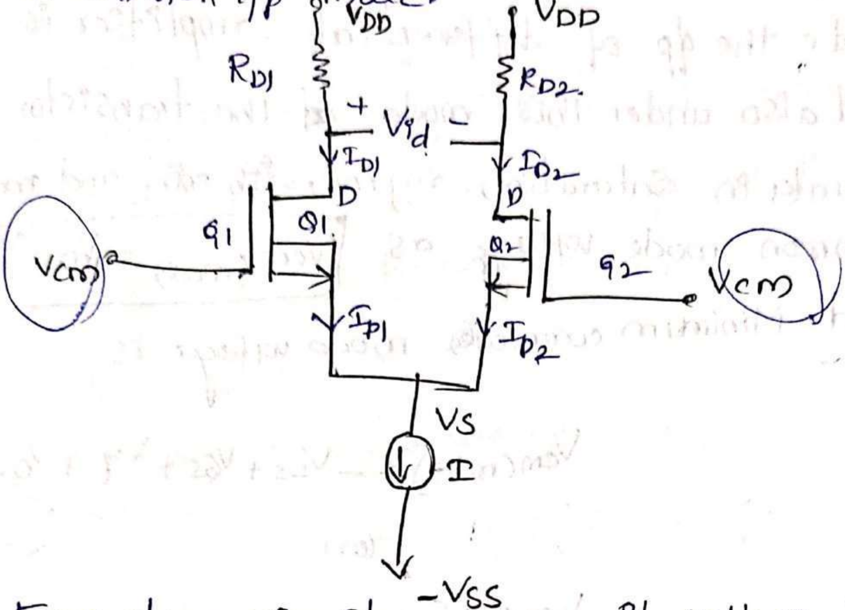
① Common i/p mode ② differential i/p Mode

③ Large signal i/p mode

④ Small signal i/p Mode.

Differential Amplifier as a Common mode is applied b/n two i/p signals:- ① Mode.

If same voltage (V_{in1} & V_{in2}) applied at Q_1 & Q_2 transistors then the differential amplifier operates in common i/p mode.



From above circuit, if same i/p voltage is applied to Q1 & Q2 then both transistors will turn on and they operate in saturation region.

such that $I_{D1} = I_{D2} = I/2 \Rightarrow \boxed{I_{D1} + I_{D2} = I}$.

→ We know that drain current of a MOSFET is

$$I_D = \underbrace{\frac{k_n'}{2}\left[\frac{\overset{\text{width}}{W}}{\underset{\text{Length of oxide layer.}}{L}}\right]}_{g_m}(V_{GS}-V_t)^2$$

$V_{GS}-V_t = V_{ov}$

For Q_1:-

$$I_{D1} = \frac{I}{\cancel{2}} = \frac{k_n'}{\cancel{2}}\left(\frac{W}{L}\right)(V_{ov})^2$$

where V_{ov} — Over drive Voltage.

$$(V_{ov})^2 = \frac{I}{\left(\frac{k_n' W}{L}\right)} \Rightarrow V_{ov} = \sqrt{\frac{I}{k_n'(W/L)}}$$

From drain side:-

$$V_{D1} = V_{DD} - \frac{I}{2}R_{D1}$$

$$V_{D2} = V_{DD} - \frac{I}{2}R_{D2}$$

From common mode i/p signal:

$V_{D1} = V_{D2}$

$\Rightarrow V_D = 0$

Thus the difference b/n two drains voltage must be zero (Ideal)

→ Under this mode of operation called as common mode the o/p of differential amplifier is zero. and also under this mode ~~of~~ the transistors operates in saturation region, with min and maximum common mode voltage as $\boxed{V_{cm(max)} = V_D + V_t}$ and Minimum common mode voltage is

$$V_{cm(min)} = -V_{ss} + V_{GS} + \underbrace{V_t + V_{OV}}_{V_{GS}}$$

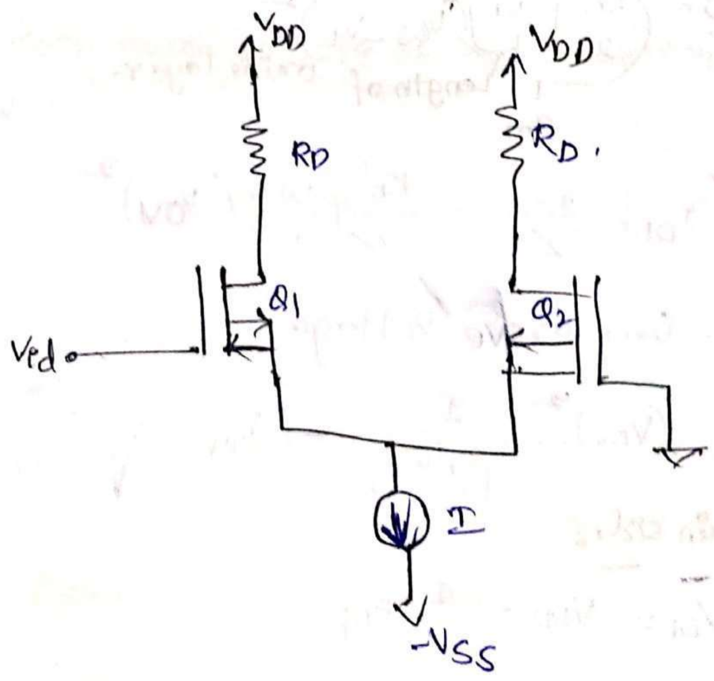
(or)

$$V_{cm(min)} = -V_{ss} + V_{GS} + V_{CS}$$

voltage across current source.

MOS Differential Amplifier with differential i/ps:-

⇒ If we apply differential i/p voltage by grounding the gate of Q_2 and apply a i/p signal V_{ID} to Q_1



We can see that $V_{ID} = V_{GS1} - V_{GS2}$ (or) $V_{G1} - V_{G2}$

→ If V_{ID} is positive, V_{GS1} will be greater than V_{GS2} and hence I_{D1} will be greater than I_{D2} and $V_{D2} - V_{D1}$ will be (+) ve. Hence Q_1 is ON and Q_2 will OFF.

Similarly,

→ If V_{ID} is negative, V_{GS2} will be greater than V_{GS1} and hence I_{D2} will be greater than I_{D1}. and $V_{D1} - V_{D2}$ will be (–) ve such that Q_2 is ON

$V_{D2} - V_{D1}$

and Q_1 is OFF

→ The output voltages are given by

$$\boxed{\begin{aligned} V_{D1} &= V_{DD} - I_{D1}R_D \\ V_{D2} &= V_{DD} - I_{D2}R_D \end{aligned}}$$

→ From above equations the o/p voltage doesnot become zero. (ie) $V_{D2} - V_{D1} \neq 0$ (or) $V_{D1} - V_{D2} \neq 0$

→ Under this conditions, the current through (Q_1) is

$$I_{D1} = \frac{1}{2} K_n'\left(\frac{W}{L}\right)(V_{GS1} - V_t)^2$$

Hence $$\boxed{I_{D1} = I = \frac{K_n'}{2}\left(\frac{W}{L}\right)(\underbrace{V_{GS1} - V_t}_{V_{GS}})^2}$$

$$I_{D1} = I = \frac{K_n'}{2}\left(\frac{W}{L}\right)(V_{OV})^2$$

$$I_{D1} = I = \frac{K_n'}{2}\left(\frac{W}{L}\right)\Big(\underbrace{\sqrt{\frac{I}{K_n'(W/L)}}}_{V_{OV} \text{—keep as it is.}}\Big)^2$$

$$\boxed{V_{OV} = \sqrt{\frac{2I}{K_n'(W/L)}}}$$

$V_{OV} = V_{GS1} - V_t$

$V_{GS1} = V_t + V_{OV}$

$V_{GS1} = V_t + \sqrt{2}\, V_{OV}$

$V_{id}(max) = V_{GS} - V_t$

$= \sqrt{2}V_{OV} + \cancel{V_t} - \cancel{V_t}$

$$\boxed{\begin{aligned} V_{id}(max) &= \sqrt{2}V_{OV} \\ V_{id}(min) &= -\sqrt{2}V_{OV} \end{aligned}}$$

Range of differential i/p voltage is $-\sqrt{2}V_{OV} \leq V_{id} \leq \sqrt{2}V_{OV}$

$$\boxed{-\sqrt{2}V_{OV} \leq V_{id} \leq \sqrt{2}V_{OV}}$$

For the MOS defferential pair (amplifier) with a common mode voltage (V_{cm}) is applied. if $V_{DD} = V_{SS} = 1.5V$; $K_n'\left(\frac{W}{L}\right) = 4mA/V^2$, $V_t = 0.5V$ $I = 0.4mAmp$, $R_D = 2.5k\Omega$ and assume current source (I) is required minimum voltage of 0.4V to operate properly. Find

a) V_{OV}

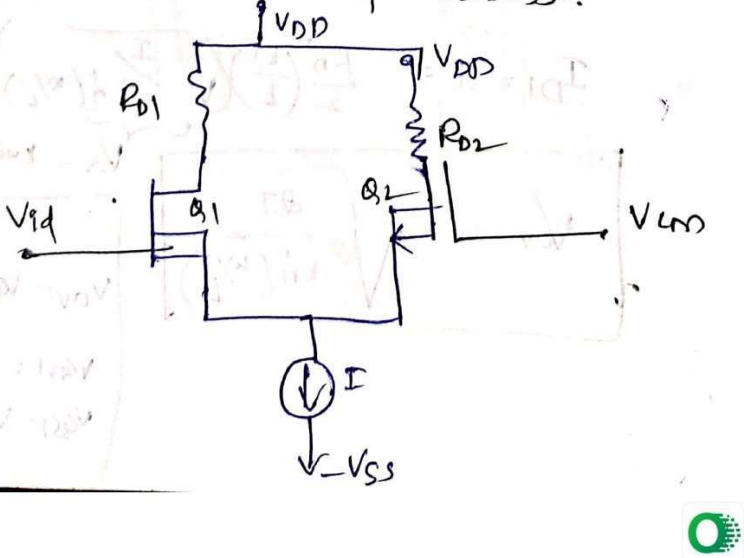
b) V_{gs} for each transistor

c) For $V_{cm} = 0$, Find V_S, I_{D1}, I_{D2}, V_{D1} & V_{D2}

d) Repeat c. if, $V_{cm} = 1V$

e) Repeat 'c' if, $V_{cm} = -0.2V$

f) Find $V_{cm}(max)$ & $V_{cm}(min)$?



i)

$I_{D1} = I_{D2} = \frac{I}{2}$

we know that

$$I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS1} - V_t)^2$$

$$\frac{I}{\cancel{2}} = \frac{k_n'}{\cancel{2}}\left(\frac{W}{L}\right)(V_{ov})^2 \qquad \sqrt{\frac{I}{k_n'(\frac{W}{L})}} \text{ (or)}$$

$$0.4\times10^{-3} = 4\times10^{-3}(V_{ov})^2$$

$$\boxed{V_{ov} = 0.316V}$$

b) V_{GS} for each transistor

$V_{ov} = V_{GS1} - V_t$

$$\boxed{V_{GS} = V_{ov} + V_t}$$

$V_{GS} = 0.316 + 0.5 = 0.816\ V$

c) When $V_{cm} = 0$,

$V_S =$

$$\boxed{V_{D1} = V_{DD} - \frac{I}{2}(R_D)}$$

$V_{D1} = 1.5 - \frac{0.4\times10^{-3}}{2}(2.5\times10^3)$

$$\boxed{V_{D1} = 1V}$$

$$\boxed{V_{D2} = 1V}$$

$\underline{\underline{I_{D1}}} = \frac{I}{2} = 0.4\ mAmp = \underline{\underline{0.2mA}}$

$\underline{\underline{I_{D2}}} = \frac{I}{2} = 0.4\ mAmp = \underline{\underline{0.2mA}}$

$$\boxed{V_S = \underset{0}{V_{cm}} - V_{GS}}$$

$V_S = -0.816\ V$

$$\boxed{V_S = -0.816V}$$

$V_{cm} = 1$ then $V_S = V_{cm} - V_{GS}$

$$\boxed{V_S = 1 - 0.816 = 0.184\ V}$$

$V_{cm} = -0.2V$ then

$$\boxed{V_S = -0.2 - 0.816 = -1.016V}$$

$V_{cm}(max) = V_D + V_t$

$= 1 + 0.5V$

$$\boxed{V_{cm}(max) = 1.5V}$$

$V_{cm}(min) = -V_{SS} + V_{CS} + V_{GS}$

$= -1.5V + 0.4V + 0.816$

$$\boxed{V_{cm}(min) = -0.284V}$$

For the MOS differential amplifier operated in differential mode, mentioned as above problem.

calculate a) the value of V_{ID} that causes Q_1 to conduct the entire current (I) and corresponding values of V_{D1} & V_{D2}?

b) Find the Value of V_{ID} that causes Q_2 to conduct entire current (I) and corresponding V_{D1} & V_{D2}?

c) Find the Range of differential $V_{o/p}$ voltage & o/p Voltage?

d) 1) $V_{OV} = \sqrt{\dfrac{2I}{k_n'(W/L)}} = \sqrt{\dfrac{2(04)\times10^{-3}}{4\times10^{-3}}}$

$V_{OV} = 0.44V$

$V_{ID} = \sqrt{2}\,V_{OV} = \sqrt{2}\times0.44 = 0.622$

a) $V_{D1} = V_{DD} - I_{D1}R_D$

$= 1.5V - 0.4\times10^{-3}(2.5\times10^3)$

$\boxed{V_{D1} = 0.5V}$

$V_{D2} = V_{DD} - I_{D2}R_D$

$= 1.5V - 0(2.5\times10^{-3})$ (Q_2 is off so $I_{D2} = 0$

$\boxed{V_{D2} = 1.5V}$

b) For second case: $V_{ID} = -\sqrt{2}V_{OV} = -\sqrt{2}(0.44) = -0.622V$

$V_{D1} = V_{DD} - I_{D1}R_D$

Q_1 is off and Q_2 is on so $I_{D1} = 0$.

$= 1.5 - 0(R_D)$

$\boxed{V_{D1} = 1.5V}$

$V_{D2} = V_{DD} - I_{D2}(R_D)$

$= 1.5 - (0.4)\times10^{-3}(2.5\times10^3)$

$\boxed{V_{D2} = 0.5V}$

c) In 1st case

$V_{D2} - V_{D1} = 1.5V - 0.5V$

$\boxed{V_{D2} - V_{D1} = 1V}$

In 2nd case

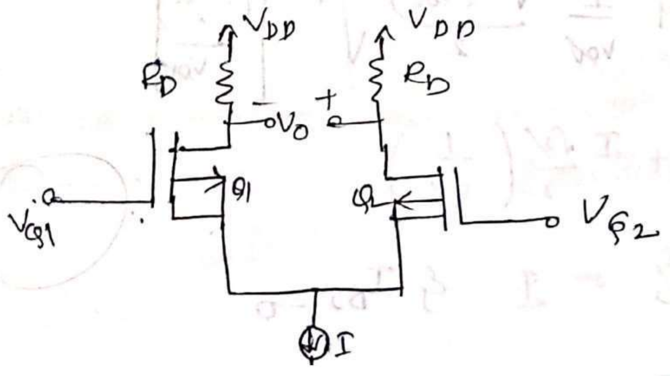
$V_{D2} - V_{D1} = 0.5V - 1.5V$

$= -1V$

$\therefore \boxed{V_{od} = -1V \text{ to } +1V}$ o/p

$\boxed{V_{id} = -0.622 \text{ to } +0.622V}$ i/p

MOS Differential Amplifier in Large Signal Mode:-



The figure shows the differential amplifier in large signal mode.

Under this conditions current is different (i.e)

$$I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)(V_{GS1}-V_t)^2$$

The transistors drive different currents and they are given by I_{D1} & I_{D2}.

$$\sqrt{I_{D1}} = \sqrt{\frac{k_n'}{2}\left(\frac{W}{L}\right)}(V_{GS1}-V_t) \longrightarrow ①$$

$$\sqrt{I_{D2}} = \sqrt{\frac{k_n'}{2}\left(\frac{W}{L}\right)}(V_{GS2}-V_t) \longrightarrow ②$$

$$\sqrt{I_{D1}} - \sqrt{I_{D2}} = \sqrt{\frac{k_n'}{2}\left(\frac{W}{L}\right)}(V_{GS1}-V_{GS2})$$

$$\sqrt{I_{D1}} - \sqrt{I_{D2}} = \sqrt{\frac{k_n'}{2}\left(\frac{W}{L}\right)}(V_{id}) \longrightarrow ③$$

we know that

$$I_{D1} + I_{D2} = I \longrightarrow ④$$

By solving eqn ③ & ④

$$I_{D1} = \frac{I}{2} + \left(\frac{I}{V_{ov}}\right)\left(\frac{V_{id}}{2}\right)\sqrt{1-\left(\frac{\left(\frac{V_{id}}{2}\right)}{V_{ov}}\right)^2} \longrightarrow ⑤ \; > \frac{I}{2}$$

$$I_{D2} = \frac{I}{2} - \left(\frac{I}{V_{ov}}\right)\left(\frac{V_{id}}{2}\right)\sqrt{1-\left(\frac{\left(\frac{V_{id}}{2}\right)}{V_{ov}}\right)^2} \longrightarrow ⑥ \; < \frac{I}{2}$$

suppose if $V_{id} = \sqrt{2}\,V_{ov}$

$$I_{D1} = \frac{I}{2} + \frac{I}{\cancel{V_{ov}}}\,\frac{\sqrt{2}(\cancel{V_{ov}})}{2}\sqrt{1-\left[\frac{\left(\frac{\sqrt{2}V_{ov}}{2}\right)}{V_{ov}}\right]^2}$$

$1-\frac{2}{4}$

$\sqrt{1-\frac{1}{2}} = \sqrt{\frac{1}{\sqrt{2}}}$

$$I_{D1} = \frac{I}{2} + I\frac{\cancel{\sqrt{2}}}{2}\left(\frac{1}{\cancel{\sqrt{2}}}\right)$$

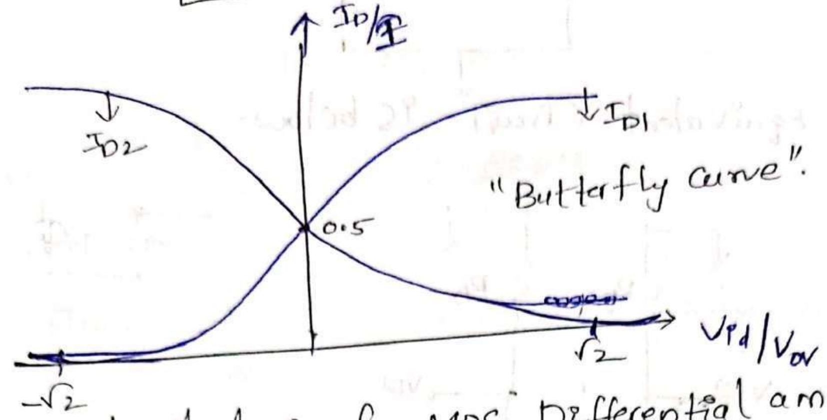
$$I_{D1} = \frac{2I}{2} = I \;\; \& \;\; I_{D2} = 0$$

If $V_{id} = -\sqrt{2}V_{OV}$

$I_{D1} = 0$ & $I_{D2} = I$

The range of differential voltage is

$$\boxed{-\sqrt{2}V_{OV} \le V_{id} \le \sqrt{2}V_{OV}}$$



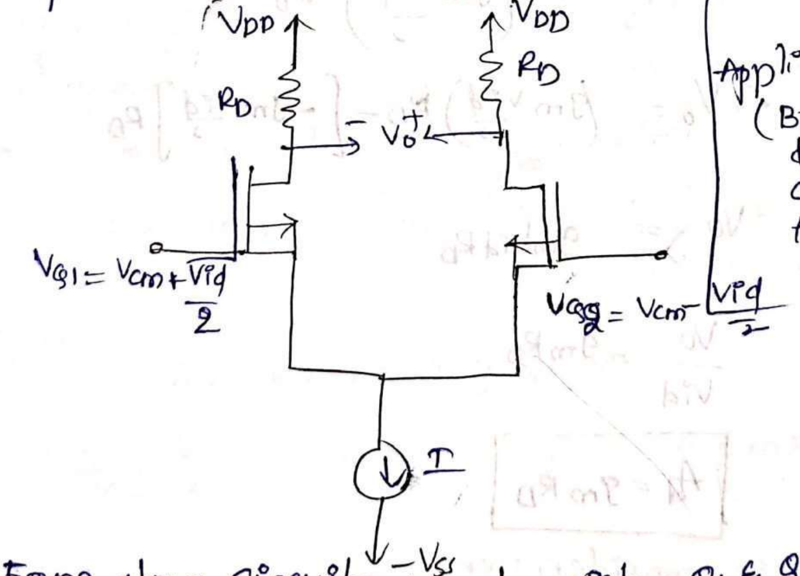
*** Small signal Analyses of MOS Differential amplifier :-

Here we can apply an i/p voltage to the gates of Q1 & Q2 of a magnitude of $\boxed{V_{cm} \pm \frac{V_{id}}{2}}$ by Drop.

considering $V_{G1} = V_{cm} + \frac{V_{id}}{2}$

$V_{G2} = V_{cm} - \frac{V_{id}}{2}$

The below figure shows the MOS differential amplifier in small signal.

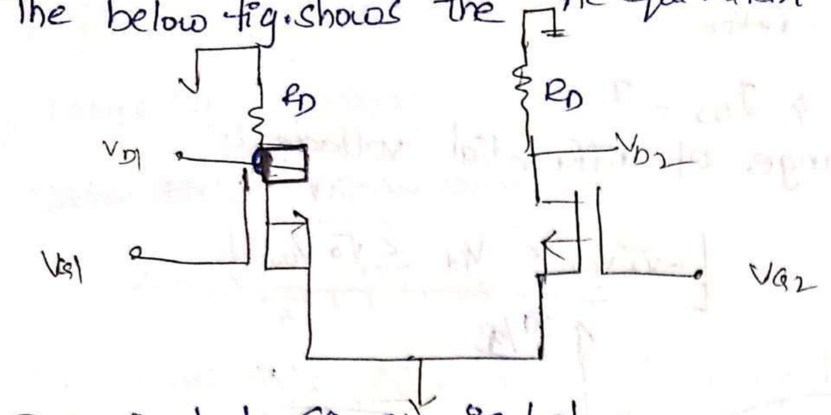


Appli (Both Q1 & Q2 drives differ currents, so they operate in ~~saturation~~ active

From above circuit, the transistor Q1 & Q2 operates in linear(active) region by drawing (drive) un equal currents I_{D1} & I_{D2}.

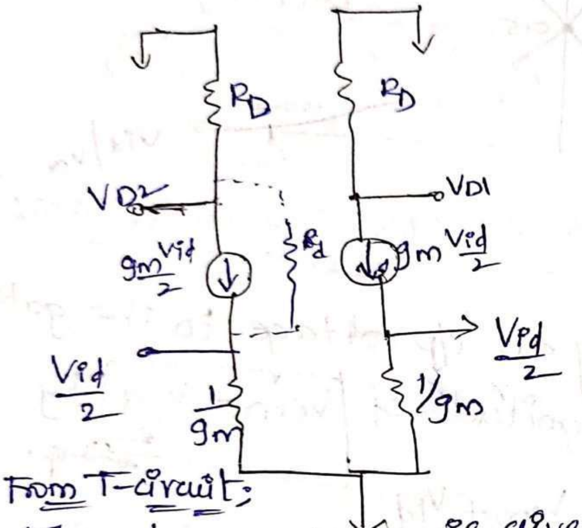
→ Here the MOS transistors operates in active region.

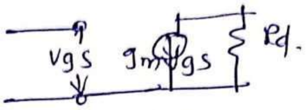
The below fig. shows the AC equivalent circuit



Capacitor, current/volt. sources are short

T-Equivalent Circuit is below.





From T-circuit:

The drain voltages is given by

$$V_{D1} = \left(g_m \frac{V_{id}}{2}\right) R_D$$

$$V_{D2} = \left(g_m \frac{V_{id}}{2}\right) R_D$$

$$\therefore V_o = \left(g_m \frac{V_{id}}{2}\right) R_D - \left[-g_m \frac{V_{id}}{2}\right] R_D$$

$$V_o = g_m V_{id} R_D$$

$$\frac{V_o}{V_{id}} = g_m R_D$$

$$\boxed{A_d = g_m R_D}$$

If r_d is consider, then

$$\boxed{A_d = g_m (r_d \| R_D)}$$

Transconductance $\boxed{(gm) = \frac{2I}{V_{OV}}}$

Consider a MOS differential amplifier is operated at a total current of 0.8mA using MOSFET with $\left(\frac{W}{L}\right)$ ratio is 100, $\underbrace{\mu_n C_{ox}}_{K_n'} = 0.2mAmp/V^2$, $V_A = 20V$ and $R_D = 5K\Omega$ calculate V_{ov}, gm, r_d, A_d ?

$$V_{ov} = \sqrt{\frac{I}{K_n'(W/L)}} = 0.2\,V$$

$$gm = \frac{2I}{V_{OV}} = 2.531 \times 10^{-3} = \boxed{8\,mA/V.}$$

$$\boxed{r_d = \frac{2V_A}{I} = 50K\Omega}$$

$$A_d = gm(R_D \parallel r_d) = 8\times10^{-3}\left[50K\Omega \parallel 5K\Omega\right].$$

$$\boxed{A_d = 36.36}$$

A mos differential amplifier operates in common mode at a biasing current I of 0.4mAmp. If $\mu_n C_{ox} = 0.2mA/V^2 (K_n')$. Find the requirement length of $\left(\frac{W}{L}\right)$ and resulting gm if, the MOSFETS are operated at $V_{ov} = 0.2V$, $0.3V$ and $0.4V$? and also for each value of maximum V_{id} for which the term involves V_{id} is $\left[\frac{V_{id}/2}{V_{OV}}\right]^2$ is limited to 0.1.

Given:

$$V_{OV} = 0.2V, 0.3V \;\&\; 0.4V$$

$$\therefore I_{Total} = \frac{I}{2} = \frac{0.4\times10^{-3}\,Amp}{2} = 0.2\,mAmp$$

$$I = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{OV})^2$$

$$\frac{W}{L} = \frac{2\times0.2mA}{\mu_n C_{ox}\times(V_{OV})^2} = \boxed{50}$$

$$g_m = \frac{2I}{V_{ov}} = \frac{2 \times 0.2 \times 10^{-3}}{0.2} = \boxed{2\,\text{mAmp/V}}$$

$$\left[\frac{V_{id}/2}{0.2}\right]^2 = 0.1$$

$$\frac{(V_{id})^2}{(0.4)^2} = 0.1 \times 0.$$

$$(V_{id})^2 = 0.1 \times 0.16$$

$$V_{id} = \sqrt{0.1 \times 0.16}$$

$$\boxed{V_{id} = 0.126\,V}$$

When $V_{ov} = 0.3V$

$$I = \frac{1}{2}\mu_n C_{ox}\left(\frac{W}{L}\right)(V_{ov})^2$$

$$\left(\frac{W}{L}\right) = \frac{0.2 \cancel{\times 10^{-3}} \times 2}{0.2 \cancel{\times 10^{-3}} \times (0.3)^2} = \boxed{22.22\text{ volts.}}$$

$$g_m = \frac{2I}{V_{ov}} = \frac{2 \times 0.2 \times 10^{-3}}{0.3} = \boxed{1.33\,\text{mA/V}}$$

$$\left[\frac{V_{id}/2}{0.3}\right]^2 = 0.1$$

$$\left(\frac{V_{id}}{0.6}\right)^2 = 0.1$$

$$(V_{id})^2 = 0.1 \times 0.36$$

$$\boxed{V_{id} = \sqrt{0.036} = 0.1897\,V}$$

when $V_{OV} = 0.4V$

$$\left(\frac{W}{L}\right) = \frac{0.2\times10^{-3}\times2}{0.2\times10^{-3}\times(0.4)^2} = \boxed{12.5}$$

$$\boxed{g_m = \frac{2I}{V_{OV}} = 1mAmp/V}$$

$$\left(\frac{\frac{V_{id}}{2}}{0.4}\right)^2 = 0.1$$

$$(V_{id})^2 = 0.1\times0.64$$

$$V_{id} = \sqrt{0.1\times0.64}$$

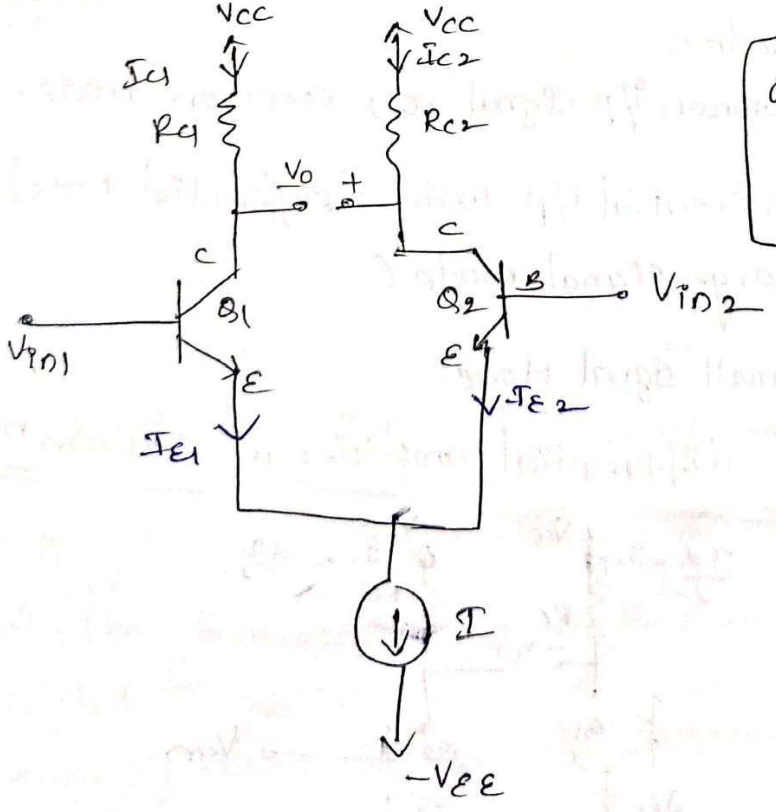
$$\boxed{V_{id} = 0.2529\ V}$$

BJT Differential Amplifier:-

⇒ It consists of two BJT's (Q_1 & Q_2) and their emitters are connected to each other.

⇒ It consicts of 2 resistors, 2 voltage sources

⇒ The below fig. shows the BJT differential amplifie



Q_1 & Q_2 are npn transistr

⇒ Under BJT differential amplifier the collector & emitter current are different as a relation of

$$\boxed{I_C = \alpha I_E}$$

where $\alpha < 1$ (i.e, 0.98)

⇒ If the above circuit work as an differential amplifier it emitts the following conditions. ie,

1) Two transistor Q_1 & Q_2 are of same type($Q_1 = Q_2$

2) Total Current $\boxed{I = I_{E1} + I_{E2}}$

3) $R_{C1} = R_{C2} = R$

4) $V_{C1} = V_{CC} - I_{C1} R_{C1}$

$V_{C2} = V_{CC} - I_C R_{C2}$

5) $V_O = V_{C1} - V_{C2}$ (or) $V_{C2} - V_{C1}$

6) $V_{id} = V_{B1} - V_{B2}$ (or) $V_{B2} - V_{B1}$

Ideal conditions of E

& for MOSFET also notations are di

like V_{d1}, R_{d1}, I_{d1} (E

⇒ BJT differential amplifier can operates in 4 diffe modes.

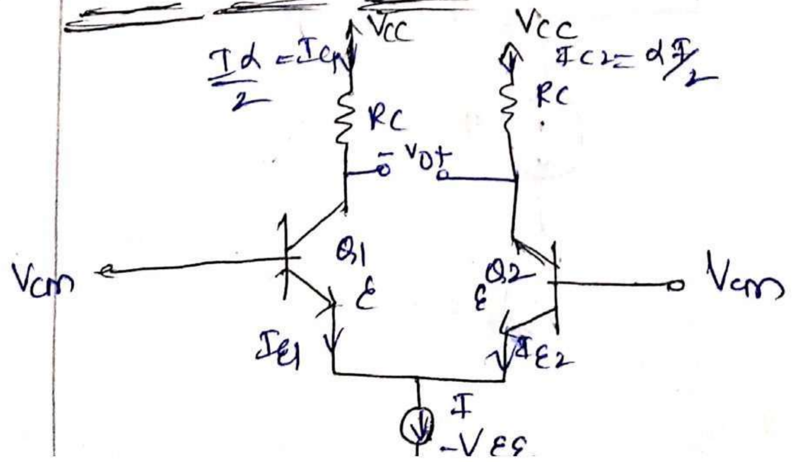
1) Common i/p signal (or) common mode.

2) Differential i/p mode. (Differential Mode).

3) Large signal mode (

4) Small signal Mode.

1) BJT differential amplifier in common mode:



Here we can apply common i/p signal to both Q_1 & Q_2 transistor, then it is called BJT differential amplifier in common mode.

→ The ~~below~~ above fig shows the BJT differential amplifier of common mode

→ If same voltage is applied b/n Q_1 & Q_2 then both transistors will drives into saturation (i.e) turn ON) so they will draw equal currents.

$$I_{E1} = I_{E2} = \frac{I}{2}$$

$$\boxed{I_{E1} + I_{E2} = I}$$

$$\therefore \boxed{\begin{matrix} I_{C1} = \frac{\alpha I}{2} \\ I_{C2} = \frac{\alpha I}{2} \end{matrix}}$$

∴ collector voltages are $V_{C1} = V_{CC} - \left(\frac{\alpha I}{2}\right) R_C$

$$\boxed{V_{C2} = V_{CC} - \left(\frac{\alpha I}{2}\right) R_C}$$

o/p voltage $V_O = V_{C2} - V_{C1}$

$$= V_{C2} - V_{C1}$$

$$\boxed{V_O = 0V}$$

→ From above eqn, o/p voltage of common mode differential amplifier is zero(V).

Max & min values of common mode voltage is given as

For Si — 0.3v for Ge.

$$\boxed{V_{cm(max)} = V_C + 0.4V}$$

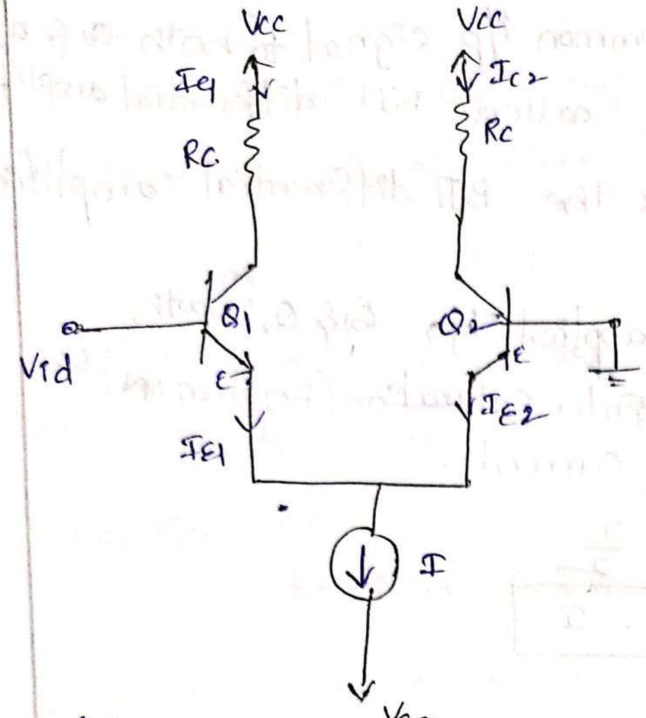
voltage across current source

$$\boxed{V_{cm(min)} = -V_{EE} + V_{CS} + V_{BE}}$$

2) BJT differential amplifier in differential Mode :-

→ ~~If~~ Here we can apply a differential voltage to one of bases of the transistors and another base will be connected to ground.

→ The below fig. shows the BJT differential amplifier in differential mode.



Under this mode; if Vid is (+)ve if $V_{B1} > V_{B2}$

then $V_{C1} > V_{C2}$

so $I_{C1} > I_{C2}$

Hence <u>Q1 ON</u> & <u>Q2 OFF</u> $[\therefore I_{C1} = I \; \& \; I_{C2} = 0]$

$\therefore V_{C1} = V_{CC} - \alpha I R_C$; $V_{C2} = \cancel{V_{CC}} - 0$

$V_0 = V_{C2} - V_{C1} \; \alpha R_C$

$V_0 = \cancel{V_{CC}} - [\cancel{V_{CC}} - \alpha I R_C]$

$$\boxed{V_0 = \alpha I R_C}$$

If $V_{B1} < V_{B2}$ (ie Vid is (-)ve) then

$V_{C1} \cancel{>} V_{C2}$ (<)

$I_{C1} \cancel{>} I_{C2}$ (<)

Hence <u>Q1 is OFF</u> & <u>Q2 is ON</u>. $[I_{C1} = 0, I_{C2} = I]$

$V_{C1} = V_{CC} - 0$

$V_{C2} = V_{CC} - \alpha I R_C$

$$\therefore \boxed{V_0 = -\alpha I R_C}$$

BJT differential Amplifier in large signal Mode:-

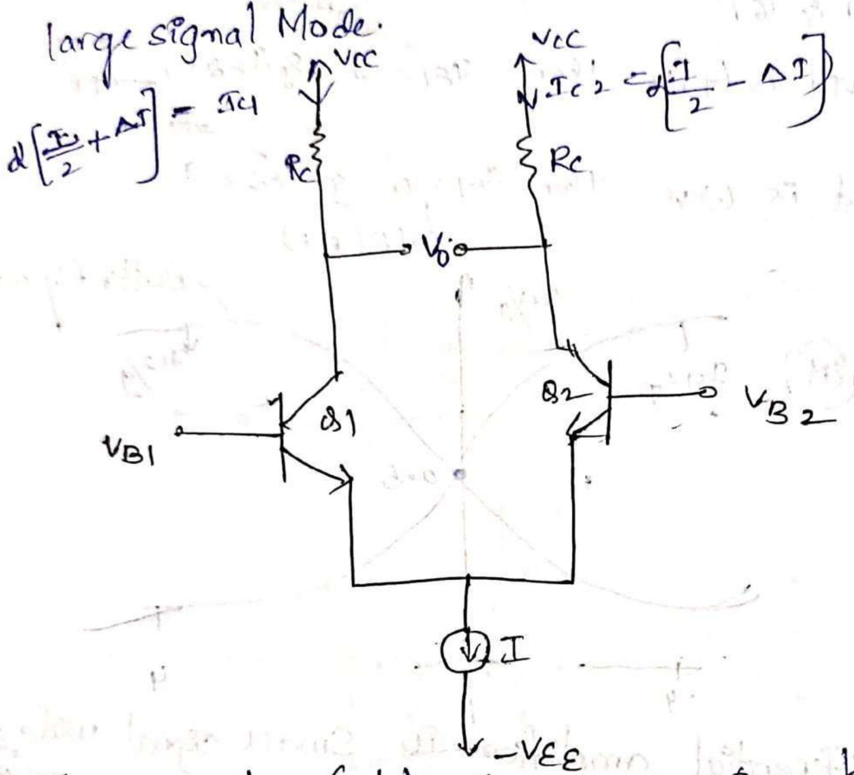
→ We can apply different i/p voltages to bases of Q_1 and Q_2 transistor's, then it is called large signal mode

→ Here both transistors are in saturation, but they do not share equal currents. such that there is a change in current of ΔI.

$$I_{E1} = \frac{I}{2} + \Delta I$$

$$I_{E2} = \frac{I}{2} - \Delta I$$

The below figure shows the BJT diff. amplifier in large signal Mode.



Assumption
$V_{B1} > V_{B2}$
So
$I_{E1} > I_{E2}$
$I_{E1} = \frac{I}{2} + \Delta I$
Here transistor operates in non-linear region

The collector (o/p) voltages are given by

$$V_{C1} = V_{CC} - \alpha\left[\frac{I}{2} + \Delta I\right] R_C$$

$$V_{C2} = V_{CC} - \alpha\left[\frac{I}{2} - \Delta I\right] R_C$$

We know, when transistor operates in non-linear region then the collector current $I_C = I_S e^{V_{BE}/V_T}$

$$I_{E1} = \frac{I_S}{\alpha} e^{V_{BE1}/V_T} \longrightarrow ①$$

$I_C = \alpha I_E$

$I_E = I_C/\alpha$

$$I_{E2} = \frac{I_S}{\alpha} e^{V_{BE2}/V_T} \longrightarrow ②$$

$$\frac{①}{②} \quad \frac{I_{E1}}{I_{E2}} = \frac{I_S}{\alpha} e^{\left[V_{BE1}-V_{BE2}\right]/V_T} \rightarrow ③$$

$$I_{E1}+I_{E2} = I \longrightarrow ④$$

By solving ③ & ④

$$I_{E1} = \frac{I}{1+e^{-V_{id}/V_T}} \longrightarrow ⑤$$

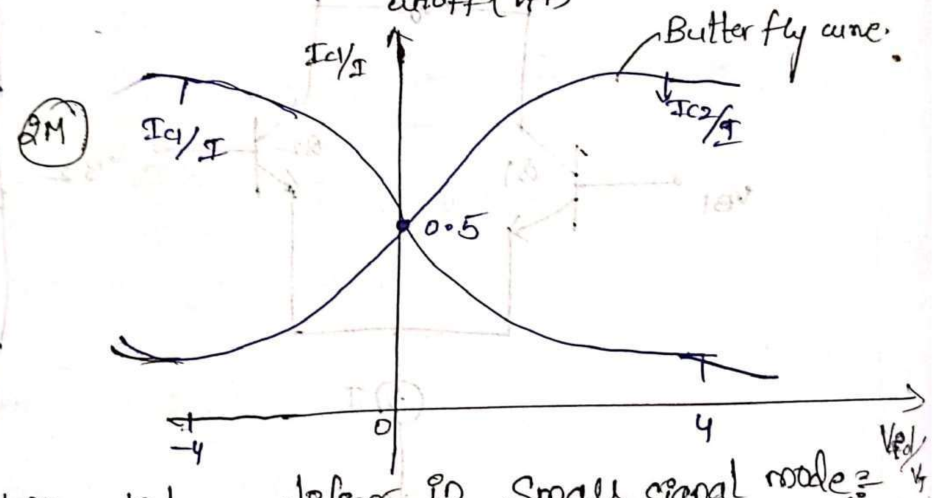
Vid is (−)ve
$I_{E1} = 0$
$I_{E2} = +I$

$$I_{E2} = \frac{I}{1+e^{V_{id}/V_T}} \rightarrow ⑥ \quad \left[V_{id} = V_{BE1} - V_{BE2}\right]$$

From ⑤ & ⑥

If Vid is (+)ve then $I_{E1} = I$ & $I_{E2} = 0$ — cutoff, OFF

If Vid is (−)ve then $I_{E1} = 0$ & $I_{E2} = I$ — cutoff (OFF)

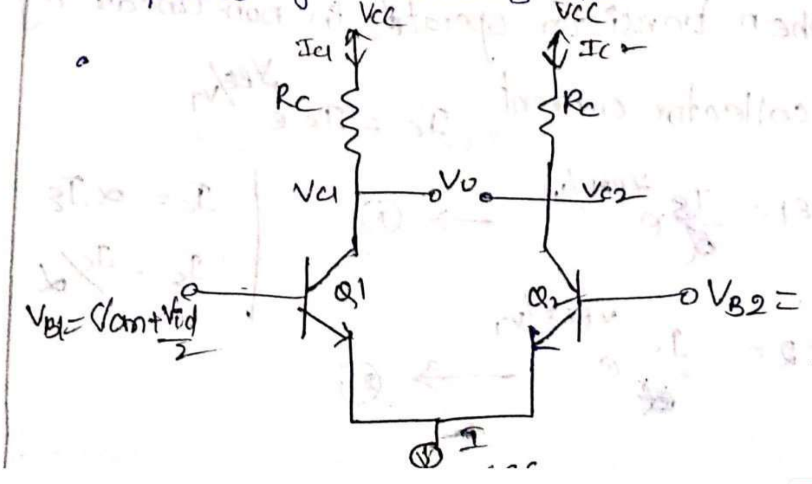


BJT differential amplifier in Small signal mode:- (Analysis)

Here we can apply input voltages for Q_1 & Q_2 is

$$V_{B1} \,\&\, V_{B2} = V_{cm} \pm \frac{V_{id}}{2}$$

The below figure shows the BJT in small signal mode



combination of AC & DC (Vid & Vcm)

Here collector currents are given by

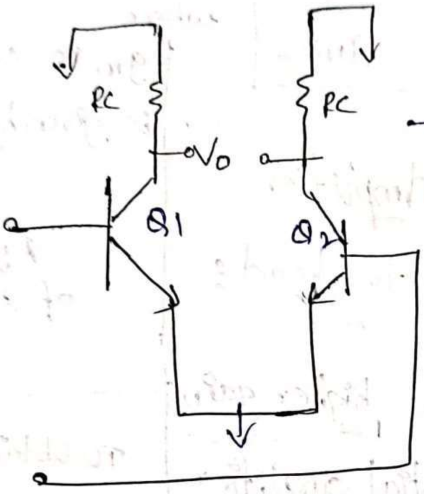
$$I_{C1} = I_{C2} = \frac{\alpha V_{id}}{2r_e}$$

The collector voltages are given by

~~V_{od}~~ =

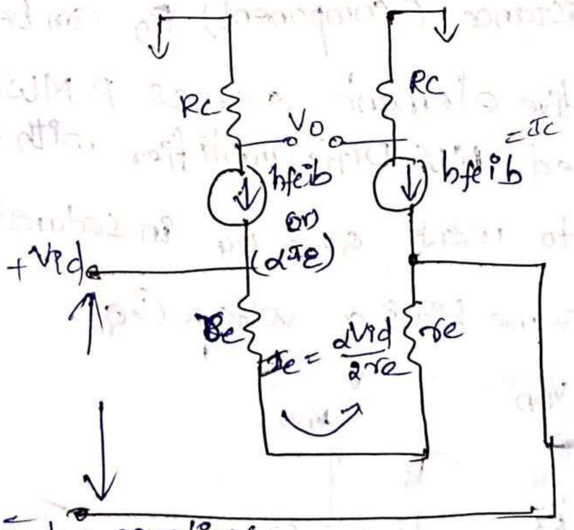
$$\boxed{\begin{aligned} V_{C2} &= \frac{\alpha V_{id} R_C}{2r_e} \\ V_{C1} &= -\frac{\alpha V_{id} R_C}{2r_e} \end{aligned}}$$

AC equivalent circuit is shown below:



In AC circuit, all ~~capacitors~~ & current sources are short

Here hie is replaced with re.



equivalent T-Model

(r-model.

on collector equations

output voltage is given by

$$\boxed{V_O = V_{C2} - V_{C1}}$$

$$V_O = \frac{\alpha V_{id} R_C}{2r_e} + \frac{\alpha V_{id} R_C}{2r_e}$$

$$V_O = \frac{\cancel{2}\alpha V_{id} R_C}{\cancel{2} r_e}$$

$$\frac{V_o}{V_{id}} = \frac{\alpha R_C}{r_e}$$

$$\boxed{A_d = \frac{\alpha R_C}{r_e}}$$

$$\boxed{A_d = \frac{\alpha R_C}{r_e + R_E}}$$ if an

→ external resistor R_E at emitters of Q_1 & Q_2 then differential gain is $\boxed{A_d = \frac{\alpha R_C}{r_e + R_E}}$

We can also express A_d in terms of transconductance (g_m) as $\boxed{A_d = g_m R_C}$

where g_m is called transconductor is given by $\boxed{\frac{\alpha}{r_e} = g_m}$

Dynamic resistance of emitter diode $\frac{\alpha I}{V_T}$

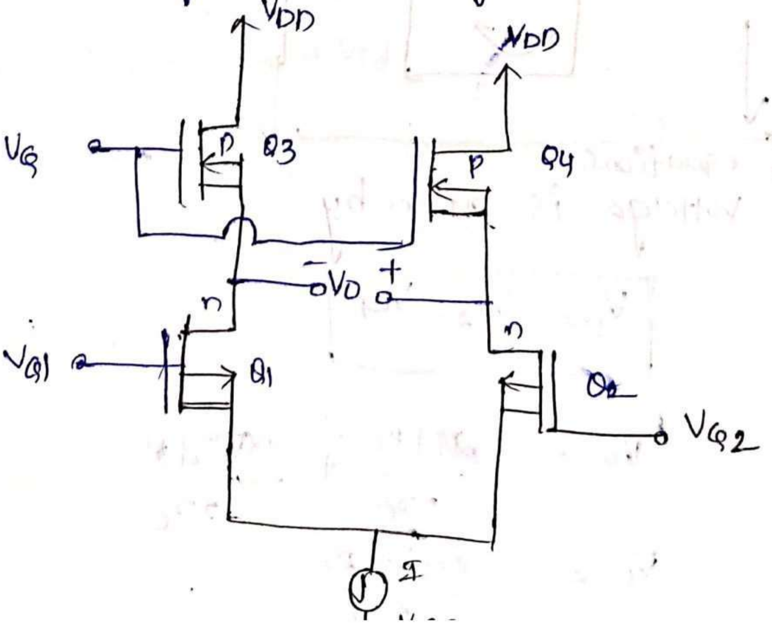
V_T → 26mV At room temp

MOS Differential Amplifier with Active Load:

To obtain high gains we use this.

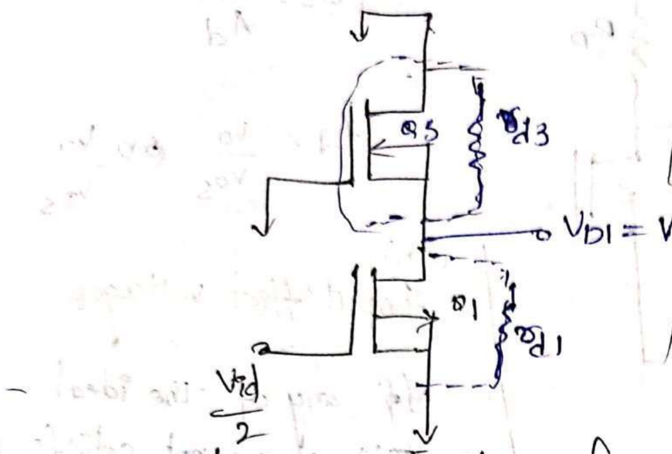
→ Inorder to obtain higher gains of MOS Differential amplifier the passive resistance (component) R_D can be replaced with an active element such as P-MOSFET then it is called MOS Diff. amplifier with active load.

→ Here inorder to work Q_3 & Q_4 in saturation, we can apply some biasing voltage (V_Q).



(i) the ckeage contain.

Now we can analyse the above circuit using small ~~signal~~ half circuit method instead of analyzing full differential amplifer.



$$V_{od} = \frac{g_m V_{id}}{2}(R_D \| r_d)$$

$$\frac{V_{od}}{V_{id}} = \frac{g_m}{2}[r_{d1} \| r_{d3}]$$

2200

$$A_d = \frac{g_m}{2}[r_{d1} \| r_{d3}]$$

If $r_{d1} = r_{d3} = r_d$ then

$$\boxed{A_d = \frac{g_m}{2}\left[\frac{r_d}{2}\right] = \frac{g_m r_d}{4}}$$

⇒ Nonideal characteristics of MOS-Differential Amplifier.

⇒ We studied MOS Differential amplier if same voltage is applied to the inputs then output becomes zero, under ideal conditions, such as:

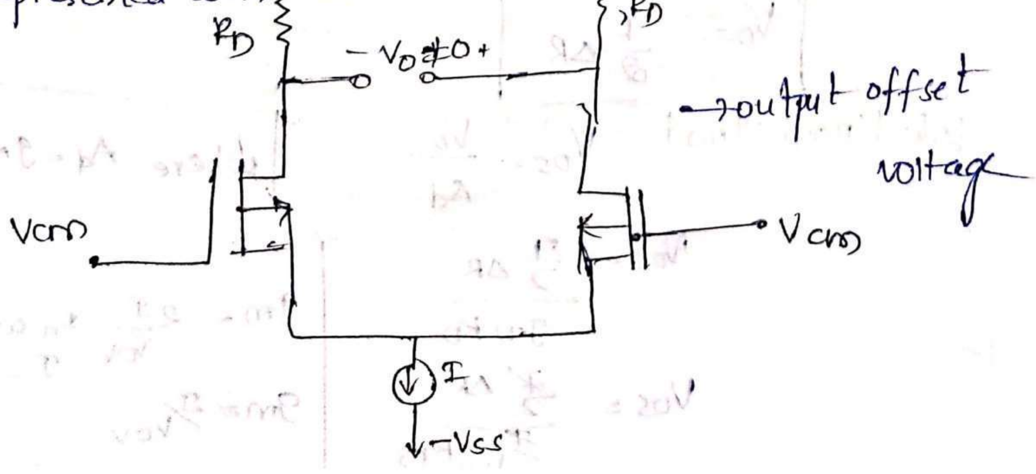
(i) If both resistances(~~Rd1~~, rd) are same.

(ii) Both transistors have same $\left(\frac{W}{L}\right)$ ratio;

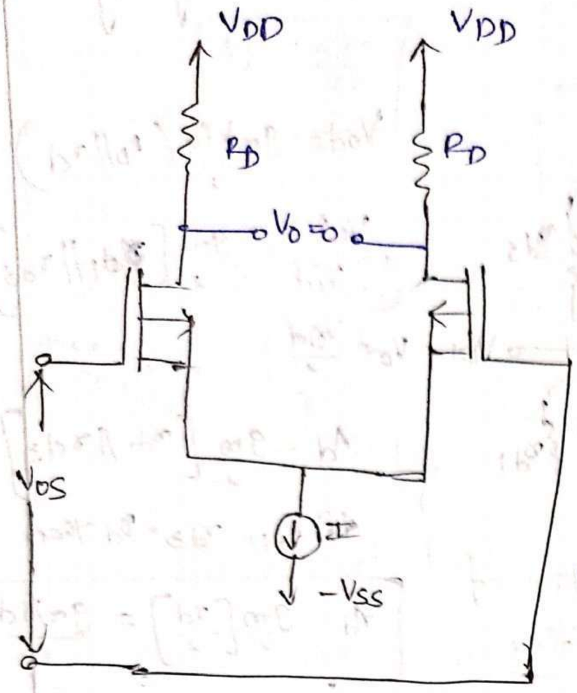
(iii) Both transistor have same threshold voltage (V_T)

⇒ (2M) suppose if any one of the above conditions are not satisfied then output ~~of~~ will not becomes zero which is known as: o/p off set voltage.

⇒ To make the o/p off set voltage as zero by applying some i/p voltage to the gates of Q1 & Q2 transistors represented with Vos.



Input offset voltage (2M)



$$V_{OS} = \frac{V_O}{A_d}$$

$$A_d = \frac{V_O}{V_{OS}} \text{ or } \frac{V_O}{V_{IS}}$$

(2M) Input offset voltage:

If any of the ideal conditions are not satisfied then o/p voltage becomes zero which is known as i/p offset voltage

Case (i) 1st Non-ideal Conditions:

Drain resistances are not equal, there is a change in drain resistance.

$$R_{D1} = R_D + \frac{\Delta R}{2} \; ; R_{D2} = R_D - \frac{\Delta R}{2}$$

$$V_{D1} = V_{DD} - \frac{I}{2}\left(R_D + \frac{\Delta R}{2}\right)$$

$$V_{D2} = V_{DD} - \frac{I}{2}\left(R_D - \frac{\Delta R}{2}\right)$$

$$\therefore V_{O1} = V_{D2} - V_{D1} \Rightarrow \cancel{V_{DD}} - \cancel{\frac{I}{2} R_D} + \frac{I}{2}\frac{\Delta R}{2} - \left[\cancel{V_{DD}} - \cancel{\frac{I}{2} R_D} - \frac{I}{2}\frac{\Delta R}{2}\right]$$

$$V_O = \frac{I}{2}\frac{\Delta R}{2} + \frac{I}{2}\frac{\Delta R}{2}$$

$$\boxed{V_O = \frac{I}{2}\Delta R}$$

We know that $V_{OS} = \frac{V_O}{A_d}$

where $A_d = g_m R_D$

$$V_{OS} = \frac{\frac{I}{2}\Delta R}{g_m R_D}$$

$g_m = 2\frac{I}{V_{OV}}$ In common mode $I = I/2$

$g_m = I/V_{OV}$

$$V_{OS} = \frac{\frac{\cancel{I}}{2}\Delta R}{\frac{\cancel{I}}{V_{OV}} R_D}$$

$$\boxed{V_{DS} = \frac{V_{OV}}{2} \times \frac{\Delta R}{R_D}}$$

case ii:- 2nd Non-ideal conditions:-

Both transistors $\left(\frac{W}{L}\right)$ ratios are not same.

$$\left(\frac{W}{L}\right)_1 = \left(\frac{W}{L}\right) + \frac{1}{2}\Delta\left(\frac{W}{L}\right)$$

$$\left(\frac{W}{L}\right)_2 = \left(\frac{W}{L}\right) - \frac{1}{2}\Delta\left[\frac{W}{L}\right]$$

So, as the $\left(\frac{W}{L}\right)$ changes so drain current changes.

$$I_{D1} = \frac{I}{2}\left[1 + \frac{\Delta\left(\frac{W}{L}\right)}{2(W/L)}\right] = \frac{I}{2}\left[1 + \frac{\Delta(W/L)}{2(W/L)}\right]$$

Illy $I_{D2} = \frac{I}{2}\left[1 - \frac{\Delta(W/L)}{2(W/L)}\right]$

Change in current is given by:-

$$I_D = I_{D2} - I_{D1}$$

$$I_D = \frac{I}{2}\left[\cancel{1} \frac{\Delta(W/L)}{2(W/L)} - \cancel{1} - \frac{\Delta(W/L)}{2(W/L)}\right]$$

$$I_D = \frac{I}{2}\left[\frac{(-)\Delta(W/L)}{(W/L)}\right]$$

(or) (+) (or) (-ve) convention

$$V_{OS} = \frac{V_O}{A_d}$$

$$V_{OS} = \frac{V_O}{g_m R_D} \quad \frac{V_O}{R_D} = I$$

$$V_{OS} = \frac{I}{g_m} = \frac{\frac{I}{2}\left[\frac{\Delta(W/L)}{(W/L)}\right]}{I/V_{OV}}$$

$$\boxed{V_{OS} = \frac{V_{OV}}{2}\left[\frac{\Delta(W/L)}{(W/L)}\right]}$$

Case iii: 3rd Non-ideal conditions:-

→ Both transistors threshold voltages are not same

[i.e) $V_{t1} \neq V_{t2}$]

$$V_{t1} = V_t + \frac{\Delta V_t}{2}$$

$$V_{t2} = V_t - \frac{\Delta V_t}{2}$$

Due to this changes, drain currents will differ by

$$I_{D1} = \frac{k_n'}{2}\left(\frac{W}{L}\right)\left(V_{GS} - \left(V_t + \frac{\Delta V_t}{2}\right)\right)^2$$

$$I_{D2} = \frac{k_n'}{2}\left(\frac{W}{L}\right)\left(V_{GS} - \left(V_t - \frac{\Delta V_t}{2}\right)\right)^2$$

The above eqn's can be simplified using Taylor's series

$$I_{D1} = \frac{I}{2}\left(1 - \frac{\Delta V_t}{(V_{GS} - V_t)}\right)$$

$$I_{D2} = \frac{I}{2}\left(1 + \frac{\Delta V_t}{V_{GS} - V_t}\right)$$

Change in current $\Delta I = I_{D2} - I_{D1}$

$$\Delta I = \frac{I}{2}\left(\cancel{1} + \frac{\Delta V_t}{V_{GS} - V_t}\right) - \cancel{\frac{I}{2}} + \frac{I}{2}\left[\frac{\Delta V_t}{(V_{GS} - V_t)}\right]$$

$$\Delta I = \frac{I \Delta V_t}{(V_{GS} - V_t)} = \frac{I \Delta V_t}{V_{OV}}$$

Input offset voltage $(V_{OS}) = \frac{I}{g_m}$ (or) $\frac{\Delta I}{g_m}$

$$V_{OS} = \frac{I}{I/V_{OV}} \Rightarrow V_{OS} = \frac{\cancel{I}\Delta V_t / \cancel{V_{OV}}}{\cancel{I}/\cancel{V_{OV}}}$$

$$\boxed{V_{OS} = \Delta V_t}$$

suppose if the above 3 conditions will occur at a time then expression for Input offset Voltage

$$V_{OS} = \sqrt{\left(\frac{V_{OV}}{2} * \frac{\Delta R}{R_D}\right)^2 + \left(\frac{V_{OV}}{2}\left(\frac{\Delta(W/L)}{(W/L)}\right)\right)^2 + (\Delta V_t)^2}$$

Non-Ideal characteristics of BJT

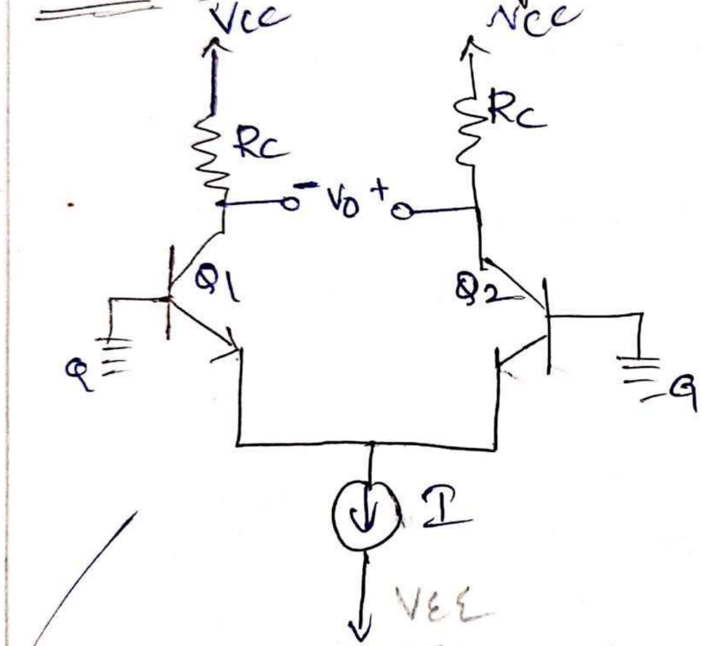
Differential Amplifier :-

$V_{OS} = V_T\left(\frac{\Delta R_C}{R_C}\right)$

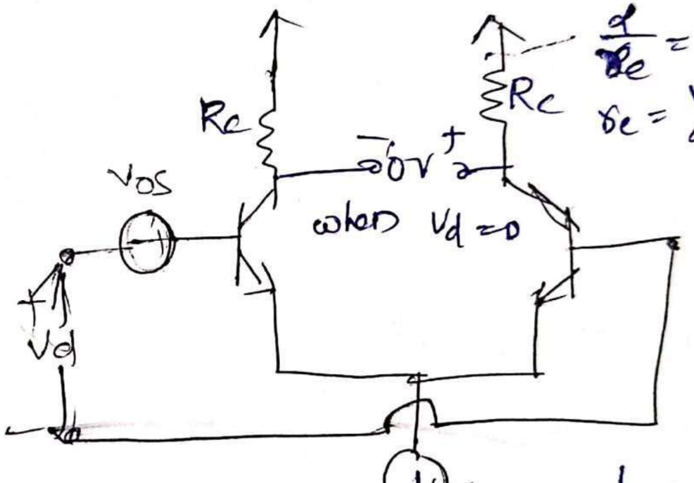
$V_{OS} = V_T\left(\frac{\Delta I_S}{I_S}\right)$

By adding all three conditions and square because effective at a time

Input offset voltage :-



$R_{C1} = R_C + \frac{\Delta R_C}{2}$; $R_{C2} = R_C - \frac{\Delta R_C}{2}$



$\frac{\alpha}{r_e} = V_T$

$r_e = \frac{V_T}{I}$

Input bias currents can be mismatched.

Common Mode Rejection Ratio (CMRR) :- ®

$$CMRR = \frac{A_d}{A_{cm}}$$

CMRR refers how much the common mode i/p signal can be rejected by the differential amplifier and it can also tells the how the differential amplifier respond to differential input and completely rejects the common mode signal.

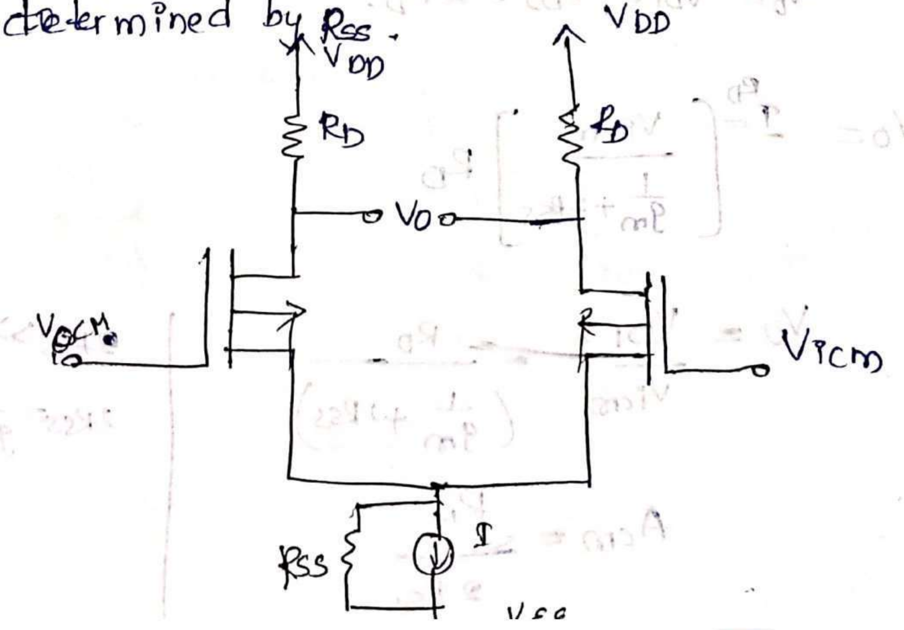
⇒ Based on this, CMRR is defined as it is the ratio of differential gain to common mode gain of differential amplifier (i.e, $\boxed{CMRR = \frac{A_d}{A_{cm}}}$)

$CMRR = \frac{A_d}{A_{cm}}$ in general for a differential amplifier, common mode i/p signal is zero. So

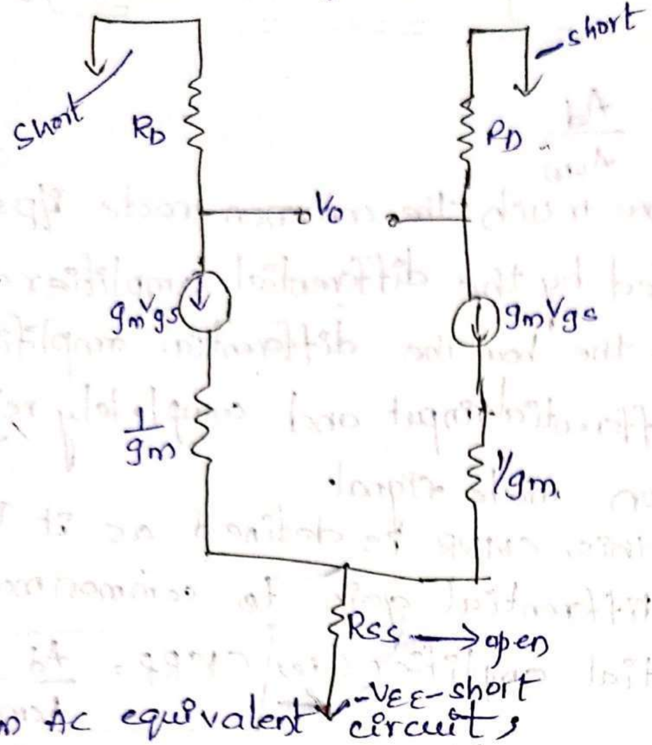
$\therefore CMRR = \frac{A_d}{0}$ Differential amplifier has

only Theoritically possible → $\boxed{CMRR = \alpha}$ i.e, high CMRR ratio

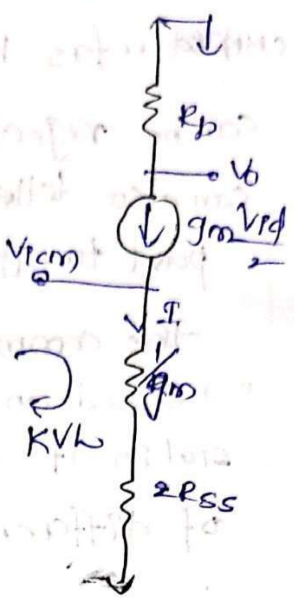
MOS case :- In general the CMRR can be derived by considering the diff. amplifier in common mode with an incremental change in (V_{cm}) by considering (a/resistor in parallel to) current source (I) as a resistor in parallel determined by R_{ss}.



Ac equivalent circuit is shown below



Half circuit:



From AC equivalent circuit,

By apply KVL to i/p Loop.

$$V_{icm} - I/g_m - 2I R_{SS} = 0$$

$$V_{icm} - I/g_m - 2IR_{SS} = 0$$

$$V_{icm} = I\left[\frac{1}{g_m} + 2R_{SS}\right]$$

$$I = \frac{V_{icm}}{\left[\frac{1}{g_m} + 2R_{SS}\right]}$$

*Imp

$\therefore$ $V_D = V_{D1} = V_{D2} = IR_D$. (No mismatch)

$$V_O = \overset{R_D}{I} = \left[\frac{V_{icm}}{\frac{1}{g_m} + 2R_{SS}}\right] R_D$$

$$V_O = \frac{V_{D1}}{V_{icm}} = \frac{R_D}{\left(\frac{1}{g_m} + 2R_{SS}\right)}$$

$$A_{cm} = \frac{R_D}{2R_{SS}}$$

$2R_{SS} >> 1/g_m$

$2R_{SS} = \frac{1}{g_m} + 2R_{SS}$

$$\therefore \text{Then } CMRR = \frac{A_d}{A_{cm}} = \frac{g_m R_D}{R_D/2R_{ss}}$$

$$\boxed{CMRR = 2 g_m R_{ss}}$$ Imp

If there is a mismatch in R_D, then

[$R_D = \Delta R_D$

ACM~~RR~~ $= \frac{\Delta R_D}{2R_{ss}}$

$$\therefore CMRR = \frac{A_d}{A_{cm}}$$

$$CMRR = \frac{g_m R_D}{\frac{\Delta R_D}{2R_{ss}}}$$

$$\boxed{CMRR = \frac{2 g_m R_{ss}}{\frac{\Delta R_D}{R_D}}}$$

suppose if there is a mismatch in 'gm'

$$\boxed{CMRR = \frac{2 g_m R_{ss}}{\left(\frac{\Delta g_m}{g_m}\right)}}$$

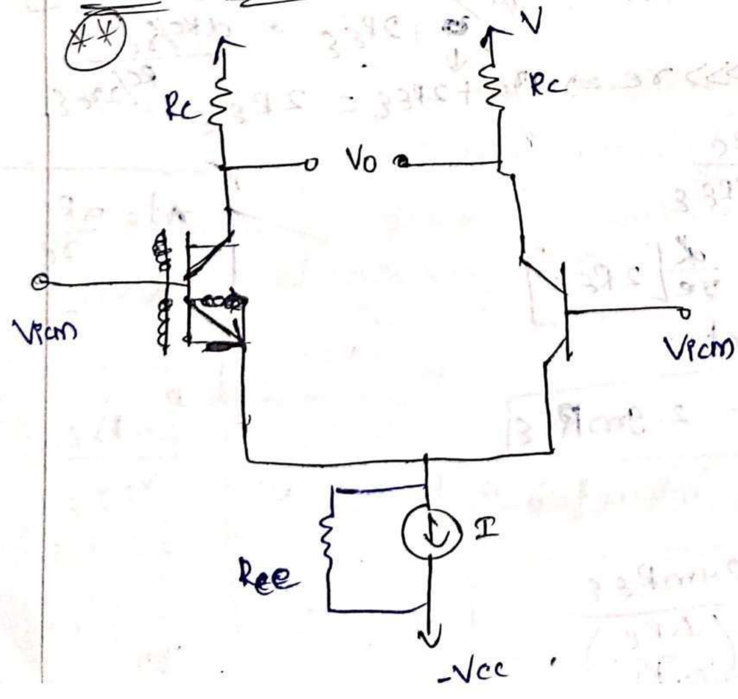
[gm is very high

$$CMRR \text{ in dB} = 20\log\left[\frac{A_d}{A_{cm}}\right]$$

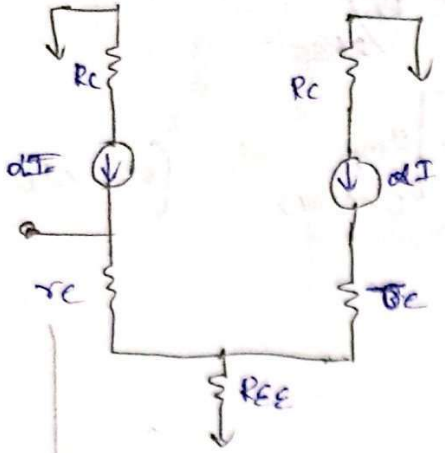
$$\boxed{CMRR \text{ in dB} = 20\log(CMRR)}$$

CMRR for BJT :-

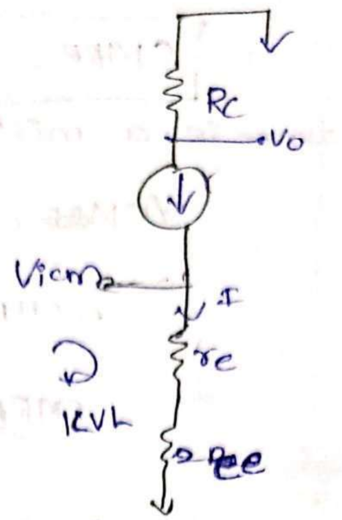
(**)



AC circuit



Half circuit



Apply KVL to input loop :-

$$\boxed{V_{icm} = I\left[r_e + 2R_{EE}\right]}$$

$$I = \frac{V_{icm}}{r_e + 2R_{EE}}$$

$$V_o = V_{c1} = V_{c2} = I R_C$$

$$V_o = \left(\frac{V_{icm}}{r_e + 2R_{EE}}\right) R_C \Rightarrow \frac{V_{c1}}{V_{icm}} = \left[\frac{R_C}{r_e + 2R_{EE}}\right]$$

$$\boxed{A_{cm} = \frac{R_C}{\;+2R_{EE}}}$$ If $2R_{EE} >>> r_e \Rightarrow 2R_{EE}$

$$\therefore \text{CMRR} = \frac{A_d}{A_{cm}} = \frac{R/r_e}{R_C/\;+2R_{EE}} = \left[\;+2R_{EE}\right] = \frac{\alpha R_C/r_e}{R_C/2r_{EE}}$$

If $2R_{EE} >>> r_e \Rightarrow r_e + 2R_{EE} = 2R_{EE}$

$$A_{cm} = \frac{R_C}{2R_{EE}}$$

$$\therefore \text{CMRR} = \frac{\alpha}{r_e}\left[2R_{EE}\right]$$

we know that

$$\boxed{\text{CMRR} = 2 g_m R_{EE}}$$

$$A_d = \frac{\alpha R_C}{r_e}$$

$$r_e = V_t / I_E$$

$$\frac{2\alpha R_{EE}}{V_t/I_E}$$

$$\frac{2 I_C R_{EE}}{V_t}$$

$$\frac{2}{g_m} g_m R_{EE}$$

If there is a mismatch in RC,

$$\therefore \text{CMRR} = \frac{2 g_m R_{EE}}{\left(\frac{\Delta R_C}{R_C}\right)}$$

CMRR in dB = 20 log (CMRR)

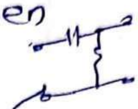
Effect of Cascading on Gain and Bandwidth of Multistage amplifier

1) Effect of cascading on Gain:-

→ We know that, in Multistage amplifiers, the overall gain is equal to the product of individual voltage gains. i.e, $A_V = A_{V1} \times A_{V2} \times \cdots \times A_{Vn}$.

→ We know that $A_V = (A_m)^n$ in mid frequencies.

→ If 'n' no. of identical stages are cascaded then overall gain as follows, $\boxed{A_{mv} = (A_m)^n}$ at mid frequencies



(2) At low frequencies, the gain of the amplifier for a single stage is

$$\boxed{A_L = \frac{A_m}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}}}$$

in low freq $f_L = \frac{1}{2\pi RC}$ Av depends on lowpass circuit

For 'n' identical stages

$$\boxed{(A_V) = \frac{(A_m)^n}{\left[1+\left(\frac{f_L}{f}\right)^2\right]^{n/2}}}$$

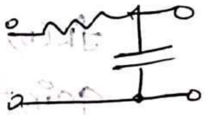
$f_L = \frac{1}{2\pi RC}$

(3) At high frequencies, the gain of the amplifier for single stage is

$$\boxed{A_H = \frac{A_m}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}}$$

$f_H = \frac{1}{2\pi RC_{ds}}$

Gain depends High pass circuit



$$\boxed{A_H = \frac{(A_m)^n}{\left[1+\left(f/f_H\right)^2\right]^{n/2}}}$$

1) A multistage amplifier with four identical stages each of which as a lower cutoff frequency of $f_L = 20Hz$ and upper cutoff frequency of $f_H = 20KHz$ Calculate the gain of the Multistage amplifier at mid frequency, 7.5 Hz and 200 KHz? Assume mid band gain (A_m) of each stage is 10?

$f_L = 20Hz$; $f_H = 20KH$; $A_m = 10$, $n = 4$

At mid frequency

$= A_{mv} = (10)^{(4)}$

$A_{mv} = 10000$,

At $f = 7.5Hz$ (Low frequency).

$$\therefore A_L = \frac{A_m}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}} = \frac{10}{\sqrt{1+\left(\frac{20}{7.5}\right)^2}}$$

= 1~~232.87~~

= 151.998

At f = 200KHz [→ upper cutoff so use At high frequency]

$$A_H = \frac{(A_m)^n}{\left[1+\left(f/f_H\right)^2\right]^2}$$

$$A_H = \frac{(10)^4}{\left[1+\left(\frac{200K}{20K}\right)^2\right]^{4/2}}$$

$$\boxed{A_H = 0.98}$$

Effect of cascading on bandwidth:

Bandwidth is the difference between upper cutoff frequency and lower cutoff frequency $\boxed{\begin{array}{l} BW = f_H - f_L \\ (or)\ f_2 - f_1 \end{array}}$

⇒ In multistage amplifiers, due to cascading the frequency response and bandwidth of the amplifier get effected and the bandwidth of cascaded amplifier is always less than that of a single stage amplifier.

For Cascaded amplifiers:- Lower 3dB frequency:-

The lower 3dB frequency of 'n' identical cascaded stages is $f_{L(n)}$ and it is the frequency at which the overal gain falls to $\left(\frac{1}{\sqrt{2}}\right)$ times ~~of~~ its mid band gain (max Av)

⇒ We know that $A_L = \frac{(A_m)^{\cancel{n}}}{\left[1+\left(f_L/f_{L(n)}\right)^2\right]^{n/2}} = \frac{(\cancel{A_m})^n}{\sqrt{2}}$

$$A_L \Rightarrow \frac{1\ (f_L)}{\left[1+\left(f_L/f_{L(n)}\right)^2\right]^{n/2}} = \frac{1}{\sqrt{2}}$$

$$\left[1+\left(\frac{f_L}{f_{L(n)}}\right)^2\right]^{n/2} = \sqrt{2}$$

Squaring on both sides.

$$2 = \left[1+\left(\frac{f_L}{f_{L(n)}}\right)^2\right]^n$$

$$2^{1/n} = 1+\left[\frac{f_L}{f_{L(n)}}\right]^2$$

$$2^{1/n} - 1 = \left[\frac{f_L}{f_{L(n)}}\right]^2$$

Taking square root on both sides.

$$\sqrt{(2^{1/n}-1)} = \frac{f_L}{f_L(n)}$$

$$\boxed{f_L(n) = \frac{f_L}{(2^{1/n}-1)^{1/2}}}$$

Similarly: we know that $A_H = \frac{(A_m)^n}{\left[1+\left(\frac{f}{f_H}\right)^2\right]^{n/2}}$ =

Upper cutoff frequency $f_{H}(n)$ is the at which the gain of the amplifier decreases to $\left(\frac{1}{\sqrt{2}}\right)$ times of its mid band frequency.

$$A_H \Rightarrow \frac{(A_m)^n}{\left[1+\left(\frac{f_H(n)}{f_H}\right)^2\right]^{n/2}} = \frac{(A_m)^n}{\sqrt{2}}$$

$$\left[1+\left(\frac{f_H(n)}{f_H}\right)^2\right]^{n/2} = \sqrt{2}$$

$$\boxed{f_H(n) = f_H\sqrt{2^{1/n}-1}}$$

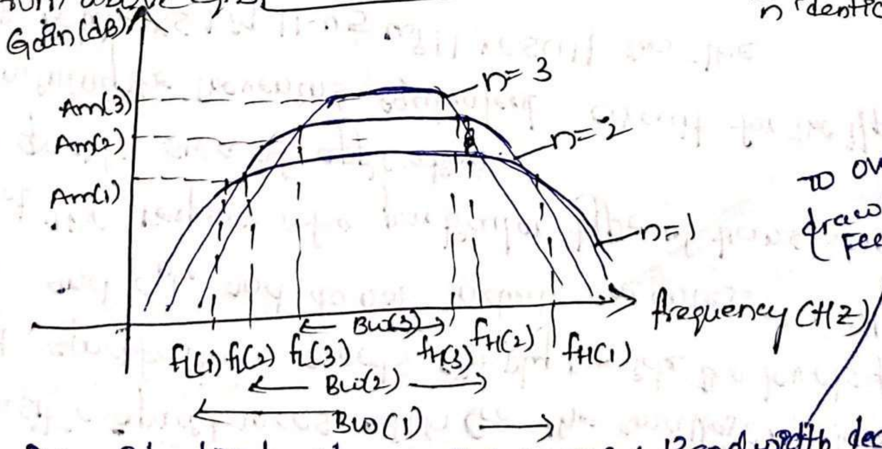
$$2 = \left[1+\left(\frac{f_H(n)}{f_H}\right)^2\right]^n$$

$$2^{1/n} = 1+\left(\frac{f_H(n)}{f_H}\right)^2$$

$$2^{1/n}-1 = \left(\frac{f_H(n)}{f_H}\right)^2$$

$$\boxed{f_H(n) = f_H\sqrt{2^{1/n}-1}}$$ Upper cutoff frequency for 'n' identical stages

From above eqns'



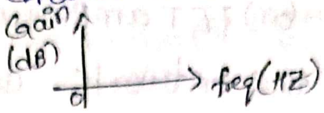
To overcome drawback Feedback Amplifier

As, identical stages increases, Bandwidth decreases so, it is not good for amplifier (BW should be high for good amplifier)

UNIT-3

Frequency Response of BJT & MOSFET Amplifiers

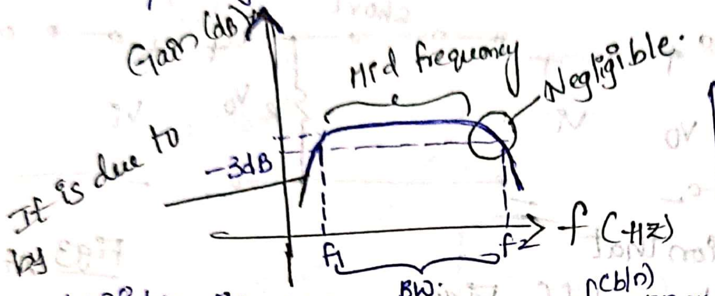
Frequency Response:- It is the graph drawn on semilogarithmic graph between frequency (VS) gain of the amplifier.



Frequency range :- few Hz to MHz.

→ It is a non-linear graph.

→ On x-axis, frequencies are considered as a multiple of decade.



Bandwidth (BW) = f2 - f1)

Band Width is the difference of (cb/n) upper cutoff frequency and lower cutoff frequency.

Why -3dB we considered?

The decreased gain is negligible, so at that curve we considered (-3dB).

(*) Lowercutoff Frequency:- The gain of the amplifier increases. At low frequency, gain is fall off because coupling and bypass capacitor.

→ The frequency at which the gain drops by 3dB below its mid band frequency is called lower cutoff frequency (f_L)

Upper cutoff frequency:-

→ At higher frequencies, the gain of the amplifier falls because of internal junction capacitances of the BJT transistor (or) MOSFETs.

→ The frequency at which the gain drops by 3dB below its midband frequency.
above

Low Frequency Analysis of BJT and MOSFET:

→ In the low frequency region of the single-stage BJT (or) FET amplifier, it is the RC combinations formed by the network capacitors C_c, C_E and C_{in} and the network resistive parameters that determine the cutoff frequencies.

→ Fig-1: can be estabilished for each capacitive element and the frequency at which the output voltage drops to 0.707 of its maximum value determined.

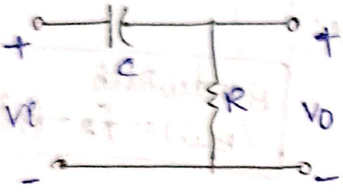


Fig1 : RC combination that will define a low cutoff frequency.

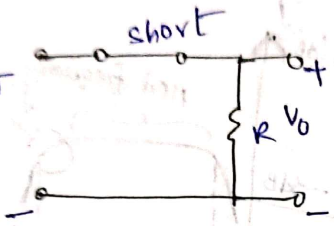


Fig2 At high frequency

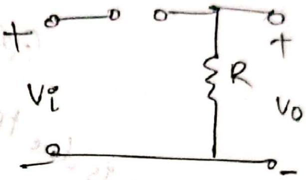


Fig3 At low frequency.

→ Once the cutoff frequencies due to each capacitor are determined, they can be compared to establish which will determine the low-cutoff frequency for the system.

→ Our analysis, therefore, will begin with the series R-C combination of fig. 1 and the development of a procedure that will result in a plot of the frequency response with a minimum of time and effort.

→ At high frequencies, $X_c = \frac{1}{2\pi \underset{\infty}{f} c} = 0\Omega$

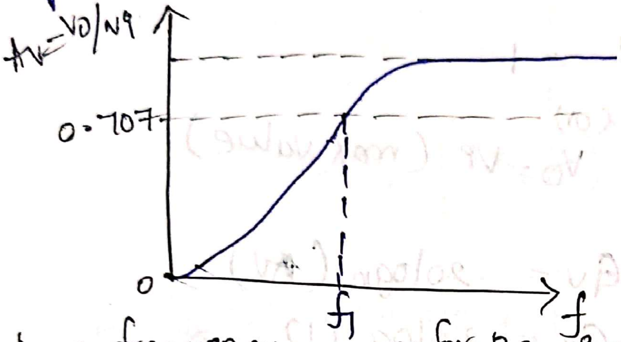
and short-circuit equivalent can be substituted for the capacitor as shown in fig. 2, The result is that $V_o = V_i$ at high frequencies.

→ At f=0Hz, $x_c = \frac{1}{2\pi f C} = \frac{1}{2\pi(0)} = \overset{\alpha}{\Omega}$

and the open circuit approximation can be applied shown in Fig. 3 with the result that $V_0=0V$ (when $R=\alpha\Omega$)

$$A_V = \frac{V_0}{V_i}$$

As the frequency increases, the capacitive reactance decreases and more of the input voltage appears across the output, so (short) terminals.

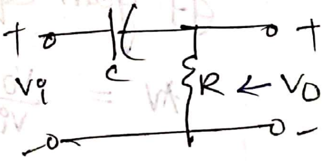


Low frequency response for RC circuit

$26mV = V_T$

The o/p and i/p voltages are related by the voltage-divider rule:

$$V_0 = \frac{RV_i}{R+X_C}$$



Magnitude of V_0

$$\boxed{V_0 = \frac{RV_i}{\sqrt{R^2+X_C^2}}}$$

when $X_C=R$,

$$V_0 = \frac{RV_i}{\sqrt{R^2+R^2}} = \frac{\cancel{R}V_i}{\sqrt{2}\cancel{R}} = \frac{V_i}{\sqrt{2}}$$

$$|A_V| = \frac{V_0}{V_i} = \frac{\frac{\cancel{V_i}}{\sqrt{2}}}{\cancel{V_i}} = 1/\sqrt{2}$$

$$\boxed{|A_V| = 1/\sqrt{2}}$$

At the frequency of which $X_C=R$, the o/p will be 70.7% (0.707) (or) (3dB) of the i/p of network.

The frequency at which this occurs is as

$$X_C = \frac{1}{2\pi f_1 C} = R$$

$$f_1 = \frac{1}{2\pi RC}$$

In terms of logs,

$$G_V = 20\log_{10} A_V = 20\log_{10}\frac{1}{\sqrt{2}}$$

$$\boxed{G_V = -3dB}$$

when

$$A_V = \frac{V_0}{V_i} = 1$$

(or)

$$V_0 = V_i \text{ (max value)}$$

$$G_V = 20\log_{10}(A_V)$$

$$G_V = 20\log_{10}(1) = 0$$

$$\boxed{G_V = 0dB}$$

If gain equation is written as

$$A_V = \frac{V_0}{V_i} = \frac{R}{R-jX_C}$$

$$A_V = \frac{1}{1-j(X_C/R)}$$

$$= \frac{1}{1-j(1/\omega CR)}$$

$$= \frac{1}{1-j(1/2\pi fCR)} \qquad f_1 = 1/2\pi f$$

$$A_V = \frac{1}{1-j(f_1/f)}$$

Magnitude and phase form

$$A_V = \frac{V_0}{V_i} = \underbrace{\frac{1}{\sqrt{1+(f_1/f)^2}}}_{\text{Mag of } A_V} \quad \underset{\substack{\downarrow \\ \text{phase } \angle \text{ angle by} \\ \text{which } V_0 \text{ leads } V_i}}{\underline{\tan^{-1}(f_1/f)}}$$

The magnitude when $f = f_1$

$$|A_V| = \frac{1}{\sqrt{1+1^2}} = \frac{1}{\sqrt{2}} = 0.707 \Rightarrow -3dB$$

In log form, the gain in dB is

$$A_V(dB) = 20\log_{10} \frac{1}{\sqrt{1+(f_1/f)^2}} = 20\log_{10}\left[\sqrt{1+(f_1/f)^2}\right]^{-1}$$

$$= -20\log_{10}\left[1+\left(\frac{f_1}{f}\right)^2\right]^{1/2}$$

$$= -\frac{1}{2}(\overset{10}{\cancel{20}}) \log_{10}\left[1+(f_1/f)^2\right]$$

$$= -10\log_{10}\left[1+(f_1/f)^2\right]$$

$$A_V(dB) = -10\log\left[(f_1/f)^2\right] \quad f << f_1 \text{ (or) } (f_1/f)^2 >> 1$$

$$\text{***} \quad \boxed{A_V(dB) = -20\log_{10}(f_1/f)} \quad (f << f_1)$$

At $f = f_1$; $A_V(dB) = -20\log_{10}(1) = 0 dB$.

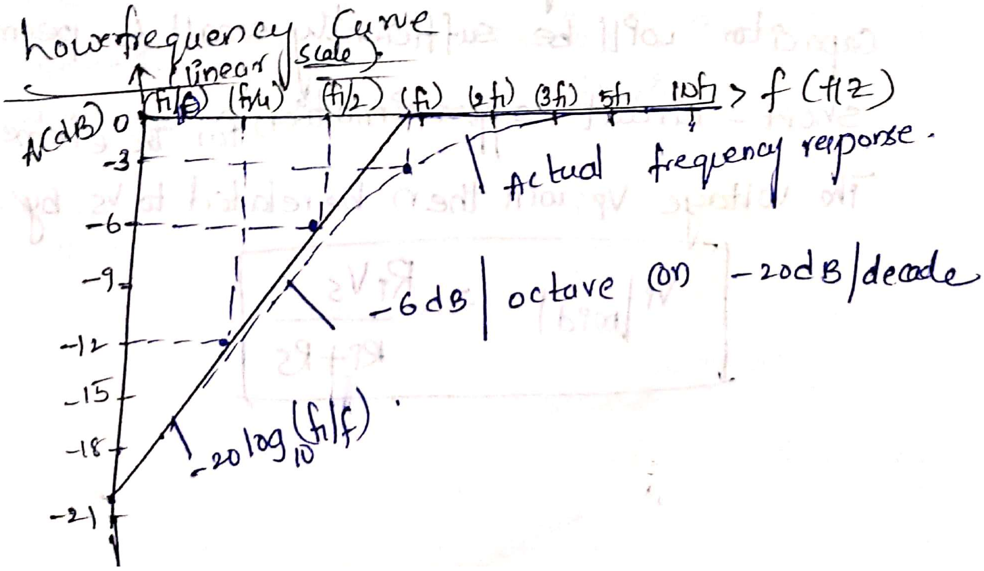
At $f = \frac{1}{2} f_1$; $A_V(dB) = -6dB$

At $f = \frac{1}{4} f_1$; $\frac{f_1}{f} = 4$; $-20\log 4 = -12dB$.

At $f = \frac{1}{10} f_1$; $\frac{f_1}{f} = 10$ and $A_V(dB) = -20\log 10(10)$

$= -20dB$.

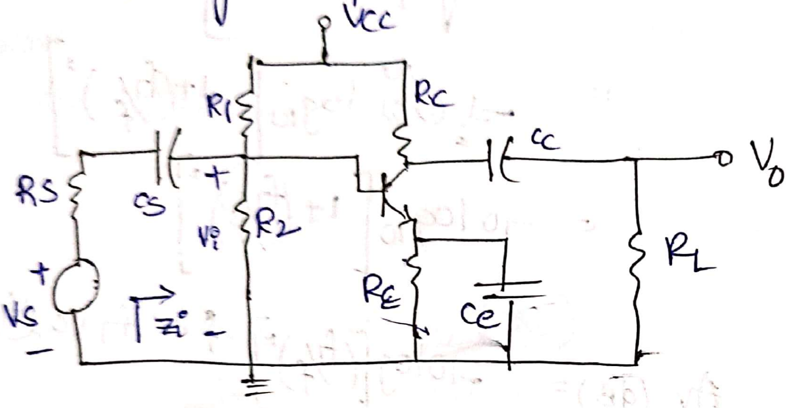
Lowfrequency Curve



Low Frequency Analysis of BJT:

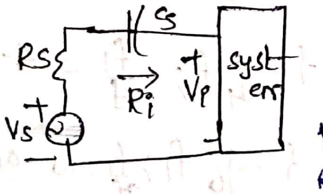
The analysis of low frequency response of BJT amplifier will employ the loaded voltage-divider BJT bias configuration, but results can be applied to any BJT configuration.

→ The capacitors C_s, C_c and C_E will determine the low-frequency response.



C_s: C_s is normally connected b/n the applied source and the active device, the general form of configuration is established as shown in fig 2. The total resistance ($R_s + R_i$) and the cutoff frequency as established.

$$f_{LS} = \frac{1}{2\pi (R_s+R_i) C_s}$$



$R_i = Z_{in}$

→ At mid (or) high frequencies, the reactance of the capacitor will be sufficiently small to permit a short-circuit approximation for the element.

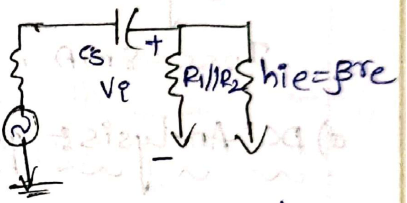
The voltage V_i will then be related to V_s by

$$\boxed{V_i\Big|_{mid} = \frac{R_i V_s}{R_i + R_s}}$$

At f_{LS}, the voltage V_i will be 70.7% of the value determined by above $V_i|_{mid}|$ equation, assuming that C_s is the only capacitive element controlling the low-frequency response.

For the network of fig1, when we analyze the effects of C_s we must make the assumption that C_E and C_C are performing their designed function or the analysis becomes too unwieldy. that is, the magnitude of the reactances of C_E and C_C permits employing a short circuit equivalent in comparision to the magnitude of the other series impedances. Using the hypothesis, the ac equivalent network for the input section of fig1 will appear as shown in below fig:-

$R_i = R_1 || R_2 || \beta r_e$

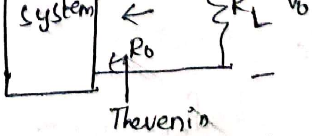


→ The voltage (V_i) applied to the input of the active device can be calculated using the voltage-divider rule

$$\boxed{V_i = \frac{R_i V_s}{R_s + R_i - jX_{Cs}}}$$

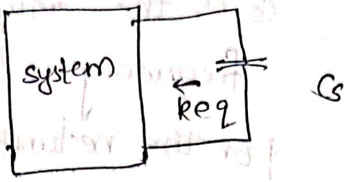
→ **C_C:-** Since the coupling capacitor is normally connected b/n the o/p of the active device and the applied load, the R-C combination that determines the low cutoff frequency due to C_C appears in below Fig. Total series resitance is now $R_o + R_L$ and the cutoff frequency due to C_C is determined by?

$$f_{LC} = \frac{1}{2\pi (R_o + R_L) C_C}$$



② Determine the effect of lower cutoff frequency.

C_s:- For the source capacitor C_s, the resistance level of importance is defined by Fig bellow. The cutoff frequency will be defined by



$$f_{Ls} = \frac{1}{2\pi R_{eq} C_s}$$

The resulting value of R_{eq}:-

$$R_{eq} = \frac{R_s}{1 + R_s(1+g_m r_d) \,/\, (r_d + R_D \| R_L)}$$

$r_d \cong \infty\Omega$ becomes $R_{eq} = R_s \| \frac{1}{g_m}$.

P:- Determine the lower cutoff frequency for the networks of fig11.32 using the following parameters?

$C_G = 0.01\mu F$, $C_C = 0.5\mu F$, $C_s = 2\mu F$, $R_S = 1k\Omega$

$R_{sig} = 10K\Omega$, $R_G = 1M\Omega$, $R_D = 4.7K\Omega$, $V_{DD} = 20V$, $R_L = 2.2\,K\Omega$

$I_{DSS} = 8mA$, $V_p = -4V$, $r_d = \infty\Omega$

a) DC Analysis:- Plotting the transfer curve of

$$I_D = I_{DSS}\left[1 - \frac{V_{GS}}{V_p}\right]^2$$

and superimposing the curve defined by $V_{GS} = -I_D R_S$ will result in an intersection at $V_{GSQ} = -2V$ & $I_{DQ} = 2mA$.

$$g_{mo} = \frac{2I_{DSS}}{|V_p|} = \frac{2(8\times10^{-3})A}{4V} = 4mS.$$

$$g_m = g_{mo}\left[1 - \frac{V_{GSQ}}{V_p}\right] = 4ms\left[1 - \left(\frac{-2V}{-4V}\right)\right] = 2ms.$$

C_G:-

$$f_{LG} = \frac{1}{2\pi(10K\Omega + 1M\Omega)(0.01\mu F)} \cong 15.8\,Hz$$

C_C

$$f_{LC} = \frac{1}{2\pi(4.7K\Omega + 2.2K\Omega)(0.5\mu F)} \cong 46.13\,Hz$$

C_S : $R_{eq} = R_S || \frac{1}{g_m} = 1k\Omega || \frac{1}{2mS} = 1k\Omega || 0.5k\Omega$

$R_{eq} = 333.33\ \Omega$

$$f_{LS} = \frac{1}{2\pi(333.33)(2\mu F)} = 238.73 Hz$$

Since, f_{LS} is the largest of the three cutoff frequencies, it defines the low cutoff frequency for the network.

(b) The midband gain of the system is determined by

$$A_{V(mid)} = \frac{V_o}{V_i} = -g_m(R_D || R_L)$$

$$= -2mS(4.7k\Omega || 2.2k\Omega)$$

$$A_{V(mid)} = -3$$

Internal capacitive Effects and the High-Frequency Model of the MOSFET and the BJT :-

→ While coupling and bypass capacitors cause the gain of transistor amplifiers to fall at the low frequency end, the gain falloff at high frequency is caused by the capacitive effects internal to the transistors.

→ In this section we shall briefly consider these effects and more importantly, show how the device small-signal model can be augmented to take these effects into account.

MOSFET: From physical operation of the MOSFET, we know that the device has internal capacitances

→ We used one of these, gate-to-channel capacitance, in our derivation of the MOSFET i-v characteristics.

We did, however, implicitly assume that the steady-stage charges on these capacitances are acquired instantaneously.

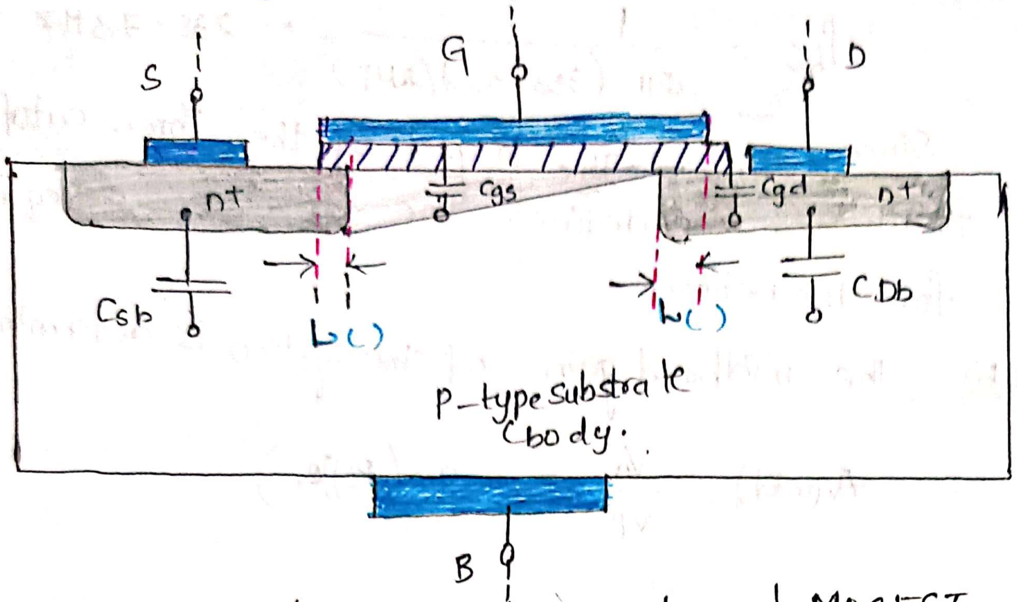


Fig:- A cross section of the n-channel MOSFET operating in the saturation region. The four internal capacitances. Cgs, Cgd+ , Csb, CdB are indicated.

Note:- The bias voltage are not shown. Also not shown that to keep the diagram simple, is the depletion region.

→ Fig: shows the cross section of an n-channel MOSFET operating in the saturation region, as signified by the tapered n-channel that is pinched off at the drain end.

→ There are four internal capacitances:

1) Two of these Cgs and Cgd, result from the gate-capacitance effect

2) The other, Csb, Cdb are the depletion capacitances of the pn junctions formed by the source region and the substrate, and the drain region and the

Low frequency Response of MOSFET (or) CS Amplifier.

→ The analysis of the MOSFET amplifier in the low-

substrate respectively.

→ The gate-capacitive effect means that, the polysilicon gate forms a parallel-plate capacitor with the channel region, with the oxide layer serving as the capacitor dielectric.

→ The gate (or) oxide capacitance per unit gate area is denoted C_{ox}.

→ When the channel is tappered and pinched off the gate capacitance is given by $\frac{2}{3} W L C_{ox}$.

→ In addition to this capacitance, there are two other small capacitances resulting from the overlap of the gate with the source region (or source diffusion) and the drain region (or drain diffusion).

→ Each of these overlaps has a length L_{ov} and thus the resulting overlap capacitances C_{ov} are given by

$$C_{ov} = W L_{ov} C_{ox}$$

Typically $L_{ov} = 0.05$ to $0.1 L$.

→ We can express the gate-source capacitance C_{gs} as $\boxed{C_{gs} = \frac{2}{3} W L C_{ox} + C_{ov}}$

→ For the gate-to-drain capacitance, we note that the channel pinch-off at the drain end causes C_{gd} to consist entirely on the overlap component C_{ov}, $\boxed{C_{gd} = C_{ov}}$

→ The depletion layer Capacitances of the two reverse -biased pn junctions formed b/n each of the source and the drain diffusions and the p-type substrate(body) can be determined and the source-body capacitance, (C_{sb})

$$\boxed{C_{sb} = \frac{C_{sb0}}{\sqrt{1+\frac{V_{SB}}{V_0}}}}$$

C_{sb0} = Value of C_{sb} at zero body-source bias.

V_{SB} = Magnitude of Reverse-bias Voltage.

V_0 = Junction built-in voltage (0.6V to 0.8V)

similarly, for the drain diffusion, we have the drain body capacitance

$$\boxed{C_{db} = \frac{C_{db0}}{\sqrt{1+\frac{V_{DB}}{V_0}}}}$$

C_{db0} = capacitance value at zero reverse-bias voltage

V_{DB} = Magnitude of the reverse bias voltage.

Note:- we have assumed that for both junctions, the grading coefficient $\boxed{m=1/2}$

P:- For an n-channel MOSFET with t_{ox} = 10nm, L = 1μm W = 10μm, L_{ov} = 0.05μm, $C_{sb0} = C_{db0}$ = 10fF, V_0 = 0.6V V_{SB} = 1V, and V_{DS} = 2V, Calculate the following capacitances when the transistor is operating in saturation: C_{ox}, C_{ov}, C_{gs}, C_{gd}, C_{sb} and C_{db}?

Given:- $C_{ox} = \frac{e_{ox}}{t_{ox}}$

e_{ox} is permittivity of the silicon dioxide.

$e_{ox} = 3.9 e_0 = 3.9 \times 8.854 \times 10^{-12} = 3.45 \times 10^{-11}$ F/m

$$C_{ox} = \epsilon_{ox} / t_{ox} = \frac{3.45 \times 10^{-11} F/m}{10 nm} = 3.45 fF/\mu m^2$$

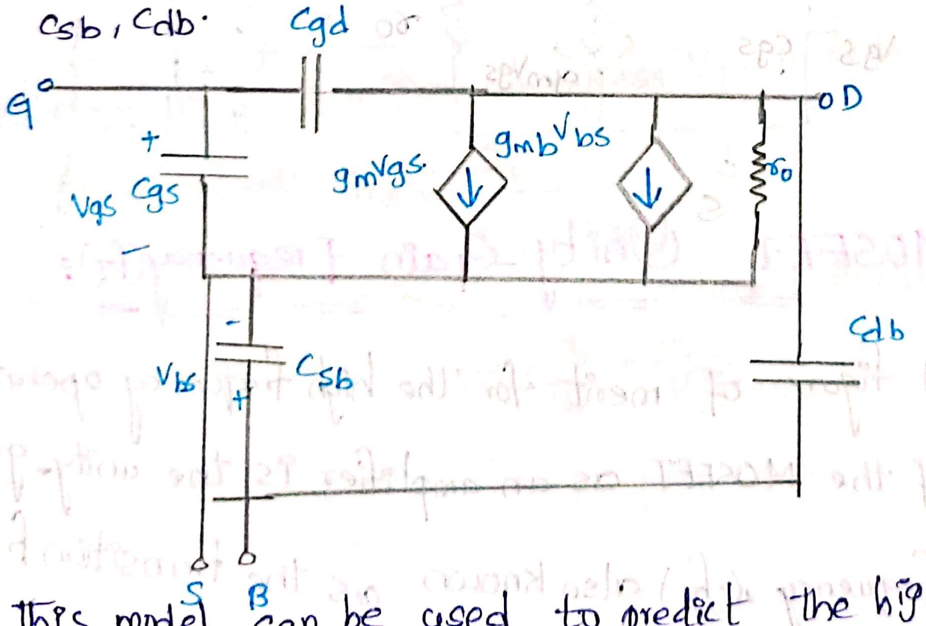
$$C_{ov} = W L_{ov} C_{ox} = 10 \mu m \times 1\text{-}05 \mu m \times 3.45 fF/\mu m^2$$

$$C_{ov} =$$

$$C_{gs} = \frac{2}{3} W L C_{ox} + C_{ov}$$

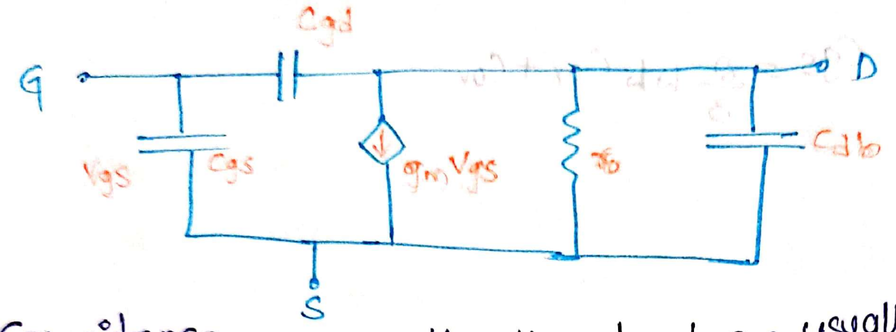
High-Frequency MOSFET Model :-

*> The below figure shows the small-signal model of the MOSFET, including the four capacitances C_{gs}, C_{gd}, C_{sb}, C_{db}.

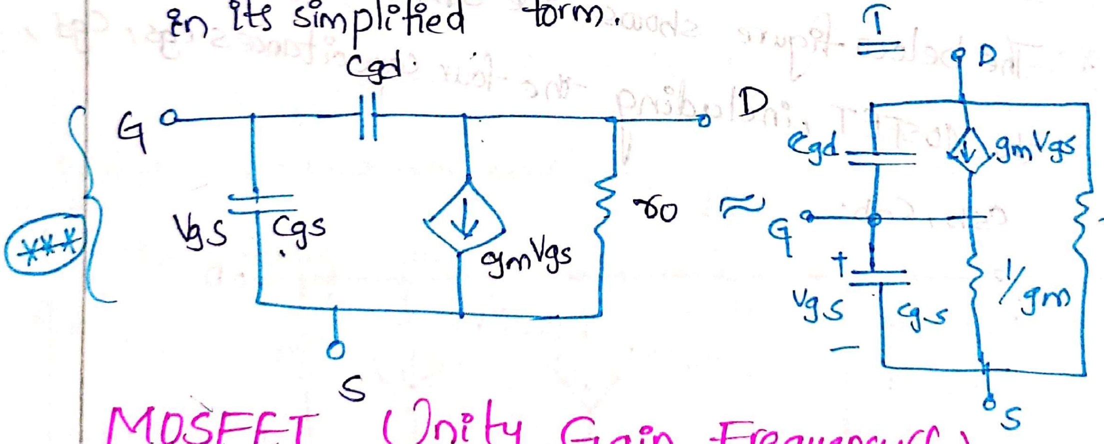


→ This model can be used to predict the high-frequency response of MOSFET amplifiers. It is, however, quite complex for manual analysis, and its use is limited to computer simulation using Ex:- (SPICE)

⇒ Fortunately, When the Source is connected to the body, the model simplifies considerably, as shown in below fig. In this model, Cgd, although small, plays a significant role in determining the high-frequency response of amplifiers and thus must be kept in model.



⇒ Capacitance Cdb, on the other hand, can usually be neglected, resulting in significant simplification of manual analysis. The resulting circuit is shown in below fig. Finally, we show in fig. the high-frequency (T) model in its simplified form.



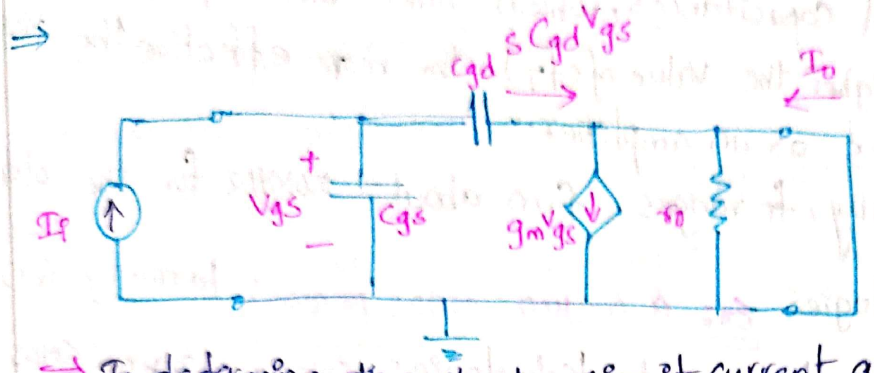
MOSFET Unity Gain Frequency(f_T):-

⇒ A figure of merit for the high frequency operation of the MOSFET as an amplifier is the unity-gain frequency, (f_T) also known as the transition frequency, which gives rise to the subscript (T).

→ It is defined as the frequency at which the short-circuit current gain of the common-source configuration becomes unity.

⇒ The below figure shows the MOSFET hybrid π model with the source as the common terminal b/n the i/p and o/p ports.

⇒



⇒ To determine the short-circuit current gain, the i/p is with a current-source signal I_i and the o/p terminals are short-circuited. It can be seen that the current in the short circuit is given by

$$\boxed{I_o = g_m V_{gs} - sC_{gd} V_{gs}}$$

→ Recalling that C_{gd} is small, at the frequencies of interest we can neglect the second term in this equation.

$$\boxed{I_o = g_m V_{gs}}$$

⇒ From above figure, we can express V_{gs} in terms of the i/p current $V_{gs} = \frac{I_i}{s(C_{gs}+C_{gd})}$

⇒ The above two equations can be combined to obtain the short-circuit current gain $\frac{I_o}{I_i} = \frac{g_m}{s(C_{gs}+C_{gd})}$

⇒ For physical frequencies $\boxed{s = j\omega}$, it can be seen that the magnitude of the current gain

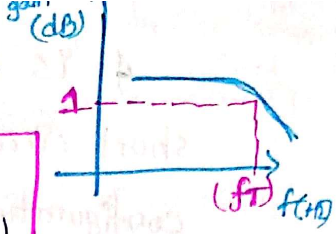
$$\left|\frac{I_o}{I_i}\right| = \frac{g_m}{\omega(C_{gs}+C_{gd})}$$

⇒ It becomes unity at the frequency

$$\omega_T = g_m/(C_{gs}+C_{gd})$$

∴ Unity-gain frequency (f_T) = $\omega_T / 2\pi$ is

$$\boxed{f_T = \frac{g_m}{2\pi(C_{gs}+C_{gd})}}$$



⇒ f_T is proportional to g_m, which determines the mid band gain, and inversely proportional to the MOSFET internal capacitances, which limit the amplifier bandwidth, the higher the value of (f_T), the more effective the MOSFET becomes as an amplifier.

⇒ Typically, f_T ranges from about 100MHz for the older technologies Ex:- (a 5-μm CMOS process) to many GHz for newer high-speed technologies. Ex:- a 0.13-μm CMOS process).

High Frequency Model of BJT:-

⇒ At low frequencies, we analyse the transistor using h-parameters, But for high frequencies the h-parameters model is not suitable for the following reasons:-

1) ⇒ Values of h-parameters are not constant at high frequencies.

2) h-parameter model is simple, and inaccurate because it neglects the early effect.

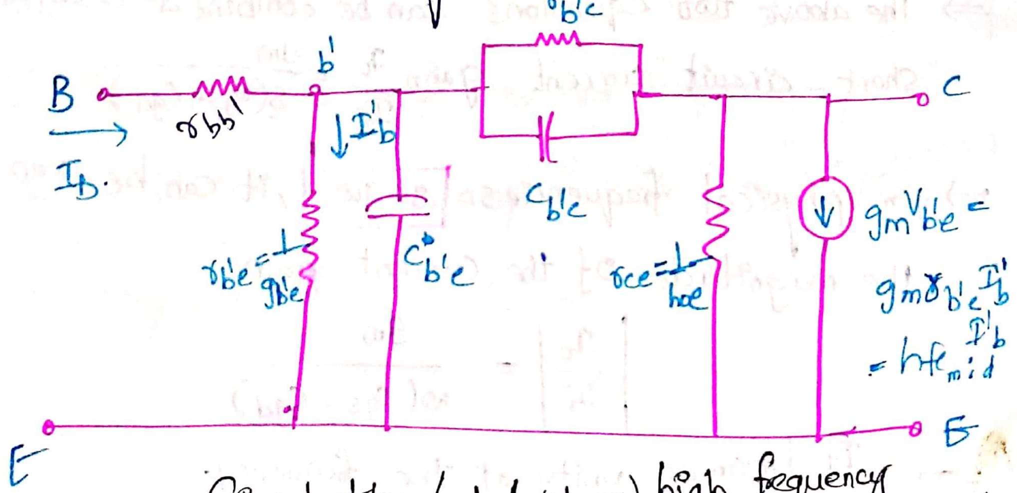


Fig:- Giacoletto (hybrid-π) high frequency transistor small-signal ac equivalent circuit

⇒ In above reason's hybrid-π model is used for the analysis of the reasonable comprise b/n accuracy and simplicity to do high frequency analysis of the transistor.

→ Analysis of circuits using this model are not too difficult and gives result which are in excellent at all frequencies for which the transistor gives reasonable amplification.

→ The below fig. shows the hybrid-π model for a transistor in CE configuration. It is also called "Giacoletto model".

1) $C_{b'e}$: The capacitive effect of normally forward biased base emitter junction of the transistor represented by $C_{b'e}$ (or) C_e in the hybrid-π model. It is due to the diffusion capacitance of forward bias emitter diode. Its typical value is 100PF.

2) $C_{b'c}$: The capacitive effect of normally reverse biased base collector junction of the transistor is represented by $C_{b'c}$ (or) C_c in the hybrid-π model. It is due to the transition capacitance of reverse bias collector diode. Its typical value is 3PF.

3) $r_{b'e}$: The resistive effect of normally forward biased base emitter junction of the transistor is represented by $r_{b'e}$ in the hybrid-π model. This is the portion of the base emitter resistance which may be thought of as being "in series" with the collector junction. Its typical value is 1KΩ.

$r_{b'c}$: The resistive effect of normally reverse biased base collector junction of the transistor is represented by $r_{b'c}$ in the hybrid-π model. This resistance is due to the early effect which is the varying voltage across the collector to emitter junction results in base width modulation. A change in the effective base width causes the emitter current to change. This feedback effect b/n output and input is taken by connecting $r_{b'c}$. Its typical value is 4MΩ.

$r_{bb'}$: The resistance effect of bulk resistance b/n the external node 'B' and internal base node b'. This resistance is called base spreading resistance. Its typical value is 100Ω

r_{ce} : The resistance effect of o/p terminals is represented by r_{ce} in hybrid-π model. It is also due to the early effect. Its typical value is 80KΩ.

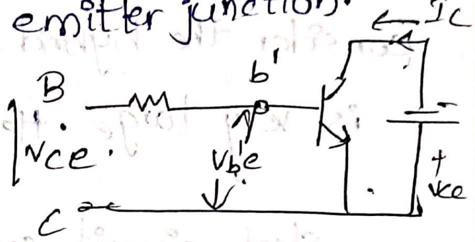
$g_m V_{b'e}$: Due to small changes in voltage $V_{b'e}$ across the emitter junction, there is excess minority carrier concentration injected into the base which is proportional to the $V_{b'e}$. Therefore resulting small signal current is proportional to $V_{b'e}$. This effect accounts for the current generator $g_m V_{b'e}$, where g_m is called transconductance. Its typical value is 50mA/V

Determination of hybrid-π parameters:-

→ Let us consider, for a given collector current the conductances and resistances of the hybrid-π parameters can be calculated from the low frequency h-parameter values in the CE configuration.

1) **Transistor transconductance (g_m)**:- Let us consider, a n-p-n transistor in the CE configuration with V_{cc} bias in the collector circuit.

→ Transconductance is the ratio of the change in the voltage ($V_{b'e}$) across the emitter junction.



$$\boxed{g_m = \frac{\Delta I_C}{\Delta V_{b'e}}}$$

we know that $I_C = \alpha I_E$

$$g_m = \frac{\Delta \alpha I_E}{\Delta V_{b'e}}$$

$$g_m = \alpha \frac{\Delta I_E}{\Delta V_{b'e}}$$

From fig: $V_{b'e} \simeq V_e$

$$\therefore = \alpha \frac{\Delta I_e}{\Delta V_e}$$

$$\boxed{g_m = \frac{\alpha}{r_e}}$$

$\frac{1}{r} = I$

$r = \frac{V}{I}$

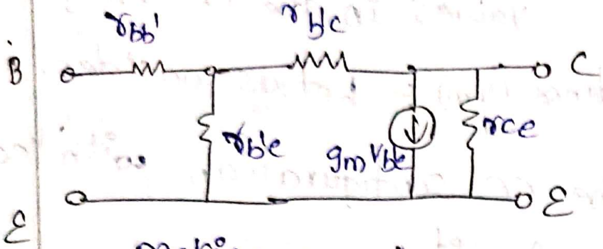
$\frac{1}{r} = \frac{I}{V}$

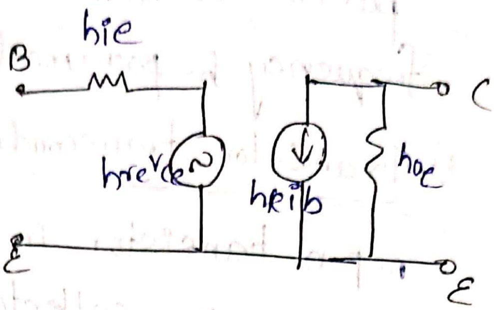
→ The emitter diode is forward biased diode and its dynamic resistance is given as $r_e = \frac{V_T}{I_E}$

$$\boxed{\therefore g_m = \alpha \frac{I_E}{V_T} = \frac{I_C}{V_T}}$$

At room temp; $\boxed{g_m = I_C / 26mV}$

Input Conductance ($g_{b'e}$) :- From figures of hybrid-π model ~~At~~ and the h-parameters model for CE configuration at low frequency. At low frequency all capacitors are negligible.





Making $V_{ce}=0$

$$\Rightarrow h_{fe} = \frac{I_c}{I_b} \leftarrow \left[I_c = h_{fe}I_b + \underbrace{h_{oe}V_{ce}} \right]$$

Consider the hybrid-π model for CE configuration, $r_{b'e}$ is very large. Hence I_b flows in $r_{b'e}$, then $V_{b'e} = I_b r_{b'e}$

short circuit current gain is given by

$$I_c = g_m V_{b'e}$$

$$= g_m I_b r_{b'e}$$

$$\frac{I_c}{I_b} = g_m r_{b'e}$$

$$\Rightarrow r_{b'e} = \frac{h_{fe}}{g_m} \text{ and } g_{b'e} = \frac{g_m}{h_{fe}} \quad \Big| \because g_{b'e} = \frac{1}{r_{b'e}}$$

Feedback Conductance $g_{b'c}$:- From h-parameter model, for CE configuration with i/p open circuit

$$I_b = 0, \; V_i = h_{re}V_{ce} \rightarrow h_{re} = \frac{V_{b'e}}{V_{ce}}$$

For hybrid-π model for CE configuration with i/p open circuit, $I_b = 0$

$$h_{re} = \frac{V_{b'e}}{V_{ce}} = \frac{I_b r_{b'e}}{I_b(r_{b'e} + r_{b'c})}$$

$$h_{re} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$$

$$r_{b'e} = h_{re} r_{b'c} + h_{re} r_{b'e}$$

$$(1-h_{re}) r_{b'e} = h_{re} r_{b'c}$$

$$r_{b'c} = \frac{(1-h_{re}) r_{b'e}}{h_{re}}$$

$(1-h_{re} << 1)$

$$\boxed{r_{b'c} = \frac{r_{b'e}}{h_{re}}}$$

then $\boxed{g_{b'c} = \frac{h_{re}}{r_{b'e}}} = \boxed{h_{re} \cdot g_{b'e}}$ $\quad \because r_{b'c} = \frac{1}{g_{b'c}}$

Base Spreading Resistance ($r_{bb'}$): The input resistance with output shorted ($V_{ce}=0$) is h_{ie} with hybrid-π model, input resistance with output shorted, is $r_{bb'} + r_{b'e}$

$$\therefore h_{ie} = r_{bb'} + r_{b'e}$$

$$r_{bb'} = h_{ie} - r_{b'e}$$

$$\boxed{r_{bb'} = h_{ie} - \frac{h_{fe}}{g_m}}$$

Output Conductance (g_{ce}): Using h-parameters the output conductance is given as $h_{oe} = \frac{I_c}{V_{ce}}$

consider hybrid-π model for ce configuration,

$$I_c = \frac{V_{ce}}{r_{ce}} + g_m V_{b'e} + \frac{V_{ce}}{r_{b'e} + r_{b'c}}$$

$$\therefore I_c = \frac{V_{ce}}{r_{ce}} + g_m \left[\frac{V_{ce} \cdot r_{b'e}}{r_{b'c} + r_{b'e}}\right] + \frac{V_{ce}}{r_{b'e} + r_{b'c}}$$

$$V_{b'e} = \frac{V_{ce} \cdot r_{b'e}}{r_{b'e} + r_{b'c}}$$

$$\frac{I_c}{V_{ce}} = \frac{1}{r_{ce}} + \frac{g_m r_{b'e}}{r_{b'c}+r_{b'e}} + \frac{1}{r_{b'e}+r_{b'c}}$$

$$\left[\because r_{b'e} = \frac{h_{fe}}{g_m}\right. \quad h_{fe} = g_m r_{b'e}$$

$$\frac{I_c}{V_{ce}} = \frac{1}{r_{ce}} + \frac{h_{fe}}{r_{b'c}+r_{b'e}} + \frac{1}{r_{b'e}+r_{b'c}}$$

$$\underbrace{\frac{I_c}{V_{ce}}}_{h_{oe}} = \frac{1}{r_{ce}} + \frac{(1+h_{fe})}{r_{b'c}+r_{b'e}}$$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{(1+h_{fe})}{r_{b'c}+r_{b'e}} \qquad [r_{b'c} >>> r_{b'e}]$$

$$\frac{1}{r_{ce}} = h_{oe} - \left[\frac{1+h_{fe}}{r_{b'c}+\underbrace{r_{b'e}}_{\approx 0}}\right]$$

$$\frac{1}{r_{ce}} = h_{oe} - \left[\frac{1+h_{fe}}{r_{b'c}}\right]$$

$$\frac{1}{r_{ce}} = h_{oe} - (1+h_{fe})g_{b'c}$$

$$\frac{1}{r_{ce}} = h_{oe} - h_{fe}g_{b'c} \qquad (h_{fe} >>> 1)$$

$$\boxed{g_{ce} = h_{oe} - h_{fe}g_{b'c}}$$

Summary: The relationship b/n low frequency h-parameters and high frequency hybrid-π parameters are

1) $g_m = \frac{I_c}{V_T}$

2) $r_{b'e} = \frac{h_{fe}}{g_m}$ & $g_{b'e} = \frac{g_m}{h_{fe}}$

3) $r_{b'c} = \frac{r_{b'e}}{h_{re}}$ & $g_{b'c} = \frac{h_{re}}{r_{b'e}} = h_{re}g_{b'e}$

4) $r_{bb'} = h_{ie} - r_{b'e} = h_{ie} - \frac{h_{fe}}{g_m}$

5) $\frac{1}{r_{ce}} = g_{ce} = h_{oe} - h_{fe}g_{b'c}$ //

CE short Circuit Current gain:

Consider a single stage CE transistor amplifier with load resistor (R_L) as shown in figure.

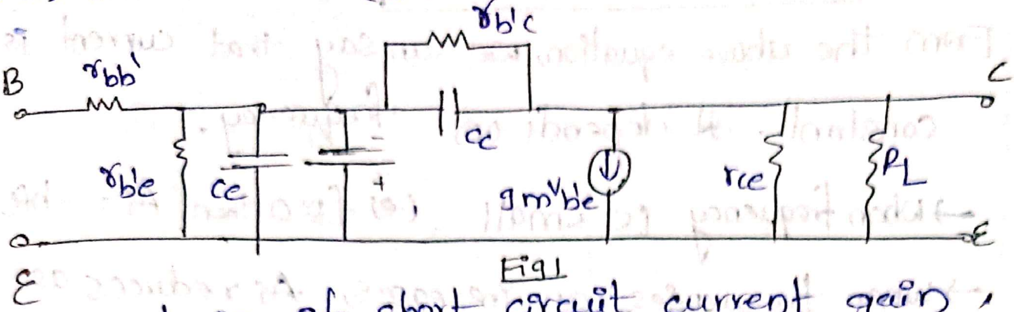


Fig1

For the analysis of short circuit current gain, assum $R_L=0$ with $R_L=0$, the o/p short circuited r_{ce} becomes zero, $V_{b'e}$, C_e and C_c appears in parallel.

→ As $r_{b'e} >> r_{b'e}$, $V_{b'c}$ is neglected. with these approximation we get simplified hybrid-π model for short circuit CE transistor as shown in fig.

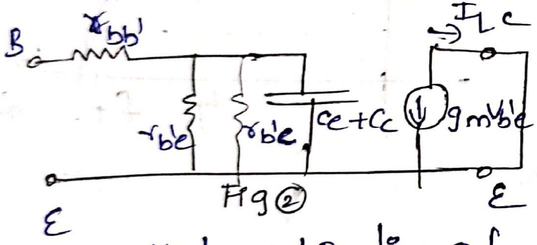


Fig ②

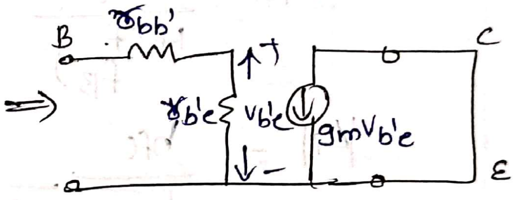


Fig ③

parallel combination of $r_{b'e}$ and $C_e + C_e$ is

$$Z = \frac{r_{b'e} \times \frac{1}{j\omega(C_e+C_c)}}{r_{b'e} + \frac{1}{j\omega(C_e+C_c)}} = \frac{r_{b'e}}{1+j\omega r_{b'e}(C_c+C_e)}$$

From fig ③;

We can write, $V_{b'e} = I_b Z \Rightarrow Z = \frac{V_{b'e}}{I_b}$

The short circuit current gain is given by

$$A_I = \frac{I_L}{I_b} = \frac{-g_m V_{b'e}}{I_b}$$

$$= -g_m(Z)$$

$$= -g_m\left[\frac{r_{b'e}}{1+j\omega(r_{b'e}(C_c+C_e))}\right]$$

We Know that $h_{fe} = g_m r_{b'e}$

$$\boxed{A_i = \frac{-h_{fe}}{1+j\omega r_{b'e}(C_e+C_c)}}$$

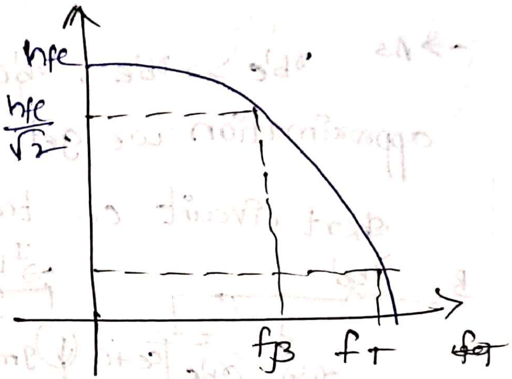
From the above equation, we can say that current is not constant. It depends on frequency.

→ When frequency is small (i.e) f ≃ 0 then $A_i = -h_{fe}$

→ When frequencies are increases, A_i reduces as shown in fig.

In above (A_i) equation, let us substitute.

$$f_\beta = \frac{1}{2\pi r_{b'e}(C_e+C_c)}$$



then

$$A_i = \frac{-h_{fe}}{1+j\frac{f}{f_\beta})}$$

$$|A_i| = \frac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$$

At $f = f_\beta$

$$\boxed{|A_i| = \frac{h_{fe}}{\sqrt{2}}}$$

<u>Gain Bandwidth product</u> :- It is the frequency at which the short circuit (CE) current gain becomes unity.

At $f = f_T$ and $A_i = 1$ then eqn $A_i = \frac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$

$$1 = \frac{h_{fe}}{\sqrt{1+(f_T/f_\beta)^2}}$$

The ratio f_T/f_β is very large $\left[\text{i.e. } 1+f_T/f_\beta = \frac{f_T}{f_\beta}\right]$

$$1 = \frac{h_{fe}}{f_T/f_\beta}$$

$$1 = \frac{h_{fe} \cdot f_\beta}{f_T}$$

$$f_T = h_{fe} f_\beta$$

$$f_T = h_{fe}\left[\frac{g_{b'e}}{2\pi(C_e+C_c)}\right]$$

$$= \frac{\cancel{h_{fe}}\ g_m}{h_{fe}\ 2\pi(C_e+C_c)}$$

$g_{b'e} = \frac{g_m}{h_{fe}}$

$$f_T = \frac{g_m}{2\pi(C_e+C_c)}$$

since $C_e >>> C_e$ then

$$f_T = \frac{g_m}{2\pi C_e}$$

$$\Rightarrow \boxed{C_e = \frac{g_m}{2\pi f_T}} \quad \text{similarly} \quad \boxed{C_c = \frac{g_m}{2\pi f_T}}$$

P At $I_c = 1mA$, and $V_{ce} = 10V$, a certain transistor data shows $C_c = C_{b'c} = 3pF$, $h_{fe} = 200$, $\omega_T = 500\,\mu\text{rad/sec}$. Calculate g_m, $r_{b'e}$, $C_e = C_{b'e}$ and ω_β?

1) $g_m = \frac{I_c}{V_T} = \frac{1mA}{26mV} = 38.46\,mA/V$.

2)

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{200}{38.46mA/V} = 5.2k\Omega$$

3) $f_T = \frac{g_m}{2\pi(C_e+C_c)} \Rightarrow \underbrace{(C_e+C_c)}_{76.92} = \frac{g_m}{2\pi f_T} = \frac{g_m}{\omega_T}$

$C_e + C_c = 76.92\,pF$

$$\therefore \omega_T = \frac{g_m}{C_e+C_c}$$

$C_e + C_c = 76.92\,pF$

$C_e = 76.92pF - 3pF$

$C_e = 73.92pF$

4) $f_T = h_{fe} f_\beta$

$2\pi f_T = h_{fe} 2\pi f_\beta$

$\omega_T = h_{fe} \omega_\beta$

$\omega_\beta = \frac{\omega_T}{h_{fe}} = \frac{500M \text{ rad/sec}}{200} = 2.5M \text{ rad/sec.}$

2) Short circuit CE current gain of transistor is 25 at a frequency of 2MHZ if f_β = 200KHZ. calculate f_T, h_{fe} and A_i at frequency of 10MHZ and 100MHZ.

1) $f_T = A_i \times f = 25 \times 2 \times 10^6 = 50MHZ$

2) $h_{fe} = \frac{f_T}{f_\beta} = \frac{50MHZ}{200KHZ} = 250$

3) We know that $A_i = \frac{h_{fe}}{\sqrt{1+(f/f_\beta)^2}}$

at f = 10MHZ, $A_i = \frac{250}{\sqrt{1+(10MHZ/200K)^2}}$

$A_i = \frac{250}{\sqrt{1+2500}} = \frac{250}{\sqrt{2501}}$

$A_i = 4.999 \approx 5$

at f = 100MHZ, $A_i = \frac{250}{\sqrt{1+\left(\frac{100MHZ}{200K}\right)^2}}$

$= \frac{250}{\sqrt{1+250000}}$

$= 0.4999$

$A_i \approx 0.5$

High Frequency Response – BJT Amplifier:-

⇒ At the high frequency end, there are two factors that will define the 3-dB point; the network capacitance(parasitic & introduced) and the frequency dependence of hfe().

⇒ In the high-frequency region, the RC network of concern has the configuration appearing in fig 11.42. At increasing frequencies, the reactance (Xc) will decrease in magnitude, resulting in a shorting effect across the o/p and a decrease in gain.

⇒ The deviation leading to the corner frequency for this RC configuration follows along similar lines to that encountered for the low-frequency region. The most significant difference is in the general form of Av, as below:-

$$A_v = \frac{1}{1+j(f/f_2)}$$

where $f_2 = 1/2\pi RC$

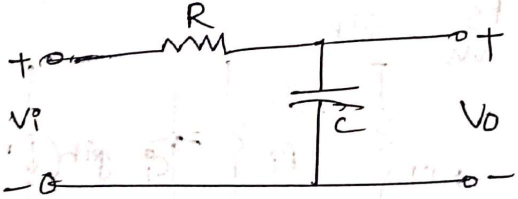


Fig 11.42:- R-C combination that will define a high cutoff frequency.

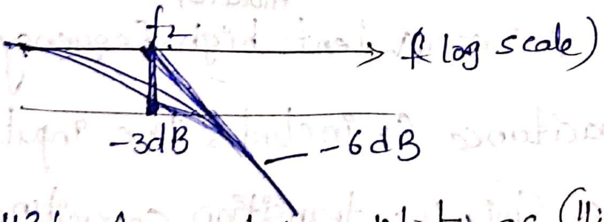
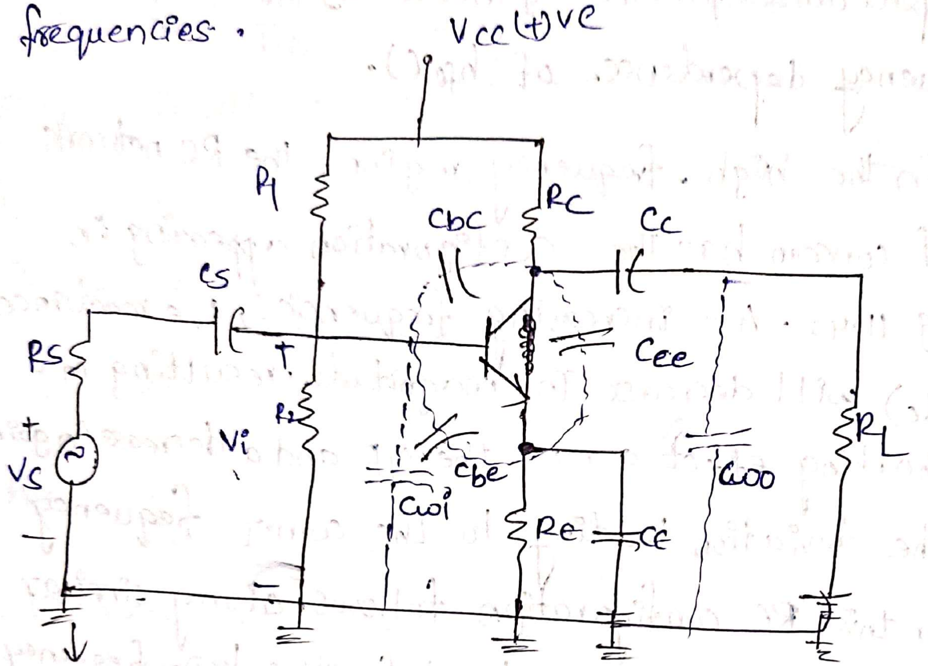


Fig 11.43:- Asymptotic plot as (11: 43).

⇒ In fig 11:44, the various parasitic capacitances ($C_{b'e}$, $C_{b'c}$, C_{ce}) of the transistor have been included and the wiring capacitances (C_{wi}, C_{wo}) introduced during construction.

→ The high frequency equivalent model for the network of Fig. 11:44 appears in (Fig 11·45). Note the absence of the capacitors (C_s, C_c, C_e), which are all assumed to be in the short-circuit state at these frequencies.



$C_i = C_{wi} + C_{be} + C_{Mi}$; $C_o = C_{wo} + C_{ce} + C_{Mo}$

Fig 11:44:- Capacitors that affect the high-frequency response

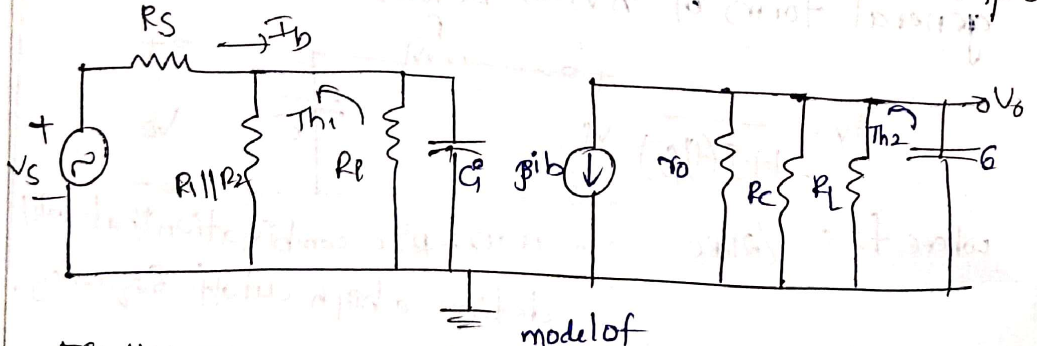


Fig 11:45:- AC equavalent model of high-frequency response

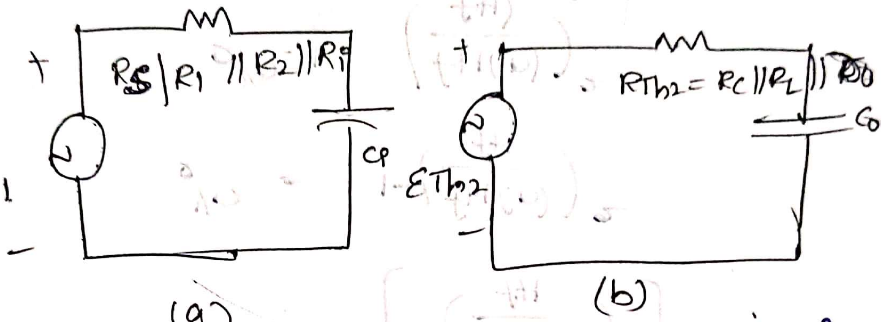
→ The capacitance C_i includes the input wiring capacitance C_{wi}, the transition capacitance $C_{b'e}$, and Miller capacitance C_{Mi}. The capacitance C_o includes the o/p wiring capacitance C_{wo}, the parasitic capacitance C_{ce} and the o/p Miller capacitance C_{Mo}.

⇒ In general, the capacitance $C_{b'e}$ is the largest of the parasitic capacitances, with C_{ce} the smallest. In fact, most specification sheets simply provide the levels of $C_{b'e}$ and $C_{b'c}$ and do not include C_{ce} unless it will affect the response of a particular type of transistor in a specific area of application.

→ Determining the Thevenin's equivalent circuit for the i/p and o/p networks Fig 11.45 will result in the configurations of Fig 11.46.

⇒ For the i/p network, the 3-dB frequency is defined by

Fig 11.46:



(a) (b)

Thevenin circuits for the i/p & o/p networks of the network in Fig 11.45.

$$f_{Hi} = \frac{1}{2\pi R_{Th1} C_i}$$

$$R_{Thi} = R_S \| R_1 \| R_2 \| R_i$$

$$C_i = C_{wi} + C_{be} + C_{Mi} = C_{wi} + C_{be} + (1 - A_v) C_{bc}$$

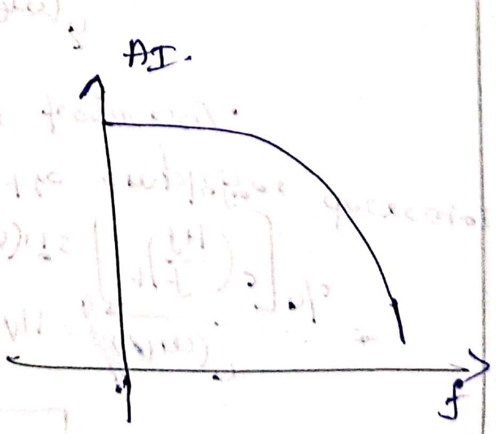
For o/p Network:

$$f_{Ho} = \frac{1}{2\pi R_{Th2} C_o}$$

Verified

$$R_{Th2} = R_C \| R_L \| r_o$$

$$C_o = C_{wo} + C_{ce} + C_{Mo}$$



13/5/2

4. FEEDBACK AMPLIFIERS

⇒ We know that input impedance, current gain, voltage gain, output impedance and bandwidth are some of the important characteristics of an amplifier.

⇒ This characteristics are not constant for an amplifier.

Drawback of single stage ⇒ As, This characteristics are not constantly we can observe in single stage amplifiers, gains are not sufficient and there is a mismatch in Z_{in} and Z_o.

⇒ This drawbacks of single stage amplifier is overcome in multistage amplifiers.

Drawback of Multi stage amplifier ⇒ In multistage amplifiers, the gain increases but at the same time, the circuit provides Unstability (i.e Bandwidth is decreases)

⇒ To overcome above problem we go for feedback amplifiers.

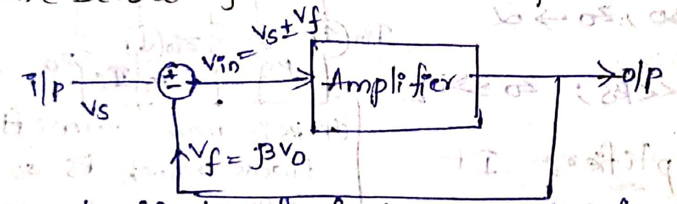
⇒ Feedback plays an important role in almost all electronic circuits

⇒ It is used to improve the performance and to make it more ideal.

Feedback means, process of combining a fraction of output back to the input.

2 types

⇒ The below fig. shows the simple block diagram of feed back amplifi



$V_f = \beta V_o$

$\boxed{V_{in} = V_s \pm V_f}$

① If, net effect of feedback (~~amplifier~~) signal is to reduce the magnitude of input signal, then it is called (-)ve (or) inverse (or) Degenerative feedback. i.e) $\boxed{V_{in} = V_s - V_f}$ (or) $\boxed{I_{in} = I_s - I_f}$

② If, net effect of feedback signal is to increase the magnitud of input signal then it is called (+)ve (or) Direct (or) Regenerat feedback. ie) $\boxed{V_{in} = V_s + V_f}$ (or) $\boxed{I_{in} = I_s + I_f}$

⇒ Negative feedback reduces the gain of the amplifier, but it has the following advantages:-

1) stabilisation of gain
2) Reduction in distortion
3) Reduction in Noise
4) change in i/p & o/p impedances.
5) Increases the bandwidth (Range of Uniform amplification).

⇒ Positive feedback increases the gain of the amplifier, but it has following disadvantages:

1) It Provides Instability.
2) It increases the Noise
3)

Due to this disadvantages positive feedback is not used in amplifier but it is used in oscillator circuit to produce oscillations.

** Classification of Amplifiers:

Before preceeding with the concept of feedback it is necessary to understand the classification of amplifiers based on the magnitude of the input and output impedances of an amplifier relative to the source (R_S) and load resistors (R_L)

Based on this, amplifiers are classified into four types.

1) Voltage Amplifier   2) Current Amplifier.
3) Transconductance amplifier   4) Transresistance amplifier

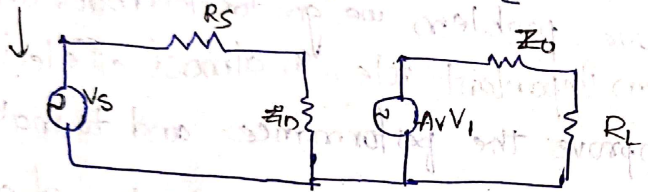
Voltage Amplifier: It produces output voltage α (proportional) to input voltage $V_o \alpha V_{in} \Rightarrow V_o = A_V V_{in}$

$$\therefore \boxed{A_V = \frac{V_o}{V_{in}}}$$

Here for ideal case: $Z_{in} \to \alpha$, $Z_o \to 0$

For practical, $Z_{in} >> R_S$; $Z_o << R_L$

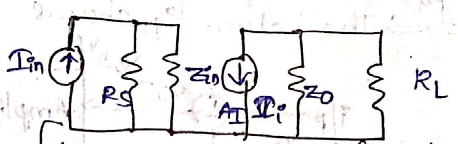
If Z_o is high it will drops at R_L
If Z_{in} is ~~small~~ high α so ~~R_S~~, it will drops at R_S (source)



Current Amplifier: It produces output current proportional to input current i.e, $I_o \alpha I_{in} \Rightarrow I_o = A_I I_{in} \Rightarrow \boxed{A_I = \frac{I_o}{I_{in}}}$

For ideal cases: $Z_{in} \to 0$, $Z_o \to \alpha$

practical cases: $Z_{in} << R_S$; $Z_o >> R_L$



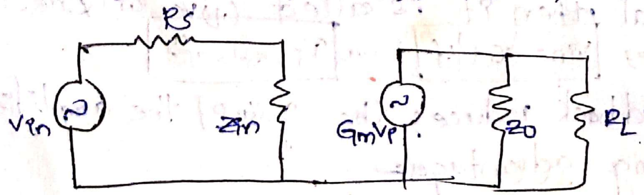
If Rs is more current is small when flows through Rs so Zin is < to allow current.

Transconductance Amplifier: It produces output current is proportional to input voltage.

$$I_o \alpha V_{in} \Rightarrow I_o = G_m V_{in} \Rightarrow \boxed{G_m = \frac{I_o}{V_i}}$$

For ideal cases: $Z_{in} = Z_o \to \alpha$

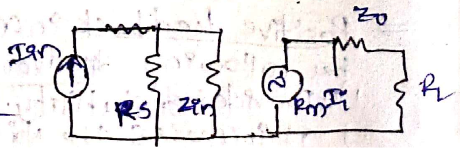
For practical cases: $Z_{in} >> R_S$; $Z_o >> R_L$



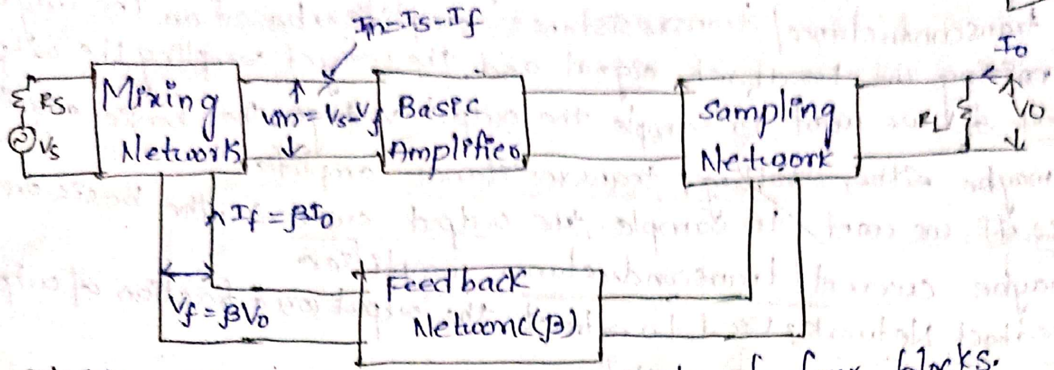
Transresistance amplifier: It produces output voltage is proportional to input current $V_o \alpha I_{in} \Rightarrow V_o = R_m I_i \Rightarrow \boxed{R_m = \frac{V_o}{I_i}}$

For ideal cases: $Z_{in} \Rightarrow Z_o \to 0$

practical cases: $Z_{in} << R_S$; $Z_o << R_L$



BLOCK DIAGRAM OF NEGATIVE FEEDBACK AMPLIFIER



⇒ (−)ve FEEDBACK AMPLIFIER consists of four blocks.

Mixing Network :- The purpose is to combine the feedback signal with the input signal.

⇒ Generally there are two ways of mixing the signal. They are :

1) Series Mixing 2) Shunt Mixing.

⇒ If the feedback signal is connected in series with Vs then it is called series mixing.

⇒ If the feedback signal is connected in shunt/parallel with Vs then it is called shunt Mixing.

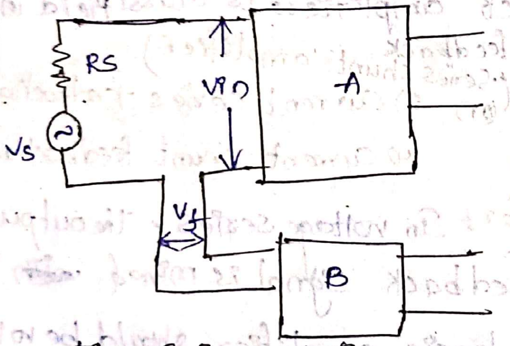


Fig: Series Mixing.

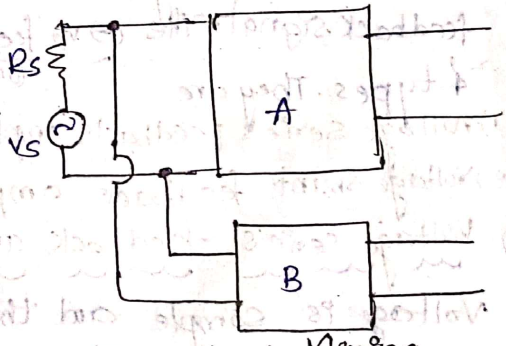


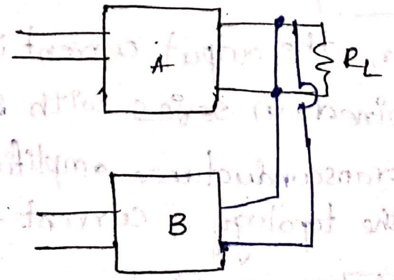
Fig: shunt Mixing.

Sampling Network :- It is used to the way of sampling/extracting the output signal from the amplifier.

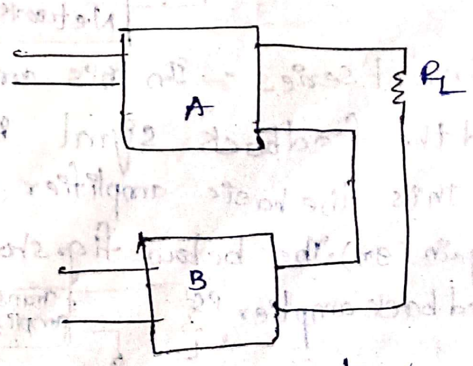
⇒ Generally amplifier output is Voltage (or) current.

⇒ If we want sample Voltage the feedback network is connected in shunt/parallel with RL (output), then it is called Voltage samplin

⇒ If we want to sample output current the feedback network is connected in series with RL (output), then it is called Current San



Voltage sampling.



Current sampling

Basic Amplifier:- It is used to amplify/ strengthen the weak signal. Here basic amplifier maybe either voltage/current/ transconductance/ transresistance amplifier, based on the way of mixing the feedback signal and the way of sampling the output.

exe If we want to sample the output voltage, then basic amplifier maybe either Voltage/ transresistance amplifier

Eg: If we want to sample the output current, the basic amplifier maybe current/ transconductance amplifier

Feedback Network:- Used to extract the output (or) a fraction of output signal from basic amplifier.

Generally, it is a passive two port network, which consists of Resistors, capacitors and inductors. In (-)ve feedback, resistors whereas capacitors & inductors are used in (+)ve feedback, and it provides a reduced portion of output voltage and it can be represented as $\boxed{X_f = \beta X_0}$ feedback → β : Feedback Ratio/ feedback factor. (lies b/n 0-1) ($\propto \beta < 1$)

Classification of feedbacks Amplifiers:-

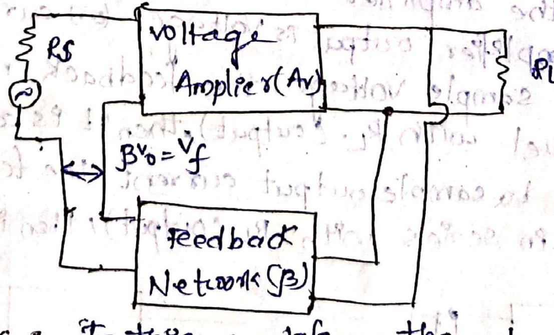
1) Based on the way of sampling the output and way of mixing the feedback signal. The (-)ve feedback amplifiers is classified into 4 types. They are

1) voltage series Feedbacks amplifier (or only feedback series shunt amplifier) 2) Current series feedback amplifier

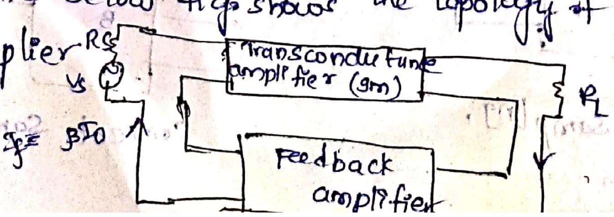
3) Voltage shunt feedbacks amplifier 4) Current shunt feedback amplifier

1) **Voltage series feedback amplifier:-** In voltage series, the output Voltage is sample and the feedback signal is mixed ~~with~~ in series with input. In this the basic amplifier should be voltage amplifier.

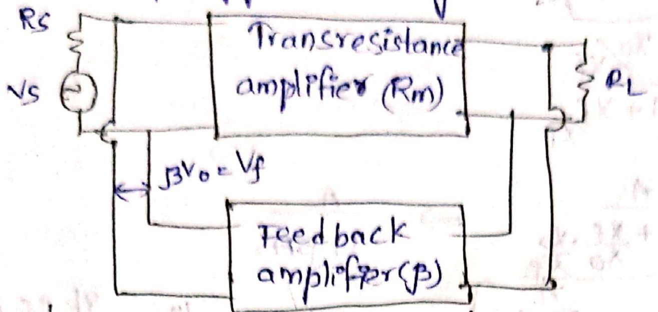
The below fig shows the Topology of voltage-series feedback amplifier



2) **Current series:-** In this amplifier, the output current is sampled and the feedback signal is mixed in series with input. In this the basic amplifier is transconductance amplifier with gain (gm). The below fig shows the topology of current series feedback amplier

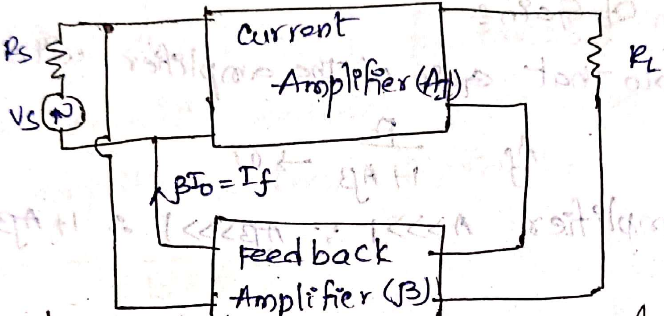


3) Voltage shunt:- Here output voltage is sampled and the feedback signal is mixed in shunt with input. In this the basic amplifier is an transresistance amplifier. The below fig. shows the topology of voltage shunt feedback amplifier.



shunt-parallel

4)) Current shunt: Here output current is sampled and the feedback signal is mixed in shunt with i/p. In this basic amplifier is current amplifier (AI). The below fig shows the topology of the current shunt feedback amplifier.



Gain
Impedance
Bandwidth
are characteristics.

Ideal (or) General

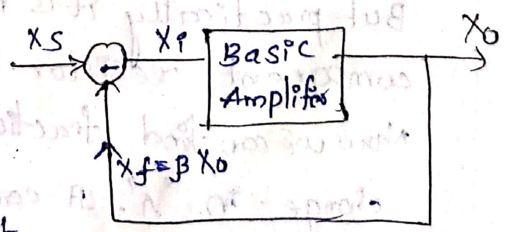
Characteristics of Negative feedback Amplifier:-

1) It reduces the gain (transfer gain) of the amplifier.
2) It provides stabilization of gain.
3) It reduces the Noise and destortion in amplifier.
4) It increases the bandwidth of an amplifier.
5) It changes the magnitudes of i/p & o/p impedances.

-Series - Incre Impedan
Shunt - Parallel
-o/p imp decrea

Effect of (-)ve feedback on amplifier characteristics:-

i) Transfer gain:- Consider a simple block diagram of (-)ve feedback amplifier.



Xs → source voltage (or) current
Xi → input voltage (or) current
Xo is o/p voltage (or) current
Xf is feedback voltage (or) current

∴ From this we can define

The gain without feedback is $A = \frac{X_o}{X_i}$

Gain with feedback is $A_f = \frac{X_o}{X_s}$

feedback factor (or) Ratio, $\beta = \frac{X_f}{X_o}$

Due to (-)ve feedback, the magnitude of i/p signal decreases.

From $A_f = \frac{X_o}{X_s}$

$$\boxed{A_f = \frac{X_o}{X_i + X_f}}$$ Divide numerator (or) denominator with (X_i)

$$A_f = \frac{X_o/X_i}{1 + X_f/X_i}$$

For voltage gain
$X \rightarrow V$
For current gain
$X \rightarrow I$

$$A_f = \frac{A}{1 + \frac{X_f}{X_o}\cdot\frac{X_o}{X_i}} \Rightarrow \frac{A}{1+\beta A}$$

$$\therefore \boxed{A_f = \frac{A}{1 + A\beta}} \rightarrow ①$$

From this equation it is clear that the gain of the amplifier with feedback reduces by a factor of $(1+A\beta)$ times of gain of the amplifier (A) without feedback.

(2) Stabilisation of Gain:-

We know that gain of the amplifier with feedback is

$$A_f = \frac{A}{1+A\beta} \rightarrow ①$$

For an amplifier, $A >>> 1$ ∴ $A\beta >>> 1$ ∴ $1 + A\beta \approx A\beta$

$$A_f = \frac{A}{1+A\beta}$$

$$A_f = \frac{A}{A\beta}$$

$$\boxed{A_f = \frac{1}{\beta}} \rightarrow ②$$

From this eqn② it is clear that (A_f) depends only on feed back factor (β)

suppose if we use feedback networks with resistive element as constant then gain should ~~be~~ remains constant. Then A_f is also constant. But practically it is not possible because the feed back component resistor is variable (varies) due to some reasons. Now we can find fractional change in (A_f) with fractional change in "A". It can be obtained by differentiating eqn① w.r.t "A".

$$\frac{dA_f}{dA} = \frac{(1+A\beta)1 - A(\beta)}{(1+A\beta)^2}$$

$$\boxed{\frac{dA_f}{dA} = \frac{1}{(1+A\beta)^2}} \rightarrow$$ [illegible]

$$dA_f = \frac{dA}{(1+A\beta)^2} \quad ③$$

Divide eqn ⑤ by eqn ①

$$\frac{dA_f}{A_f} = \frac{\frac{dA}{(1+A\beta)^2}}{\frac{A}{1+A\beta}}$$

$$\frac{dA_f}{A_f} = \frac{dA}{(1+A\beta)^2} \times \frac{(1+A\beta)}{A}$$

$$\frac{dA_f}{A_f} = \frac{dA}{A} \times \frac{1}{(1+A\beta)}.$$

$$\frac{dA_f/A_f}{\frac{dA}{A}} = \frac{1}{1+A\beta}$$

$\boxed{S = \frac{1}{1+A\beta}}$ Ratio (S) is called sensitivity.

⇒ Sensitivity: It is ratio of fractional change in gain of the amplifier with feedback to fractional change in gain of the amplifier without feedback.

Here $\frac{1}{1+A\beta} << 1$

Hence; $\boxed{\frac{dA_f}{A_f} <<< \frac{dA}{A}.}$

Reciprocal of sensitivity is called desensitivity.

$$\boxed{D = 1+A\beta}$$

1) 2M or 4M Calculate the gain of (-)ve feedback amplifier with an internal gain of 200 and feedback factor of $\frac{1}{20}$(β)?

Given: $A = 200$

$\beta = \frac{1}{20}$

$A_f = \frac{A}{1+A\beta}$

$\boxed{A_f = 18.1818}$

2) Overall gain of Multistage amplifier is 100 when a (-)ve feedback is applied gain reduces to 10. Find the fraction of output (ie) feedback to the i/p?

Given: $A = 100$

$A_f = 10$

$A_f = \frac{A}{1+A\beta}$

$1 + A\beta = \frac{A}{A_f} \Rightarrow \beta = \frac{\left(\frac{A}{A_f} - 1\right)}{A} = 0.09.$

3) In a negative feedback amplifier $A = 100$; $\beta = 0.04$ and $V_s = 50\,mV$. Find

(a) Gain with feedback (b) output voltage (c) feedback voltage

Given: $A = 100$; $\beta = 0.04$; $V_s = 50\,mV$

(a) $A_f = \frac{A}{1+A\beta} = \frac{100}{1+100 \times 0.04} = \boxed{20}$

(b) output voltage = A

$A_f = \frac{V_o}{V_s}$

$V_s \cdot A_f = V_o$

$\boxed{V_o = 1V}$

(c) feedback voltage $V_f = \beta V_o$

$\boxed{V_f = 0.04 \text{ Volts}}$

A negative feedback of $\beta = 0.002$ is applied to an amplifier with a gain of 1000 (A). Calculate the % change in overall gain of the feedback amplifier if the gain of the amplifier is subjected to a gain reduction of 15%?

$A_f = \frac{A}{1+A\beta}$; $\frac{dA}{A} = 15\%$

$\boxed{\frac{dA_f}{A_f} = \frac{dA}{A}\left[\frac{1}{1+A\beta}\right]}$ – use this formula also. $0.15\left[\frac{1}{1+1000 \times 0.002}\right]$

$\% \frac{dA_f}{A_f} = 0.05 \times 100$

$= 5\%$ ✓

$A_f = \frac{A}{1+A\beta} = \frac{1000}{1+1000 \times 0.002} = 333.33$

change of 15% means $A' = (1-0.15) \times 100 = 850$

Then $A_f' = A'\left[\frac{1}{\frac{1}{\cancel{A}}+A'\beta}\right]$

$A_f' = \frac{A'}{1+A'\beta} = 314.8$

∴ percentage change in gain is $\frac{A_f - A_f'}{A_f} \times 100$

$= \frac{333.33 - 314.8}{333.33} \times 100$

$\% \boxed{A^{a} \doteq 5.559}$

An amplifier gain changes by ±10%. using (-)ve feedback the amplifier is to be modified to gives a gain of 100 with ±0.1% variation. Find the required $\underbrace{\text{open loop}}_{A}$ gain of the amplifier and the amount of (-) ve feedback? closed loop gain AL

$A_f = 100$

$\frac{dA}{A} = \pm 10\% = 0.1$ ∴ $\% \frac{dA_f}{A_f} = \pm 0.1\%$

$\frac{dA_f}{A_f} = \pm 0.1\% = 0.001$

$$\frac{dA_f}{A_f} = \frac{dA}{A}\left[\frac{1}{1+A\beta}\right]$$

$$\frac{1}{1+A\beta} = \frac{dA_f}{dA/A}$$

$$1+A\beta = \frac{dA/A}{dA_f/A} \Rightarrow A\beta = \left[\frac{dA/A}{dA_f/A} - 1\right] \Rightarrow A\beta = \overbrace{\left[\frac{0.1}{0.001} - 1\right]}^{99}$$

$$\boxed{A_f = \frac{A}{1+A\beta}}$$

$$\boxed{1+A\beta = 1+99 = 100}$$

$A_f = \frac{A}{100}$

$A = 100 \times 100$

$A = 10{,}000$

$1 + A\beta = 100$

$A\beta = 99$

$\beta = \frac{99}{10{,}000} \Rightarrow \boxed{\beta = 0.0099,}$

3) **Reduction in Noise & distortion:**

Distortion: Let an amplifier 'A' produces distortion 'D' without feedback. suppose (-)ve feedback is applied the gain reducesto A_f and the distortion becomes D_f.

→ Now the fraction of output distortion feedback to input is βD_f.

→ After amplification the distorted output is $A\beta D_f$

∴ Net distortion = original distortion - Distorted output

$$D_f = D - A\beta D_f$$

$$D_f + A\beta D_f = D$$

$$D_f(1+A\beta) = D$$

$$\boxed{D_f = \frac{D}{1+A\beta}}$$

From above eqn, the distortion with feedback reduces by a factor $(1+A\beta)$ times ~~of~~ distortion without feedback.

(~~Distortion~~) Reduction in Noise :

Let an amplifier produces a noise (N) without feedback.

⇒ suppose -ve feedback is applied the gain reduces to Af and the noise in the output becomes Nf.

→ Now fraction of output noise feedback to i/p is βNf.

→ After amplification, the noise output is $A\beta Nf$

Net Noise = original Noise – Noise output

$$Nf = N - A\beta Nf$$

$$(A\beta + 1)Nf = N$$

$$\boxed{Nf = \frac{N}{1+A\beta}}$$

From this N_f equation, the noise with feedback reduces by a factor $(1+A\beta)$ times noise without feedback.

Eg An amplifier as an i/p of 10mV and a gain of 200 without feedback. The distortion produced at o/p of an amplifier is 10%. It is desired to reduce distortion to 1% by using negative feedback. calculate gain, i/p voltage, o/p voltage with feedback ?

$$V_s = V_{in} = 10mV$$

$$A = 200$$

$$D_f = 10\% \quad = 0.01$$

$$D = 10\% \quad = 0.1$$

$$D_f = \frac{D}{(1+A\beta)}$$

$$1 + A\beta = \frac{D}{D_f}$$

$$A\beta = \frac{D}{D_f} - 1 \Rightarrow \beta = \frac{\left(\frac{0.01}{0.1} - 1\right)}{200} = \boxed{+0.0045}$$

$$A_f = \frac{A}{1+A\beta}$$

$$\boxed{A_f = \frac{200}{1+200(0.0045)} = 20}$$

$$A = \frac{V_o}{V_{in}} \Rightarrow V_o = AV_{in} \Rightarrow 200 \times 10 \times 10^{-3} = \boxed{2V}$$

$$A_f = \frac{V_o}{V_s} \Rightarrow V_s = \frac{V_o}{A_f} = \frac{2V}{20V} = \boxed{0.1\ V}$$

7M Imp

Increase in bandwidth :

we know that $\boxed{A_f = \frac{A}{1+A\beta}}$

By using above eqn, $A_{f\,mid} = \frac{A_{mid}}{1+A_{mid}\beta}$

The gain at low frequency $A_{f low} = \frac{A_{low}}{1+A_{low}\beta}$

The gain at high frequency $A_{f High} = \frac{A_{high}}{1+A_{high}\beta}$.

Now we can analyse the effect of -ve feedback on lower & upper cutoff frequencies of an amplifier.

ⓘ Lower cut-off frequency (Lower 3dB frequency):

We know that relation b/n gain at low and gain at mid

$$A_{low} = \frac{A_{mid}}{1-j\left(\frac{f_L}{f}\right)}$$ substitute the A_{low} in $A_{f low}$

$$A_{f low} = \frac{\frac{A_{mid}}{1-j(f_L/f)}}{1+\frac{A_{mid}}{[1-j(f_L/f)]}\beta} = \frac{A_{mid}}{1+\frac{A_{mid}\beta}{1-j(f_L/f)}}$$

$$A_{f low} = \frac{A_{mid}}{[1-j(f_L/f)] + A_{mid}\beta}$$

$$A_{f low} = \frac{A_{mid}}{(1+A_{mid}\beta) - j\left[\frac{f_L}{f}\right]}$$

$\div (1+A_{mid}\beta)$

$$A_{f low} = \frac{A_{mid}/1+A_{mid}\beta}{1-j\left[\frac{f_L}{f(1+A_{mid}\beta)}\right]}$$

$$= \frac{A_{f mid}}{1-j\left[\frac{\frac{f_L}{1+A_{mid}\beta}}{f}\right]}$$

$$\left[\because \left\{ f_{Lf} = \frac{f_L}{1+A_{mid}\beta} \right\}\right]$$

$$\boxed{A_{f low} = \frac{A_{f mid}}{1-j\left[\frac{f_{Lf}}{f}\right]}}$$

Upper cutoff frequency:

We know that the relation b/n gain at mid frequency to gain at high frequency is given by

$$A_{high} = \frac{A_{mid}}{1-j\left[\frac{f}{f_H}\right]}$$

Sub value of A_{high} in $A_{f high}$.

$$A_{f\,high} = \frac{\dfrac{A_{mid}}{1-j(f/f_H)}}{1+\dfrac{A_{mid}}{1+j(f/f_H)}\beta}$$

$$A_{f\,hig} = \frac{A_{mid}}{1+A_{mid}\beta - j(f/f_H)}$$

Divide both numerator & denominator with $1+A_{mid}\beta$

$$A_{f\,high} = \frac{\left.\dfrac{A_{mid}}{1+A_{mid}\beta}\right\} A_{f\,mid}}{\dfrac{1-j(f/f_H)}{1+A_{mid}\beta}} = \frac{\dfrac{A_{mid}}{1+A_{mid}\beta}}{1-j\left[\dfrac{f}{\underbrace{f_H(1+A_{mid}\beta)}_{f_{HF}}}\right]}$$

$$A_{f\,high} = \frac{\cancel{A_{mid}}\; A_{f\,mid}}{1-j\left(\dfrac{f}{f_{Hf}}\right)}$$

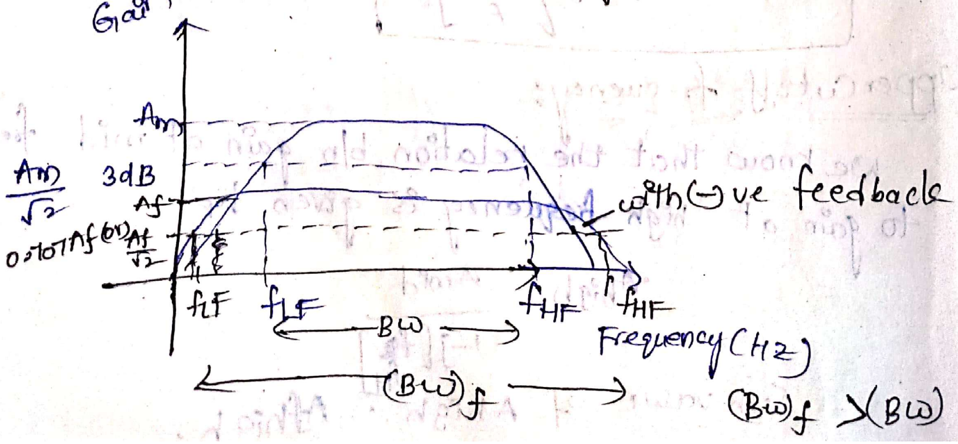
∴ called upper cutoff freque with feedback.

∴ Bandwidth of the feedback amplifier is

$$(B.\omega)_f = f_{HF} - F_{LF} = f_H(1+A_{mid}\beta) - \frac{f_L}{1+A_{mid}\beta}$$

From above eqn it is clear that the bandwidth of the amplifier with feedback is always greater than the b.w of amplifier without feedback because upper cutoff frequency is multiplied by a factor of $(1+A_{mid}\beta)$. And the lower cutoff frequency is decreases as it is divided by $(1+A_{mid}\beta)$ so overall difference increases.

The below figure shows the frequency response of the amplifier without feedback by indicating bandwidth:



$(B\omega)_f > (BW)$

1 An Amplifier has a mid frequency gain of 800, Its upper & lower cutoff frequencies are 16KHZ & 40HZ respectively. Determine b.w of an amplifier. (Bandwidth) what will be the bandwidth after 2% of the signal is given as (−) ve feedback?

$\text{Mid}_{\text{freq}} = 800\text{HZ} = A_{mid}$

$\beta = 2\%$

$f_H = 16KHZ$; $f_L = 40HZ$.

$\beta = 0.02$

$\text{Band width} = f_H - f_L$

$= 16KHZ - 40HZ$

$\boxed{(B.w) = 15.960 \text{ KHZ}}$

$$(B.w)_f = f_H(1 + A_{mid}\beta) - \frac{f_L}{1 + A_{mid}(\beta)}$$

$$= 16KHZ(1 + 800(0.02)) - \frac{40}{1 + (800)(0.02)}$$

$$\boxed{(B.w)_f = 271.997 \text{ KHZ}}$$

(5) **Change in i/p & o/p impedances:-**

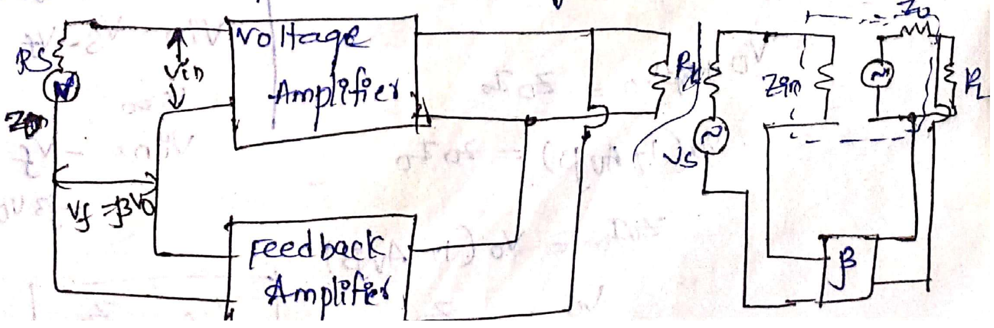
We know that from topologies of (−) ve feed back amplifier there is a change in i/p & o/p impedances due to the series & parallel connection of feedback network to the basic amplifier at i/p & o/p sides.

Ex:- In series mixing the feedback network is connected in series to i/p side of basic amplifier. So Z_{in} increases. whereas in shunt mixing the feedback is connected in parallel to basic amplifier so Z_{in} decreases.

Ily:- For voltage sampling, the feed back network is connected in parallel to o/p side of amplifier. So Z_o decreases, whereas in current sampling, the feed back network is connected in series with o/p side of an amplifier so Z_o increases.

series shunt Amp

(i) Voltage Series feedback Amplifier:- Consider topology of voltage series feedback amplifier, we know that in voltage series, the basic amplifier is voltage amplifier.



Input Impedance :-

I/P impedance

Ric, Rif ay circ

Zin

$$Z_{in} = \frac{V_{in}}{I_{in}} \qquad Z_{if} = \frac{V_s}{I_{in}}$$

without fedback — with feedback

From fig;

V_{in} ~~V_{in}~~ $= V_s - V_f$

(or) $V_s = V_{in} + V_f$

$V_f = \beta V_o$

$V_o = AV_{in}$

$V_s = V_{in} + \beta A V_{in}$

$V_s = (1+A\beta) V_{in}$

$V_s = (1+A\beta) V_{in}$

Divide the above eqn with I_{in} on both sides.

$$\frac{V_s}{I_{in}} = \frac{(1+A_v\beta)V_{in}}{I_{in}}$$

$$Z_{if} = \frac{(1+A_v\beta)V_{in}}{I_{in}}$$

$\frac{V_{in}}{I_{in}} = Z_{in}$

$$\boxed{Z_{if} = Z_{in}(1+A_v\beta)}$$

Impedance increases by a factor of $(1+A_v\beta)$ of Z_{in}.

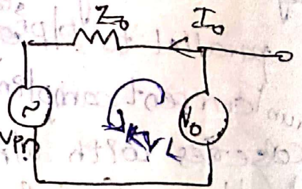
Output Impedance :-

$$Z_{of} = \frac{V_o}{I_o} \quad \Big| \quad Z_{of} = \frac{V_o}{I_o}$$

Let Z_o, Z_{of} are the o/p impedances of with^out^ & with~~out~~ feedback.

In order to measure o/p impedance short circuit the source voltage ($V_s = 0$) and $R_L \to \infty$) and connect a voltmeter.

Apply KVL to o/p loop. :-



$V_o - Z_o I_o - A_v V_{in} = 0$

$V_o = Z_o I_o + A_v V_{in}$ with $V_s = 0$

$V_o - A_v V_{in} = Z_o I_o$

~~$V_s = V_{in} - V_f$~~

$V_{in} = V_s - V_f$

$V_s = 0$

$V_{in} = -V_f$

$-\beta V_o$

$V_o + A\beta V_o = Z_o I_o$

$V_o(1+A_v\beta) = Z_o I_o$

$Z_o I_o = V_o(1+A_v\beta)$

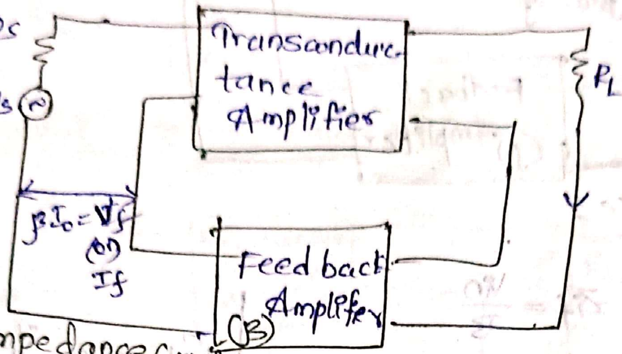
$$\frac{V_o}{I_o} = \frac{Z_o}{1+A_v\beta} \Rightarrow \boxed{Z_{of} = \frac{Z_o}{1+A_v\beta}}$$

The o/p impedance (Z_{of}), decreases by a factor of $1+A_v\beta$ times of Z_0 without feedback in voltage sampling.

Current Series feedback Amplifier: (Series Series Amplifier)

⇒ Consider the topology of current series feedback amplifier:

I/p & o/p are in series



Input Impedance (Z_{in}): Let $Z_{in} = \frac{V_{in}}{I_{in}}$; $Z_{if} = \frac{V_s}{I_{in}}$

From topology, $V_{in} = V_s - V_f$

$V_f = \beta V_0$; $I_0 = G_m V_{in}$

$\boxed{V_f = \beta I_0} \rightarrow ①$

$V_s = V_{in} + V_f = V_{in} + G_m \beta V_{in}$

$V_s = V_{in}(1 + G_m\beta)$

Divide with I_{in}

$$\frac{V_s}{I_{in}} = \frac{V_{in}}{I_{in}}(1+G_m\beta)$$

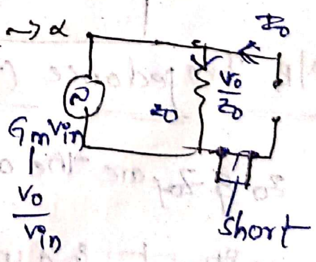
$$\boxed{Z_{If} = Z_{in}[1+G_m\beta]}$$

Output Impedance (Z_0): Let Z_0 & Z_{of} are the o/p impedances of without & with feedback.

$Z_{of} = \frac{V_0}{I_0}$; ~~Zofo~~

⇒ To measure o/p impedance; $V_s = 0$ & $R_L \rightarrow \alpha$

By using KCL



$$I_0 = G_m V_{in} + \frac{V_0}{Z_0}$$

$$\frac{V_0}{Z_0} = I_0 - G_m V_{in}$$

with $V_s = 0$; $V_{in} = -V_f$

$V_{in} = -\beta I_0$

$V_{in} = V_f = \beta I_0$ from ①

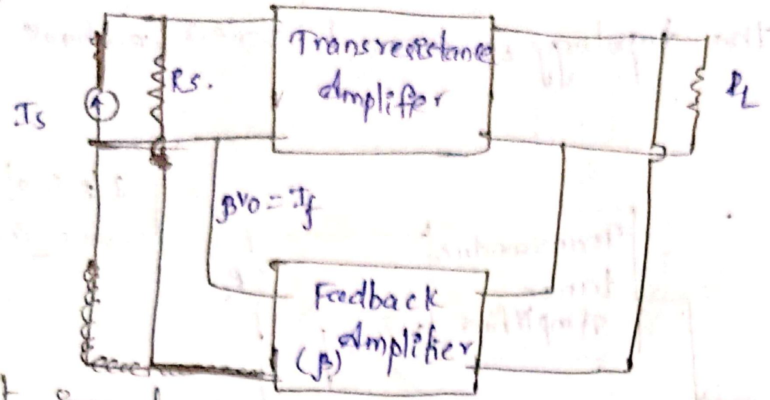
$$\frac{V_0}{Z_0} = I_0 - G_m(-\beta I_0)$$

$$\frac{V_0}{Z_0} = I_0[1+G_m\beta]$$

$$\frac{V_0}{I_0} = Z_0[1+G_m\beta] \Rightarrow \boxed{Z_{of} = Z_0[1+G_m\beta]}$$

Voltage shunt (shunt shunt Amplifier) Amplifier:

(7M) Imp



Input impedance:

$Z_{in} = \frac{V_{in}}{I_{in}}$; $Z_{if} = \frac{V_{in}}{I_s}$

o/p vo ∝ i/p current in transresistance

From topology;

$$I_s = I_{in} + I_f$$

$$I_f = \beta V_o \; ; \; V_o = R_m I_{in}$$

$$I_s = I_{in} + \beta V_O$$

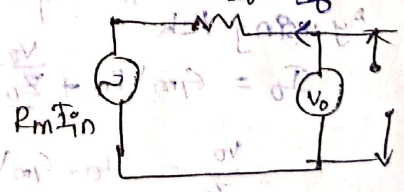
$$I_s = I_{in} + \beta (R_m I_{in})$$

$$\boxed{I_s = I_{in}(1+\beta R_m)}$$

$$\therefore Z_{if} = \frac{V_{in}}{I_{in}(1+\beta R_m)} = \underbrace{\frac{V_{in}}{I_{in}}}_{Z_{in}} \left[\frac{1}{1+\beta R_m}\right]$$

$$\boxed{Z_{if} = \frac{Z_{in}}{1+\beta R_m}}$$

o/p Impedance (Z_o):



Z_o & Z_{of} are the o/p impedances without and with feedback

In order to measure $V_s \to 0$ (short) and $R_L \to \alpha$.

If $I_s = 0$ open.

For

∴ By applying KVL

$$V_o - Z_o I_o - R_m I_{in} = 0$$

$$V_o = Z_o I_o + R_m I_{in}$$

$$Z_o I_o = V_o - R_m I_{in}$$

with $V_s = 0$
$I_{in} = -I_f$

$$Z_o I_o = V_o - R_m[-I_f]$$

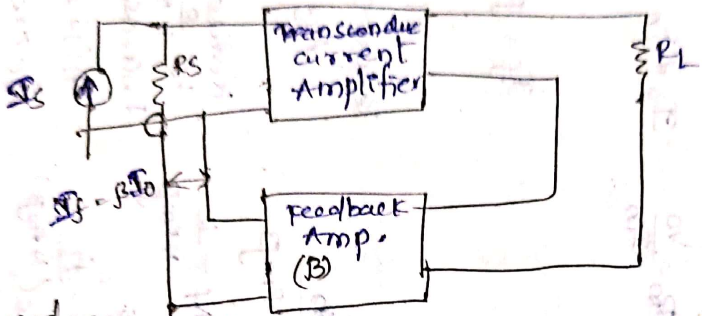
$$Z_o I_o = V_o + R_m[\beta V_o]$$

$$Z_o I_o = V_o[1+\beta R_m]$$

$$\frac{Z_o}{(1+\beta R_m)} = \frac{V_o}{I_o}$$

$$\boxed{Z_{of} = \frac{Z_o}{1+R_m\beta}} \text{ (or) } \frac{Z_o}{1+A\beta}$$

Current shunt (~~series~~ shunt series Amplifier) :-



$$\boxed{I_o = A_I I_{in}}$$

I/p impedance:- $Z_{if} = \frac{V_{in}}{I_s}$

From Topology;

$$I_f = \beta I_o$$

$$I_o = A_I I_{in}$$

$$\left[A_I I_{in} = I_o \right.$$

$$\therefore I_s = I_{in} + \beta I_o \; A_I I_{in}$$

$$I_s = I_{in} + \beta(A_I I_{in})$$

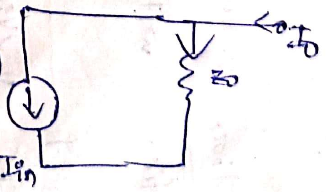
$$I_s = I_{in}(1 + A_I \beta)$$

$$\therefore Z_{if} = \frac{V_{in}}{I_{in}(1+A_I\beta)}$$

$$\boxed{Z_{if} = \frac{(Z_{in})}{(1+A_I\beta)}}$$

o/p Impedance (Zo):- $Z_{of} = \frac{V_o}{I_o}$

In order to calculate, Zof, (o/p impedance)



$R_L \to \alpha$, $V_s = 0$

Apply KCL

$$I_o = \frac{V_o}{Z_o} + A_I I_{in}$$

$$I_o - A_I I_{in} = \frac{V_o}{Z_o}$$

with $V_s = 0$ $I_s = 0$

$I_{in} = -I_f$

$$I_o[1+\beta A_I] = \frac{V_o}{Z_o} \rightarrow \frac{V_o}{I_o} = Z_o(1+\beta A_I)$$

$$\boxed{Z_{of} = Z_o[1+A_I\beta]}$$

SUMMARY OF (-)VE FEEDBACK AMPLIFER.

Type of feedback / characteristic	Voltage series	Current series	Voltage shunt	Current shunt.
① Basic Amplifier	voltage Amplifier	Transconductance Amplifier	Transresistance Amplifier.	Current Amplifier
② o/p and gain of Basic amplifier	$V_o \propto V_{in}$ $A_V = \frac{V_o}{V_{in}}$	$I_o \propto V_{in} \Rightarrow G_m = \frac{I_o}{V_{in}}$	$V_o \propto I_{in} \Rightarrow R_m = \frac{V_o}{I_{in}}$	$I_o \propto I_{in}$, $A_I = \frac{I_o}{I_{in}}$
③ Feedback signal	$V_f = \beta V_o$	$I_f = \beta I_o$	$V_f = \beta V_o$	$I_f = \beta I_o$
④ Gain with feedback Reduces	Reduces $A_{Vf} = \frac{A_V}{1+A_V\beta}$	Reduces, $G_{inf} = \frac{G_{in}}{1+G_{in}\beta}$	Reduces $R_{mf} = \frac{R_m}{1+R_m\beta}$.	Reduces, $A_{If} = \frac{A_I}{1+A_I\beta}$
⑤ Distortion & Noise	Reduces $D_f = \frac{D}{1+A_V\beta}$ | $N_f = \frac{N}{1+A_V\beta}$	Reduces $D_f = \frac{D}{1+G_m\beta}$ | $N_f = \frac{N}{1+G_v\beta}$	Reduces $D_f = \frac{D}{1+R_m\beta}$ | $N_f = \frac{D}{1+R_m\beta}$	Reduces. $D_f = \frac{D}{1+A_I\beta}$ | $N_f = \frac{D}{1+A_I\beta}$.
⑥ Bandwidth	Increases $f_H(1+A_{mid}\beta) - \frac{f_L}{1+(A_{mid}\beta)}$	Increases $f_H(1+G_{mid}\beta) - \frac{f_L}{1+(G_{mid}\beta)}$	Increases $f_H(1+R_m\beta) - \frac{f_L}{(1+R_m\beta)}$	Increases $f_H(1+A_I\beta) - \frac{f_L}{(1+A_I\beta)}$
⑦ I/p Impedance	increases	increases	decreases	decreases
⑧ o/p Impedance.	decreases	Increases	decreases	Increases.

Methodology of Feedback Amplifiers analysis:-

step1

→ From given circuit, identify the feedback n/w.

2→ To Find the type of feedback, For this we know the type of sampling & type of mixing.

3→ To find the type of sampling,

a) If you short the o/p terminal $(V_0 = 0)$ then it is called voltage sampling

b) If you open the o/p terminal $(I_0 = 0)$ then it is called current sampling.

To find sampling

If Resistor (which is common in both i/p & o/p eqn is feedback resistor

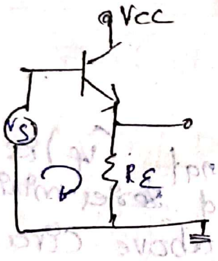
If "

4→ To find the type of mixing:

a) If the feedback signal is subtracted from externally applied signal as a voltage then it is called series mixing

b) If the feedback signal is subtracted from externally applied signal as a current then it is called shunt mixing

a) Ex:



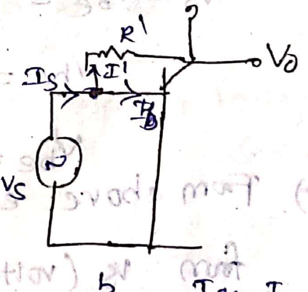
$V_o = I_E R_e \rightarrow ①$

$V_s - V_{be} - I_E R_e \Rightarrow$

$V_{be} = V_s - I_E R_e$

$V_{be} = V_s - V_f$

feedback (−) from Vs (voltage source) so it is voltage



b

$I_s = I_b + I'$

$I_b = I_s - I'$

Subtracted from current so it is shunt mixing

5) From step ③ & ④ we can identify type of feedback.

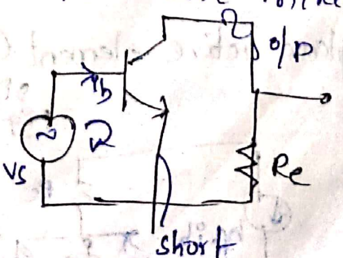
6) For the analysis, we have to find the effect of mixing feedback n/w on i/p & o/p circuit.

a) For i/p circuit for voltage sampling make $(V_o = 0)$ by shorting the o/p.

b) For current sampling, make $(I_o = 0)$ by opening the o/p circuit.

b) To find the o/p circuit, for series mixing make $(I_{in} = 0)$ by opening the i/p. For Shunt mixing make $(V_{in} = 0)$ by shorting the i/p, and of short (ground)

Ex: a) For series mixing

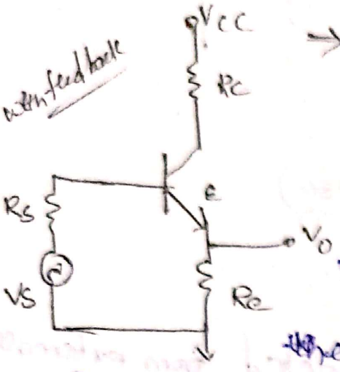


Find the values of open loop gain (A) and feedback factor (β).

⇒ From A & β find A_f, Z_{if}, Z_{of}.

2M Voltage Series feedback amplifier (series-shunt Amplifier)

Imp 14M ⇒ The practical example, of this amplifier is CC amplifier (or) emitter follower.



→ In this figure, Re resistor is feedback resistor, It is common to both i/p & o/p ckts

common
($V_o = I_E R_e$ & $V_{be} = V_S - I_E R_e$)

→ In the above circuit, short the o/p terminal the feedback signal becomes zero.

Fig 1 :-

⇒ Hence it is called voltage Sampling.

From i/p circuit Apply KVL

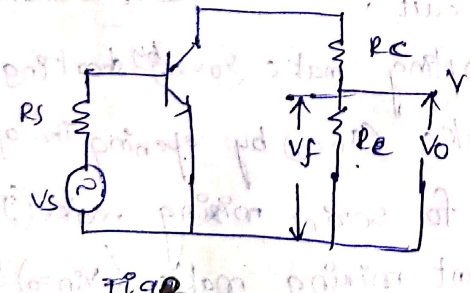
$$V_S - V_{be} - I_E R_e = 0$$

$$V_{be} = V_S - I_E R_e.$$

$$V_{be} = V_S - V_f$$

→ From above eqn the feedback signal (V_f) is subtracted from V_S (voltage source), so it is called series mixing. so the above circuit is an example of voltage series feedback amplifier

→ For finding the amplifier without feedback for voltage sampling make ($V_o = 0$).



For series mixing, o/p i/p then R_E is connected to o/p side as shown in fig.2

Fig 2

Equivalent Circuit (Replace active element (transistor) with its simplified - h parameter model)

Fig 3

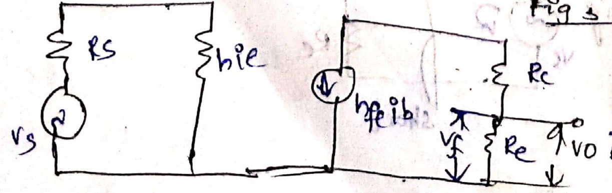


Fig 3

⇒ From fig 3; $V_f = V_o$ (i.e) $\boxed{\beta = \frac{V_f}{V_o} = \frac{V_f}{V_f} = 1}$

voltage gain $(A_v) = \frac{V_o}{V_{in}}$

$$A_v = \frac{V_o}{V_{in}} = \frac{h_{fe} i_b R_e}{(R_s + h_{ie}) i_b}$$

$$\boxed{A_v = \frac{h_{fe} R_e}{(R_s + h_{ie})}}$$

$$D = (1 + A_v) \beta$$

$$D = 1 + \left(\frac{h_{fe} R_e}{R_s + h_{ie}}\right)(\beta) = 1$$

$$\boxed{D = \frac{R_s + h_{ie} + h_{fe} R_e}{R_s + h_{ie}}}$$

$$\boxed{A_{vf}} = \frac{A_v}{\underbrace{1 + A_v\beta}_{D}} = \frac{A_v}{D} = \frac{h_{fe} R_e / (R_s + h_{ie})}{\frac{R_s + h_{ie} + h_{fe} R_e}{(R_s + h_{ie})}} = \frac{h_{fe} R_e}{R_s + h_{ie} + h_{fe} R_e}$$

$$\boxed{Z_{in} = R_s + h_{ie}}$$

$$Z_{if} = Z_{in}(1 + A_v\beta)$$

zif increases in voltage series

$$= Z_{in}[D]$$

$$= Z_{in}\left[\frac{R_s + h_{ie} + h_{fe} R_e}{R_s + h_{ie}}\right]$$

$$= (R_s + h_{ie})\frac{[R_s + h_{ie} + h_{fe} R_e]}{(R_s + h_{ie})}$$

$$\boxed{Z_{if} = R_s + h_{ie} + h_{fe} R_e}$$

o/p impedance $(Z_o) = \alpha$

$$Z_{of} = Z_o\left[\frac{1}{1 + A_v\beta}\right]$$

$$Z_{of} = \underset{R_e}{\alpha}\left[\frac{1}{1 + A_v\beta}\right]$$

$$\boxed{Z_{of} = \text{Undetermined } (\infty)}$$

To Determine (Z_{of}), make $R_e \Rightarrow \alpha$

$$Z_{of} = \underset{R_e}{\alpha}\left[\frac{(R_s + h_{ie})}{R_s + h_{ie} + h_{fe} R_e}\right] +$$

$$Z_{of}' \underset{Re\to\alpha}{=} \frac{Re[Rs+hie]}{Re\left[hfe+\frac{Rs+hie}{\underbrace{Re}_{0}}\right]}$$

$$\boxed{Z_{of}'_{Re\to\alpha} = \frac{Rs+hie}{hfe}}$$

$$Z_{of}' = \lim_{Re\to\alpha}(Z_{of})$$

To remove indeterminancy we applied limit to Re

Q The voltage series feedback of transistor amplifier as the following data of circuit is $Rs = 1K\Omega$, $Rc = 4.7K\Omega$; $Re = 100\Omega$. Calculate (a) β b) Av b) D c) R_i d) R_{if} e) R_o, f) R_{of}? assume the transister parameters are $hie = 1.1K\Omega$, $hfe = 50$?

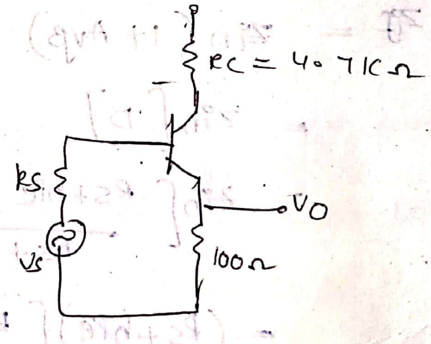
1) (i) $\beta = \frac{V_f}{V_o} = \frac{V_f}{V_f} = 1$

2) $A_v = \frac{hfeRe}{Rs+hie} = \frac{50(100)}{1K\Omega+1.1K\Omega} = 2.380$

$A_{vf} = \frac{Av}{1+Av\beta} = \frac{2.38}{3.38} = 0.704$

3) $D = \frac{Rs+hie+hfeRe}{Rs+hie} = \frac{1K\Omega+1.1K\Omega+50(100)}{1K\Omega+1.1K\Omega} = 3.3809$

$D = 3.3809$



4) $Ri = Zin = Rs+hie$

$= 1K\Omega+1.1K\Omega$

$= 2.7K\Omega$

5) $Z_{if} = R_{if} = Rs+hie+hfeRe$

$= 1K\Omega+1.1K\Omega+50(100)$

$= 7.1K\Omega$

)

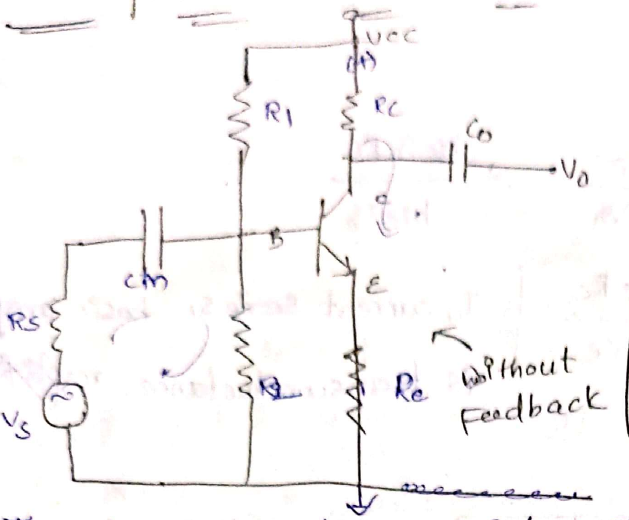
$Z_o = R_o = \alpha$

$Z_{of} = R_{of} \underset{Re\to\alpha}{=} \frac{Rs+hie}{hfe}$ | $R_{of} = R_i(1+Av\beta)$

$R_{of} = \frac{1K\Omega+1.1K\Omega}{50} = 42\Omega$

Current Series feedback amplifier (series - Series feedback am

The practical circuit (example) of series-series is an common emitter amplifier without unbypassed capacitor. (or) CE amplifier with R_E Resistor as shown in fig 1:-



→ To identify feedback resistor

o/p KVL

$V_{CC} - I_C R_C - V_{CE} - I_E R_E =$

$V_{CE} = V_{CC} - I_C R_C - I_E R_E$

R_E is co
so feed back re

i/p KVL

$V_S - I_S R_S - R_{th} i_b - R_S R_E$

$V_{be} - I_E R_E$

$V_{be} = V_S - I_S R_S - R_{th} i$

$-I_E R_E$

⇒ In the above circuit R_e resistor acts as feedback resistor. As we can short the o/p terminal ∴ then the voltage across the R_E doesnot becomes zero. Hence it is not voltage sampling. ~~Hence~~ suppose if we can open o/p terminal ∴ $I_C = 0$, then $I_E R_E = 0$. The feedback signal ~~becomes~~ becomes zero. Hence it is current sampling

From o/p circuit Apply KVL

$$V_{CC}\ (\text{or } V_S) - I_C R_C - V_{CE} - I_E R_E = 0$$

$$\boxed{V_{CE} = V_{CC} - I_C R_C - I_E R_E}$$

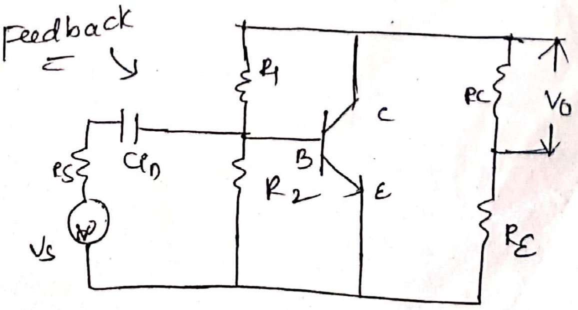
From i/p circuit

$$V_S - I_S R_S - R_{th} i_b - V_{BE} - I_E R_E = 0$$

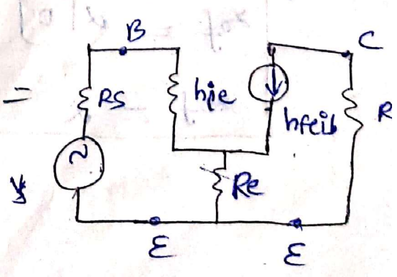
$$\boxed{V_{be} = V_S - I_S R_S - R_{th} i_b - I_E R_E}$$

From above eqns, the feedback signal is subtracted from externally applied signal as a voltage. Hence it is series mixi so from above circuit, the type of feedback is current series feedback amplifier.

with Feedback



simplified Equivalent



$\beta = \frac{V_f}{V_o}$ where $V_f = I_E R_E$

$V_o = I_C R_C$

$\beta = \frac{\cancel{I_E} R_E}{\cancel{I_C} R_C}$ $\quad | I_E \simeq I_C$

$$\boxed{\beta = \frac{R_e}{R_C}}$$

A_V (voltage gain) $= \frac{V_o}{V_{in}} = \frac{h_{fe} i_b R_C}{h_{ie} i_b}$

$$\boxed{A_V = \frac{h_{fe} R_c}{h_{ie}}}$$

In current series, basic amplifier is transconductance amplifier.

$G_m = \frac{I_o}{V_{in}}$

$$\boxed{G_m = \frac{h_{fe} \cancel{i_b}}{h_{ie} \cancel{i_b}} = \frac{h_{fe}}{h_{ie}}}$$

Range of mamp|v

$D = 1 + G_m \beta$

$D = 1 + \left(\frac{h_{fe}}{h_{ie}}\right)\beta$

$$\boxed{D = 1 + \left(\frac{h_{fe}}{h_{ie}}\right)\left(\frac{R_e}{R_c}\right)}$$

~~Avf for~~ $G_{mf} = \frac{G_m}{D}$

$$A_{vf} = \frac{A_v}{D} = \frac{\frac{h_{fe}(R_c)}{h_{ie}}}{1 + \frac{h_{fe} R_e}{h_{ie} R_c}} = \frac{h_{fe} R_c (h_{ie} \cancel{R_c})}{\cancel{h_{ie}} (h_{ie} R_c + h_{fe} R_e)}$$

$$\boxed{Z_{in} = h_{ie}}$$

$Z_{if} = Z_{in}(1 + G_m \beta)$ $\rightarrow$ $h_{ie}(R_1 || R_2)$ (If R_1 & R_2 consider

$$\boxed{Z_{if} = Z_{in}(D)}$$

$$\boxed{\begin{aligned} Z_o &= \alpha \\ Z_{of} &= \alpha[D] \\ Z_{of} &= \alpha \end{aligned}}$$

①

In current series feedback the following parameters $R_1 = 20 k\Omega$ $R_2 = 20 k\Omega$, $R_L \overset{= R_C}{} = 1 k\Omega$, $R_e = 100 \Omega$, $h_{ie} = 2 k\Omega$ & $h_{fe} = 80$. Calculate

β, A, A_f, and R_{if}
open loop gain (Gm)

$$\beta = \frac{R_e}{R_C} = \frac{100}{1 k\Omega} = 0.1$$

$$A = G_m = \frac{h_{fe}}{h_{ie}} = \frac{80}{2 k\Omega} = 0.04$$

$$A_f = A_{vf} = \frac{G_m}{D} \; ; \quad D = \frac{0.04}{1.004} = \boxed{0.0398.}$$

$$A_f = A_{vf} = G_{mf} = 0.0398.$$

$$Z_{of} = R_{if} = \underbrace{~~Z_{in}~~}_{h_{ie}} [1 + G_m \beta]$$

$$[Z_{if} = R_{if} = 2k\Omega [1 + 0.04 (0.1)] = \boxed{2.008 k\Omega}$$

R_{if} $\boxed{Z_{in} = h_{ie} = 2k\Omega}$

Q The current series feedback type of a transistor
② Assign
amplifier as the following data of circuit $R_C = 1k\Omega$, $R_e = 100\Omega$, $R_1 = 30\Omega$; $R_2 = 20\Omega$, $h_{ie} = 1k\Omega$, $h_{fe} = 100$. Find

A_v, R_i, R_{if}, A_{vf}, loop gain in dB?

$$\beta = \frac{R_e}{R_C} = \frac{100}{1k\Omega} = \frac{100}{1000k} = \frac{1}{10} = 0.1$$

$$A_V = \frac{h_{fe} R_C}{h_{ie}} = \frac{100(1k\Omega)}{1k\Omega} = 100$$

$$R_i = Z_{in} = h_{ie} = h_{ie} [R_1 \| R_2] = 1k\Omega \left[\frac{30 \times 20}{50} \right]$$

$$R_i = 12k\Omega$$

$$R_{if} = Z_{in}(D) = Z_{in}(1 + G_m \beta) = 12k\Omega \left(1 + \left(\frac{h_{fe}}{h_{ie}}\right)(0.1)\right)$$

$$R_{ef} = 12.120 k\Omega$$

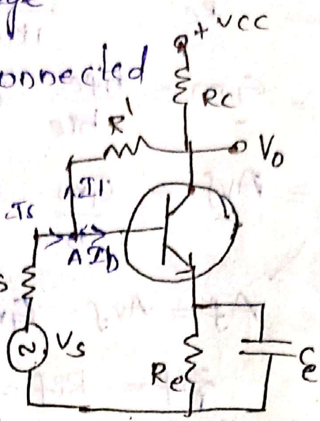
$$A_{vf} = G_{mf} = \frac{G_m}{D} = \frac{\frac{h_{fe}(R_C)}{h_{ie}}}{1 + \frac{h_{fe} R_e}{h_{ie} R_C}} = 99.009$$

loop gain in (dB) $= A = \frac{h_{fe}}{h_{ie}} = 0.1$

$$(dB) = -20 = (-20 \log (A))$$

Voltage shunt Feedback Amplifier:- The example of voltage shunt feedback amplifier CE amplifier with collector to Base Bias.

The below fig. shows the example of Voltage shunt feedback amplifier



In the above circuit, the resistor R' is connected b/n collector to base.

As we know in common emitter, base is i/p & collector is o/p. so R' acts as feedback resistor.

→ In The above circuit, if we short the o/p terminal then voltage across R' becomes zero. Hence it is called voltage Sampling.

→ By applying KCL to i/p loop, At Node "A", $I^S = I_1' + I_b$

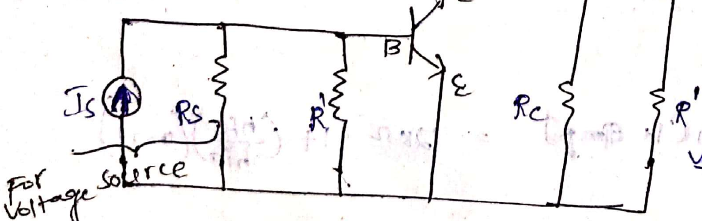
$$\therefore I_1' = I_S - I_b$$

$$I_b = I_S - I'$$

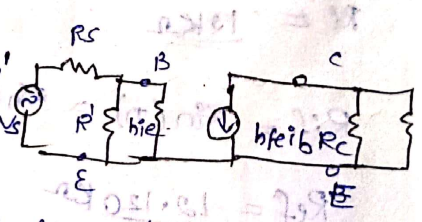
$$\boxed{I_b = I_S - I_f}$$

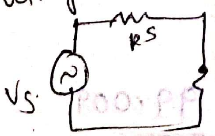
In the above eqn. feedback signal is subtracted from externally applied signal as a current. Hence it is called shunt mixing. In the above circuit, the type of feedback is voltage shunt

Fig 2 shows the amplifier without feedback :-



Equivalent Circuit :-





From fig1, $I_f = \frac{V_{in} - V_o}{R'}$ | $V_{in} <<< V_o$ ($V_{in} - V_o = -V_o$)

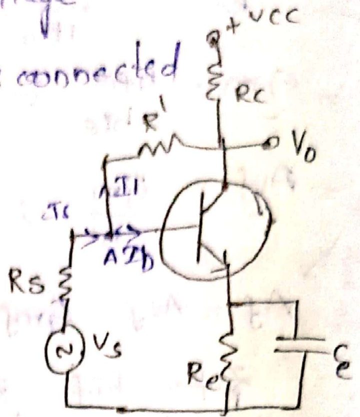
Feedback factor (β) = $I_f = -V_o/R'$

$$\frac{I_f}{V_o} = -1/R'$$

$$\boxed{\beta = -1/R'}$$

Voltage shunt Feedback Amplifier:- The example of voltage shunt feedback amplifier CE amplifier with collector to Base Bias.

The below fig. shows the example of voltage shunt feedback amplifier.



In the above circuit, the resistor R' is connected b/n collector to base.

As we know in common emitter, base is i/p & collector is o/p. so R' acts as feedback resistor.

→ In the above circuit, if we short the o/p terminal then voltage across R' becomes zero. Hence it is called voltage sampling.

→ By applying KCL to i/p loop, At Node "A", $I^{S} = I_1' + I_b$

$$\therefore I' = I_S - I_b$$

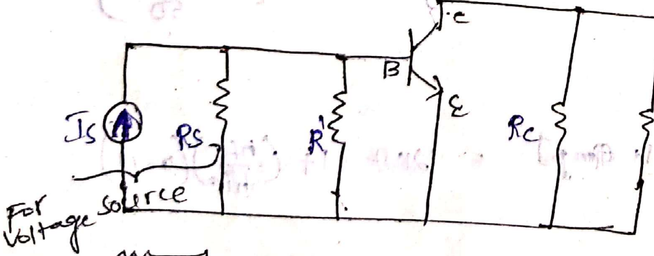
$$I_b = I_S - I'$$

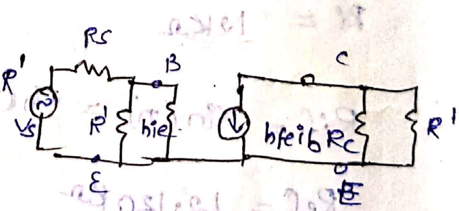
$$\boxed{I_b = I_S - I_f}$$

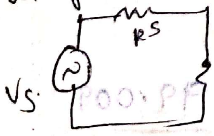
In the above eqn. feedback signal is subtracted from externally applied signal as a current. Hence it is called shunt mixing. In the above circuit, the type of feedback is voltage shunt

Fig'2 shows the amplifier without feedback :-

Equivalent Circuit :-







From fig1, $I_f = \frac{V_{in} - V_o}{R'}$ | $V_{in} <<< V_o$ ($V_{in} - V_o = -V_o$)

Feedback factor (β) = , $I_f = -V_o/R'$

$$\frac{I_f}{V_o} = -1/R'$$

$$\boxed{\beta = -1/R'}$$

open loop gain $R_m = \frac{-V_o}{I_b}$

$R_m = \frac{h_{fe} i_b (R_c \| R')}{I_b}$

$R_m = -h_{fe}(R_c \| R')$

$$\boxed{R_m = h_{fe}(R_c \| R')}$$

$D = 1 + R_m \beta$

$= 1 + \left(\frac{h_{fe}(R_c \| R')}{R'}\right)$

$$\boxed{D = 1 + \frac{h_{fe}(R_c \| R')}{R'}}$$

$R_{mf} = \frac{R_m}{D}$

$Z_{in} = h_{ie} \| R'$

$Z_{in}' = Z_{in}/D$

$$\boxed{Z_o = \alpha}$$

$Z_o' = \alpha \| R_c \| R'$

$Z_o' = R_c \| R'$

$$\boxed{Z_{of}' = \frac{Z_o'}{D}}$$

Problem:

In voltage shunt feedback amplifier, the parameters are $R_S = 600\Omega$, $\overset{R'}{R_B} = 40k\Omega$, $\underset{R_C}{R_L} = 2k\Omega$, $h_{ie} = 5k\Omega$, $h_{fe} = 80$ calculate A_{vf}, R_{if}, R_{of} ?

$\beta = -1/R' = \frac{-1}{40k\Omega} = -0.000025 = -25 \times 10^{-6}$

$A_v = \frac{V_o}{V_{in}} = \frac{-h_{fe} i_b (R_c \| R')}{h_{ie} i_b}$

$A_v = \frac{-h_{fe}(R_c \| R')}{h_{ie}} = -30.4761$

~~$A_{vf} =$~~

$R_m = h_{fe}(R_c \| R') = 80(2k\Omega \| 40k\Omega) = -152.380$

$D = (1 + R_m \beta) = 1 + (-152.380k(-25 \times 10^{-6})) = 4.8$

$A_{vf} = \frac{A_v}{D} = \frac{-30.476}{4.8095} = 6.337$

$Z_{inf} = (5k\Omega \| 40k\Omega) = 4.444\,k\Omega$

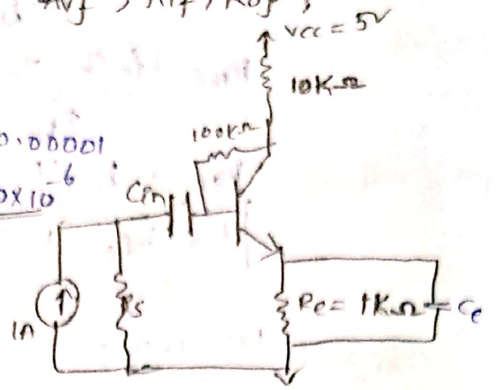
$R_{if} = Z_{inf} = \frac{Z_{in}}{D} = \frac{4.444k}{4.8095} = 924\Omega$

$R_{of} = Z_o = \alpha$

$(Z_o') \; R_{of} = Z_o \| R_c \| R'$

$(Z_{of}) \; R_{of} = \frac{Z_o'}{D} = R_c \| R' = \frac{1.904\,k\Omega}{4.8095}\,\Omega$

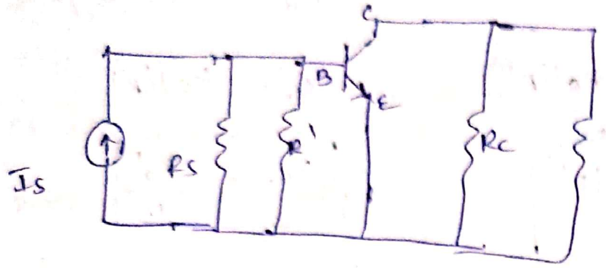
For the transistor feedback amplifier shown in fig. $h_{fe} = 100$ $h_{ie} = 1K\Omega$, $h_{re} = h_{oe} = 0$, Determine A_{vf}, R_{if}, R_{of} ?



$\beta = \frac{-1}{R'} = \frac{-1}{100K\Omega} = \frac{-1}{100\times10^3} = 0.00001$

$= -10\times10^{-6}$

By assuming $R_e = 0$ (voltage shunt).



$A_v = \frac{V_o}{V_{in}} = \frac{-h_{fe} i_b (R_c \| R')}{h_{ie} i_b} = \frac{-100(10K\Omega \| 100K\Omega)}{1K\Omega}$

$A_v = -909.090$

$R_m = -h_{fe}(R_c \| R') = -100(10K\Omega \| 100K\Omega) = 909.090 K\Omega$

$D = (1 + R_m\beta) = (1 + R_m\beta) = 1 + (909.090K)(-10\times10^{-6}) = 10.090$

$$\boxed{A_f = \frac{A_v}{D} = \frac{-909.090}{10.090} = 90.098}$$

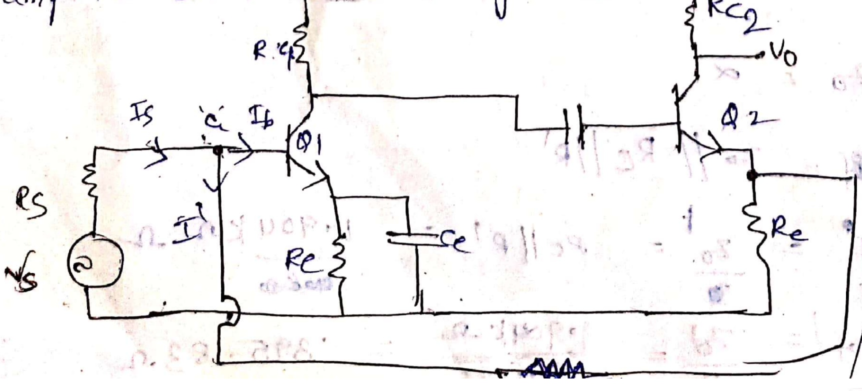
$\boxed{R_{if}}$ = $Z_{in} = h_{ie} \| R' = 990.099\Omega$ $Z_{inf} = R_{if} = \frac{Z_{in}}{D} = \boxed{98.1267}$

$R_o = Z_o = d$

$R_{of} = Z_o' = R_c \| R' = 10K\Omega \| 100K\Omega = 9.090K\Omega$

$R_{of}' = Z_{of}' = \frac{Z_o'}{D} = 900.98$

Current shunt feedback Amplifier:- Two stage RC coupled amplifier with ce-ce configuration.



if o/p & Feed back res — voltage se
If feedbo resistr are at different points taken it is called current sample

In the above circuit the feedback resistor (R') is connected Emitter of Q_2 to base of Q_1. Hence it acts as a feedback resistor.

=> As we can short the o/p terminal the feedback signal doesnot becomes zero. At the same type, if we ~~o/p~~ open o/p termin[al] the feedback signal becomes zero. Hence it is current sampling

From i/p circuit by applying KCL at Node 'A'

$$I_s = I_b + I'$$

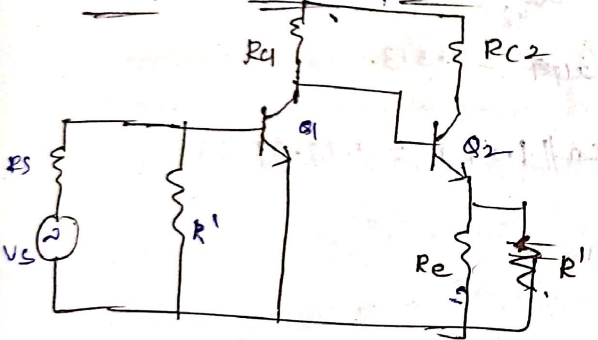
$$I_b = I_s - I'$$

$$\boxed{I_b = I_s - I_f}$$ feedback signal is subtracted from externally applied signal as current

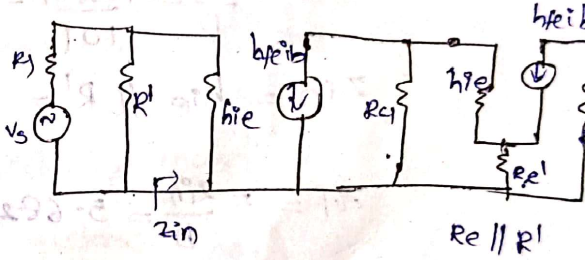
- Hence it is shunt mixing.

∴ The type of feedback for above circuit is current shunt feedback.

circuit without (CE) feedback



Equivalent Circuit



$$\beta = \frac{Re}{Re + R'}$$

$$D = 1 + A_I \beta$$

$$A_I = A_{I1} \times A_{I2}$$

$$D = 1 + (h_{fe})^2 \left(\frac{Re}{Re + R'}\right)$$

$$A_I = h_{fe} \times h_{fe}$$

$$A_I = (h_{fe})^2$$

$$A_{If} = \frac{A_I}{D} = \frac{(h_{fe})^2}{1 + (h_{fe})^2 \left(\frac{Re}{Re + R'}\right)}$$

Voltage gain $(A_v) = A_{v1} \times A_{v2}$.

$$A_v = \frac{h_{fe} R_{C1}}{h_{ie}} \times \frac{h_{fe} R_{C2}}{h_{ie}}$$ | For CE amp

$$A_v = \left(\frac{h_{fe}}{h_{ie}}\right)^2 [R_{C1} \times R_{C2}] \frac{h_{fe}}{h_{ie}} = \frac{h_{fe} R_{C1}}{h_{ie}} \times \frac{h_{fe} R_{C2}}{h_{ie} + (1 + h_{fe}) Re}$$

$$A_{vf} = \frac{A_v}{D} = \frac{A_v}{D}$$

$$R_o = Z_o = \alpha$$

$$R_i = Z_{in} = h_{ie} \| R'$$

$$R_{of} = R_o' = Z_o' = \alpha \| R_{C2} = R_{C2}$$

$$R_{if} = Z_{if} = \frac{Z_{in}}{D}$$

$$Z_{of}' = R_{of}' = Z_o' \times D$$

For circuit shown in fig.1 as the following parameters $R_s = 1.2k\Omega$ $R_{C1} = 3k\Omega$, $R_{C2} = 500\Omega$, $R_{e_2} = 50\Omega$, $R' = 1.2k\Omega$ / The transistor are identical with $h_{fe} = 50$, $h_{ie} = 1.1k\Omega$, $h_{re} = h_{oe} = 0$, Determine β, A_I, D, A_{If}, A_v, A_{vf}, Z_{in}, Z_{if}, Z_o, Z_{of}.

$$\beta = \frac{R_e}{R_e + R'} = \frac{50}{50 + 1.2k\Omega} = 0.04$$

$$A_I = A_{I1} \times A_{I2} = h_{fe} h_{fe} = 2500$$

$$D = 1 + A_I(\beta) = 101$$

$$A_{If} = \frac{A_I}{D} = 24.7524$$

$$A_v = A_{v1} \times A_{v2}$$

$$R_e' = \underbrace{R_e \parallel R'}_{48}$$

$$= \frac{h_{fe} R_{C1}}{h_{ie}} \times \frac{h_{fe} R_{C2}}{h_{ie} + (1+h_{fe}) \underset{48}{R_e'}} = \cancel{988.997} = 960.848$$

$$A_{vf} = \frac{A_v}{D} = \frac{933.99}{101} = \cancel{[illegible]} = 9.513.$$

$$Z_{in} = h_{ie} \parallel R' = 1.1k\Omega \parallel 1.2k\Omega = 573.91\ \Omega$$

$$Z_{if} = \frac{Z_{in}}{D} = 5.682\ \Omega$$

$$Z_o = \alpha$$

$$R_{of} = Z_o' = \boxed{Z_{of} = 500\Omega} \; ; \; Z_{of}' = R_{of}' = Z_o'(D) = 500(101) = 50.500\ k\Omega$$

2M

We have an amplifier of 60 dB gain. It has an o/p impedance of 10KΩ. It is required to modify its o/p impedance is 500Ω by applying -ve feedback. calculate the values of feedback factor (β) also find the % change in overall gain for a 10% change in gain of the amplifier.

$$A_{v\,dB} = 20 \log(A_v)$$

$$60 = 20 \log(A_v)$$

$$\log(A_v) = 3$$

$$A_v = 10^3 \quad (\text{Inverse log})$$

$$A_v = 1000$$

$$Z_o = 10k\Omega$$

$$Z_{of} = 500$$

$$Z_{of} = \frac{Z_o}{1 + A_v\beta}$$

$$1 + A_v\beta = \frac{Z_o}{Z_{of}}$$

$$\beta = \frac{Z_o}{Z_{of}} - 1 = 0.019$$

$$\frac{dA_f}{A_f} = \underbrace{\frac{dA}{A}}_{10} \times \frac{1}{1+A_v\beta}$$

$$\frac{dA}{A} = 10\% = 0.1$$

$$\frac{dA_f}{A_f} = 0.1 \times \frac{1}{1+1000 \times 0.019} \%$$

$$\% \frac{dA_f}{A_f} = 0.005 \times 100 = 0.5\%$$

2M

1) What is ~~regenerative~~ (or) degenerative (-ve feedback) feedback amplifier

2) what is sensitivity of amplifier?

3) what is the effect of (-)ve fedback on bandwidth?

4) Draw the block diagram of feedback amplifier.

5) what type of feedback used in emitter follower (CC) amplifier

oscillators

⑥ when will (-)ve feedback amplifier circuit be unstable?

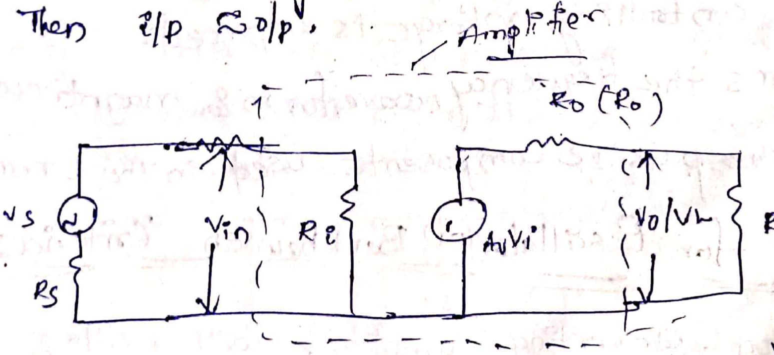
$A_v\beta = -1$ in $\frac{A}{1+A_v\beta} = \propto$.

7) when current shunt feedback is not used in practical circuit

8) Distortion in an amplifier is found to be 3% when feedback ratio (β) of (-)ve feedback amplifier is 0.04. when feedback is removed the distortion becomes 15%. Find the open & closed loops gains of the amplifier?

For any amplifier, its i/p resistance must be very high in comparision with (Rs) (source resistance) and o/p resistance must be very less in comparision with R_L (load resistance

Then i/p ≃ o/p.



BJT & FET has a switching nature

BJT has switching time is high (less delay)

FET switching has less than BJT

$$V_o = A_vV_i\left[\frac{R_L}{R_L+R_o}\right]$$ — Amplifier —

when $R_o <<< R_L$ then

$$\boxed{V_o \simeq A_v V_i}$$

i/p ≃ o/p.

$$V_i = V_s\left(\frac{R_i}{R_i+R_s}\right) \quad R_s <<< R_i$$

or

$R_i >>> R_s$

$$V_i = V_s\left(\frac{\cancel{R_i}}{\cancel{R_i}}\right)$$

$$\boxed{V_i \simeq V_s}$$

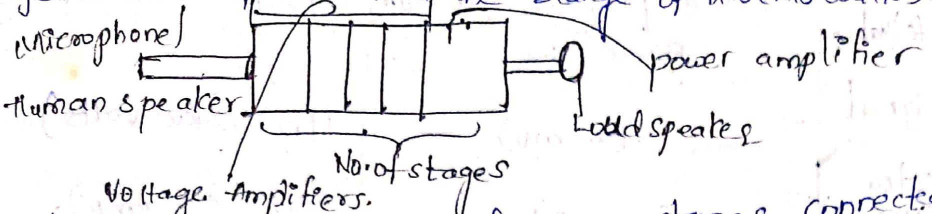
i/p = source

⇒ o/p ≃ source.

16/8/22

UNIT-5 (POWER AMPLIFIERS)

Consider a public addressing system / Amplified system as shown in fig which generates a power in the range of KW (kilowatts).



⇒ The above system consists of many stages connected in cascade. Basically it is a multistage amplifier.

→ Here i/p & intermediate stages are small signal amplifiers. i.e they provide sufficient voltage gain called as voltage amplifier.

⇒ But the last stage (power Amplifier) gives o/p to the loud speaker like a load. Hence it must be capable of handling large voltages (or) currents called as large signal amplifier.

→ The main Aim is to develop sufficient power. Hence ~~voltage~~ gain is not important in the last stage, such a stage which develops sufficient power to the loud speaker to handle large signals is called power amplifier.

⇒ It is defined as the amplifier which raises the power levels of the signal i.e both voltage as well as current levels of the signal.

⇒ It is also defined as a device / circuit which converts DC power to AC power, and whose action (or) is controlled by i/p signal.

⇒ The transistor suitable for power amplifier is power transistor

⇒ The transistor suitable for power transistors in the following aspects as it differs from conventional transistors

① The area of collector region of power transistor is large.

② The Emitter & base regions are heavily doped.

③ This are large in size and low β (hfe) value (i.e 20 to 80)

Application
④ The power amplifiers finds applications in public addressing systems, Radio receivers, Tapplayers (Tape recorder), CRO etc.

(**) Comparison of voltage amplifier & power Amplifier
10M

characteristics	VA	PA
• Basic function	To provide high voltages to load Hence voltage gain is important.	To provide high power to the load. Hence high voltages & currents are important

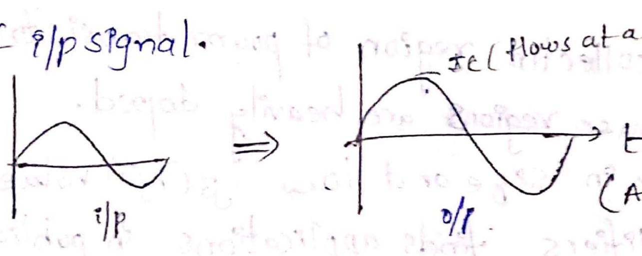
characteristics	NA	
2) Analysis	2) H-parameter model is used	2) Load-line Analysis
3) Type of transistor & its β (hfe) values	3) General purpose transistor or β>100 (hfe)	3) Power transistor (β <85) hfe
4) Input signal	4) Low (few mV)	4) High (few volts)
5) o/p (collector current)	5) Low (few mA)	5) High (few Amp).
6) o/p power	6) Low (few mwatts)	6) high (few watts)
7) Load Resistance	7) high (Range of KΩ)	7) Low (in the range of ohms)
8) o/p Impedance	8) High (Range of <10KΩ)	8) Low (<100Ω)
9) Type of coupling	9) RC coupling.	9) Transformer / Inductive Coupling
10) Type of configuration of (Q) Transistor Maybe QM	10) CE configuration (or) Features of voltage Amplifier (	10) CE configuration (Emitter follower) (or) Features of Power Amplifier (This 10)

Classification of Power Amplifiers: (or) (Large signal Amplifier)

On the basis of Mode of Operation (i.e.) portion of the i/p signal during which collector current flows.

① class-A ② class-B ③ class-C ④ class AB power amplifier

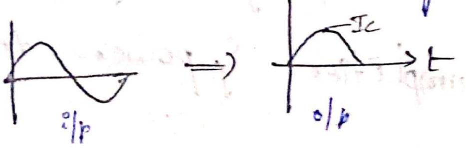
↳ When collector current flow at all times during the full cycle of i/p signal.



(Active)

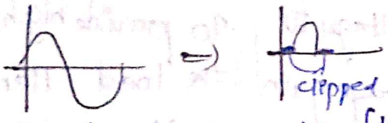
(100% i/p comes to o/p side)

② class-B: collector current flows only during either (+)ve / (-)ve half cycle.



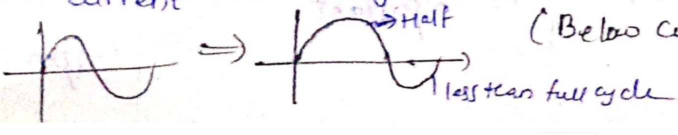
(50%) (saturation)

③ class-C: collector current flows less than half cycle of the i/p signal.



(25%) (cutoff Region)

④ class AB: Collector current flows greater than halfcycle & less than full cycle.



(Below cutoff)

Class A Power Amplifiers:-

⇒ It is the one in which the o/p collector (Icc) current flows during the entire cycle of the i/p signal.

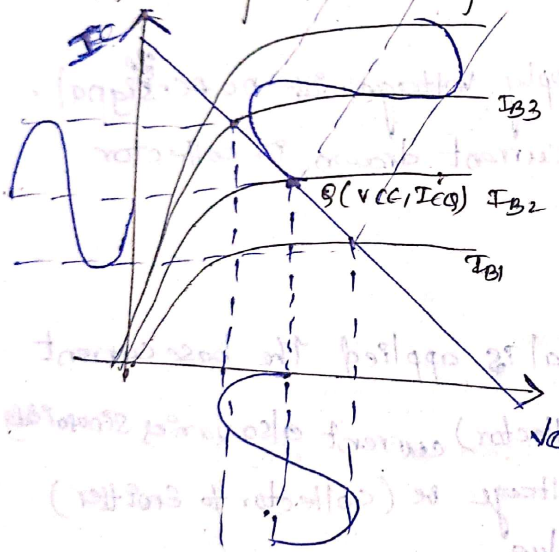
⇒ The power amplifier is said to be class 'A' if Q-point (operating (or) Quescent & i/p signal are selected in such a way that the transistor operates only over the linear (Active region) of its load line.

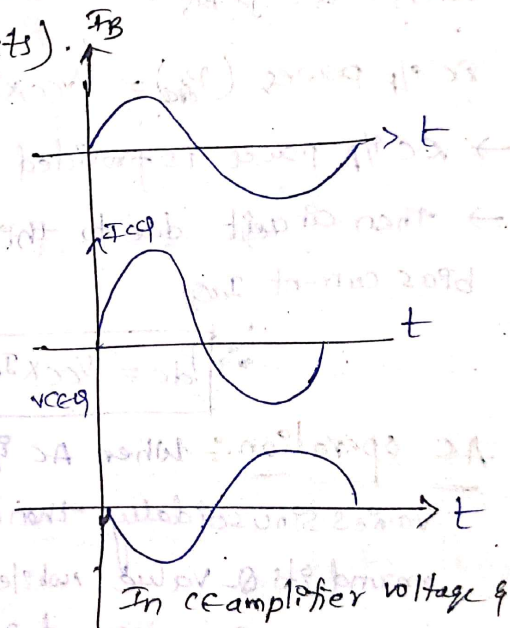
⇒ For this the Q-point should be selected at middle of the load line.

⇒ For all values of i/p signal the transistor remains in active region and never enters into saturation (or) cutoff region.

⇒ when an AC i/p signal is applied the collector voltage varies sinusoidally. Hence collector current also varies sinusoidally for 360° (Full cycle) of the i/p signal.

Fig shows the current & voltage waveforms of class A Amplifier with the help of load line & o/p characteristics).



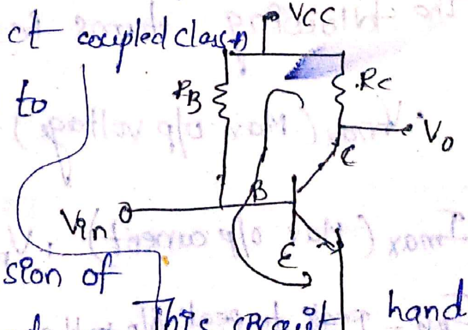


In CE amplifier voltage & current are out of phase so (-)ve to (+)ve

Class A :- two types. — series feed / Direct coupled.

The below fig shows series feed class A power Amplifier

→ The circuit is also called direct coupled class A amplifier because o/p is directly connected to o/p (collector) resistane.



→ The difference b/n small signal version of this circuit is i/p signals handled by this circuit is large. (order of Volts) This circuit handles large voltages.

⇒ Similarly transistor used is power transistor.

⇒ Here value of R_B is selected in such a way that Q-point lines centre of the DC load line.

DC operation:

→ we will study the operation of the circuit in absence of i/p AC signal. i.e. by considering supply voltage (V_{CC}).

→ we can evaluate, I_{BQ}, I_{CQ}, V_{CEQ}

→ By apply KVL to i/p loop :

$$V_{CC} - I_B R_B - V_{BE} = 0.$$

$$\boxed{I_{BQ} = \frac{V_{CC} - V_{BE}}{R_B}}$$

when $I_{CQ} = \beta I_{BQ}$

→ By apply KVL to o/p loop.

$$V_{CC} - I_C R_C - V_{CE} = 0$$

$$V_{CEQ} = V_{CC} - I_{CQ} R_C$$

$$\boxed{V_{CEQ} = V_{CC} - I_{CQ} R_C}$$

indicates DC analyses

DC i/p power (P_{dc}) = $V_{CC} \times I_{CQ}$

→ DC i/p power is provided by supply voltage with no AC i/p signal.

→ Then circuit due to this DC current drawn is collector bias current I_{CQ}

$$\therefore \boxed{P_{dc} = V_{CC} \times I_{CQ}}$$

AC operation: - When AC i/p signal is applied the base current varies sinusoidally, then o/p (collector) current also varies sinusoidally around its Q-value, while o/p voltage i.e. (collector to Emitter) voltage varies around its Q-value.

→ The varying o/p voltage & o/p current also vary sinusoidally.

→ For alternating o/p voltage & o/p current we can express the following terms i.e. V_{min}, (Minimum o/p voltage), V_{max} (Max o/p voltage), I_{min} (Minimum o/p current), I_{max} (Max o/p current), V_{pp} = peak to peak o/p voltage / ~~o/p~~ voltage, I_{pp} - peak to peak o/p ~~volt~~ current, V_m = average o/p voltage, I_m - Average o/p current, V_{rms} (RMS of o/p voltage)

I_{rms} = RMS value of o/p current.

Based on that notations,

$V_{pp} = V_{max} - V_{min}$

$I_{pp} = I_{max} - I_{min}$

$V_m = \frac{V_{pp}}{2} = \frac{V_{max} - V_{min}}{2}$

$I_m = \frac{I_{pp}}{2} = \frac{I_{max} - I_{min}}{2}$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

$V_{rms} = \frac{V_m}{\sqrt{2}}$

$I_{rms} = I_m / \sqrt{2}$

AC power o/p (P_{ac}) is the $P_{ac} = V_{rms} I_{rms}$

$$P_{ac} = \frac{V_m}{\sqrt{2}} \frac{I_m}{\sqrt{2}}$$

$$= \frac{V_m I_m}{2}$$

$$\boxed{P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}}$$

Efficiency (η) = $\frac{P_{ac}}{P_{dc}} = \frac{\text{Acpower}}{\text{Dc power}}$, It is the amount of ACpower delivered (or) transfered to the load from DC source.

It is the ratio of AC power o/p to DC power i/p.

$$\therefore \eta = \frac{P_{ac}}{P_{dc}}$$

$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100.$$

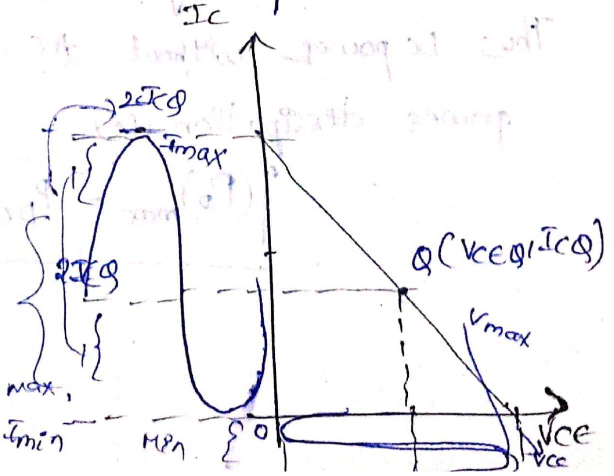
$$\boxed{\% \eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 \times V_{CC} \times I_{CQ}} \times 100}$$ — For class A

It is also called as conversion factor (% η).

Maximum Efficiency: we can assume Q-point is exactly at middle of the load line as shown in fig.

$V_{max} = V_{CC}$; $V_{min} = 0$.

$I_{max} = 2I_{CQ}$; $I_{min} = 0$



Then, $\% \eta_{max} = \frac{(V_{CC} - 0)(2I_{CQ} - 0)}{8 \times V_{CC} I_{CQ}}$

4) $100(25$
$\frac{8}{20}$

$$= \frac{2 V_{CC} I_{CQ}}{8 V_{CC} I_{CQ}} \times 100$$

$$= \frac{1}{4} \times 100$$

$$\boxed{\% \eta_{max} = 25\%}$$

Difference b/n ac power o/p to Dc power i/p is called power dissipation.

→ For class A power Amplifier, efficiency is very low, ie 25% remaining 75% of efficiency is wasted within the circuit.

Power dissipation: (P_D): The amount of power that must be dissipated by the transistor is the difference b/n Dc power i/p and AC power delivered to the load.

$$\boxed{P_D = P_{DC} - P_{AC}}$$

→ The maximum power dissipation occurs when there is zero (AC) i/p signal.

→ When AC i/p signal is zero, the ac o/p power is also zero. But the transistor operates at Q-point by drawing Dc power i/p (P_{DC} i/p) from supply voltage.

→ This entire power gets dissipated in the form of heat. Thus Dc power without AC i/p signal is the maximum power dissipation (ie,

$$\boxed{(P_D)_{max} = P_{DC} = V_{CC} I_{CQ}} \text{ (From Q point)}$$

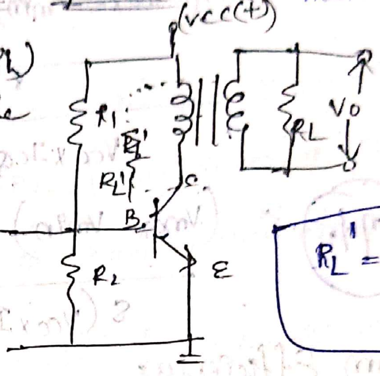
Advantages of class A (Direct coupled):

- → circuit is simple ~~to~~ design & implement.
- → Load is directly connected to collector, This makes the circuit cheaper. (Less cost)
- → Less no. of components are required.

Disadvantages: efficiency is very poor (i.e 25%).

- → power dissipation is more (i.e 75%).
- → o/p impedance is high. Hence circuit cannot be used for loud speakers such as low impedance circuits.

Transformer Coupled class A power amplifiers: (It has impedance matching property)



$$\boxed{R_L^{1} = \left(\frac{N_1}{N_2}\right)^2 \times R_L}$$

The fig shows, the load resistor (R_L) is connected to secondary of the transformer and its primary is connected to ~~p~~ collector circuit. Hence it is called Transformer Coupled Amplifier.

→ Due to impedance matching property of the transformer the load resistor (R_L) will ~~can~~ appears as a reflective resistance at the primary winding; which is connected to collector circuit and it is given by $\boxed{R_L' = \left(\frac{N_1}{N_2}\right)^2 \times R_L}$

- For stepdown – R_L^1 increa (N1) his
- For stepup trans – R_L^1 deeree (N2 high) (So decrease)

n_1 – No. of turns on primary.

n_2 – No. of turns on Secondary.

DC operation: For this operation, we assume that no AC i/p signal. But we can operate the transistor with supply voltage (or) DC voltage.

Under this conduction it is assumed that ~~a~~ winding resistance of the transformer is zero. Hence for DC, resistance is zero.

Apply KVL to o/p

$$V_{CC} - V_{CE} = 0$$

$$V_{CEQ} = V_{CC}$$

$$I_{BQ} = \frac{V_{CC} - 0.7V}{R_B} \quad \Big| \text{ where } R_B = R_1 // R_2$$

$I_{CQ} = \beta I_{BQ}$

Dc power i/p $\cdot (P_{DC}) = V_{CC} \times I_{CQ}$

AC operation:- AC operation of transformer coupled is same as that of Direct coupled.

{ content copy from AC in Direct coupled upto all formulas

i.e $P_{AC} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}$

Hence, $\eta \% = \frac{P_{ac}}{P_{dc}} \times 100$

$$= \frac{\frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}}{V_{CC} \times I_{CQ}} \times 100$$

Conversion factor:

$$\boxed{\eta \%} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 (V_{CC} \times I_{CQ})} \times 100$$

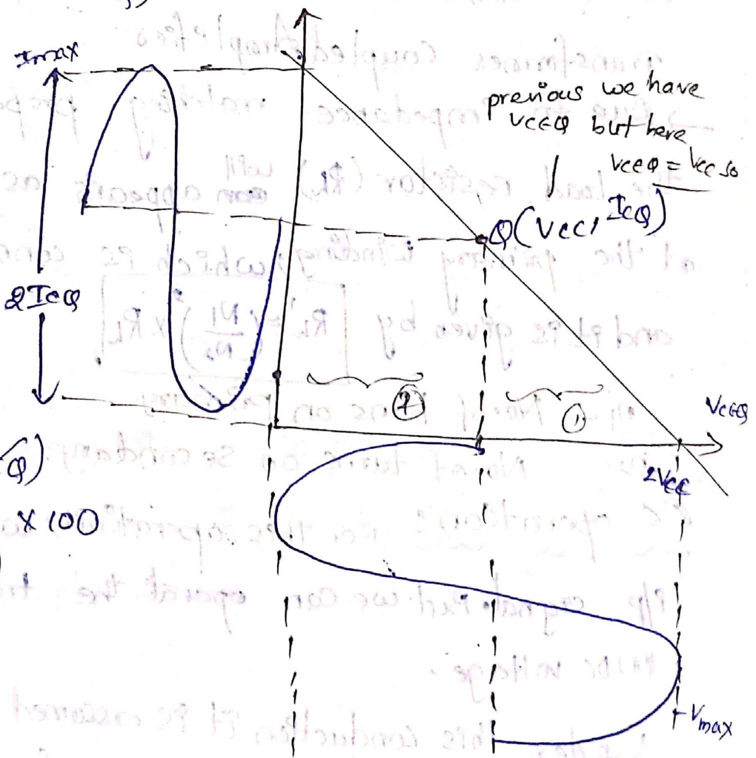
Maximum Efficiency:-

$V_{max} = 2V_{CC}$

$V_{min} = 0$

$I_{max} = 2I_{CQ}$

$I_{min} = 0$



$$\% \eta_{max} = \frac{(2\cancel{V_{CC}} - 0)(2\cancel{I_{CQ}})}{8(\cancel{V_{CC}} \times \cancel{I_{CQ}})} \times 100$$

$$= \frac{1}{2} \times 100$$

$$\boxed{\% \eta_{max} = 50\%}$$

2Vcc because previous we have only VCEQ only but here VCEQ=Vcc

Power dissipation:- $P_D = P_{DC} - \underset{\sim}{P_{AC}}$

=0 for DC (Max power dissipation occurs at i/p ac =0 only

$(P_D)_{max} = P_{DC}$

$(P_D)_{max} = V_{CC} I_{CQ}$

Advantages :- → Efficiency is improved from 25% to 50%

→ Power dissipation also reduces from 75% to 50% compared to Direct coupled.

→ Impedance matching is provided.

Disadvantages :- Due to transformer circuit becomes bulky, heavier and costly.

→ circuit is complex to design.

→ Frequency response is poor due to transformer.

List the differences b/n Direct coupled & Transformer coupled class A - power Amplifier? (Imp)

class B power Amplifier :- The power amplifier is said to be class-B, if the Q-point & i/p signal are selected such that o/p signal is obtained only for one half cycle (either (+)ve/(-)ve) for a full cycle i/p.

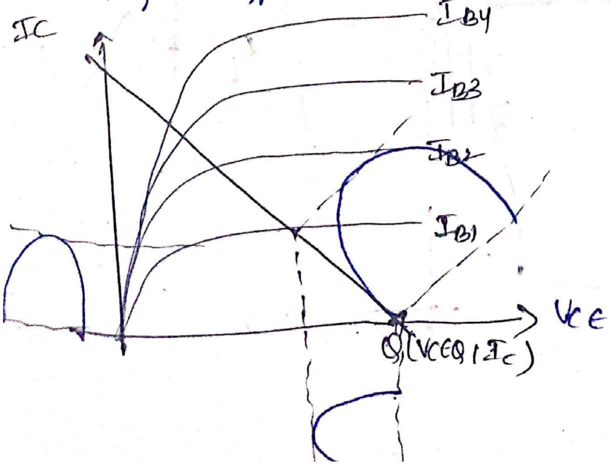
→ For this operation, Q-point is shifted on X-axis ie voltage axis. (ie) The transistor is biased to cutoff region.

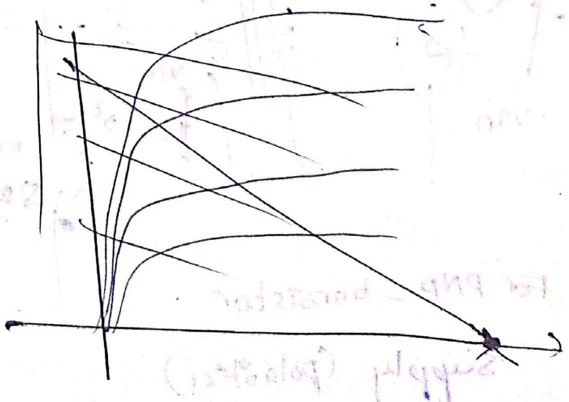
→ Due to the selection of Q-point on X-axis the transistor remains in active region only for (+)ve half cycle of the i/p. Hence this half cycle is reproduced at the o/p. as (fig 18).

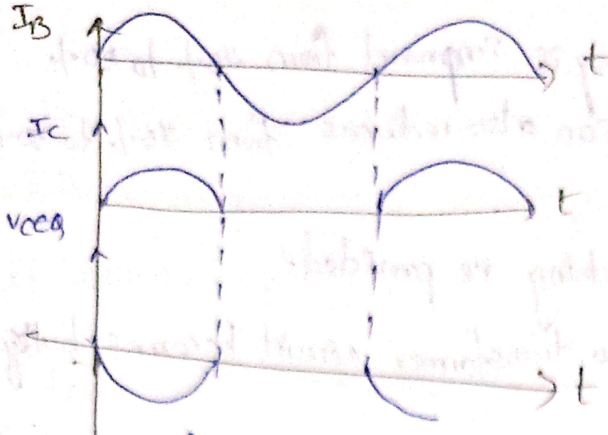
→ But in a (-)ve half cycle, transistor enters into cutoff region. and no signal is produced at o/p.

→ The collector current flows only 180° (i.e Half cycle) of the i/p signal.

→ The waveforms of I_B, I_C, V_{CE} are shown in fig. with the help of o/p characteristics with load line.







From above waveforms, for class-B operation the Q-point is selected on x-axis itself due to this I_c (collector current) flows only for half cycle for a given full cycle i/p.

→ Due to this the o/p signal is distorted. To get full cycle o/p across the load a pair of transistors are used in class-B operation.

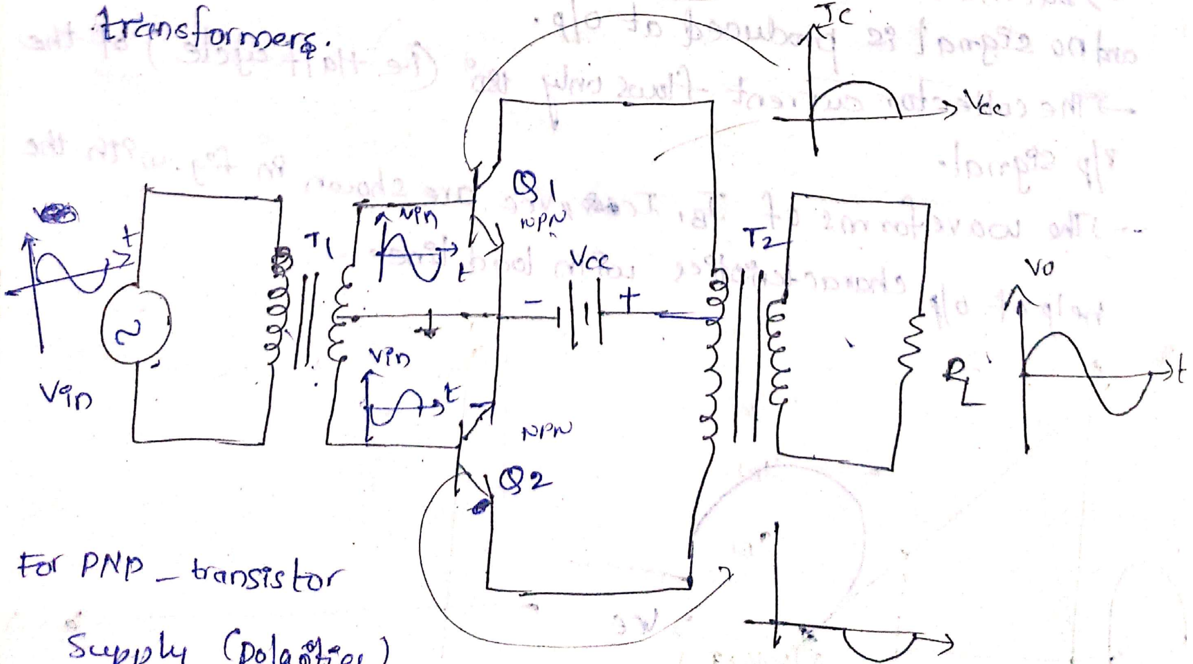
→ The two transistors conduct in alternate half cycles of i/p and get a full cycle o/p across the load.

→ Depending upon type of transistors whether NPN (or) PNP class-B power amplifiers are of two types

1) Push Pull class-B power amplifier (Both transistors are same type) i.e., (either NPN (or) PNP).

2) Complementary symmetry class-B: when one transistor is NPN and another transistor is PNP.

Pushpull class-B power amplifier: It requires two transformers.



For PNP transistor Supply (polarities) changes as (+ -)

The above fig. requires two transformers .

1) Input transformer (Driver transformer) and the other to connect to load

2) Output transformer & the input signal is applied to the primary of driver transformer and the load resistor (R_L) is connected to secondary of output transformer.

→ Both the transformers are of centre tapped transformers

→ It uses two transistors (Q_1 & Q_2) of same type called NPN

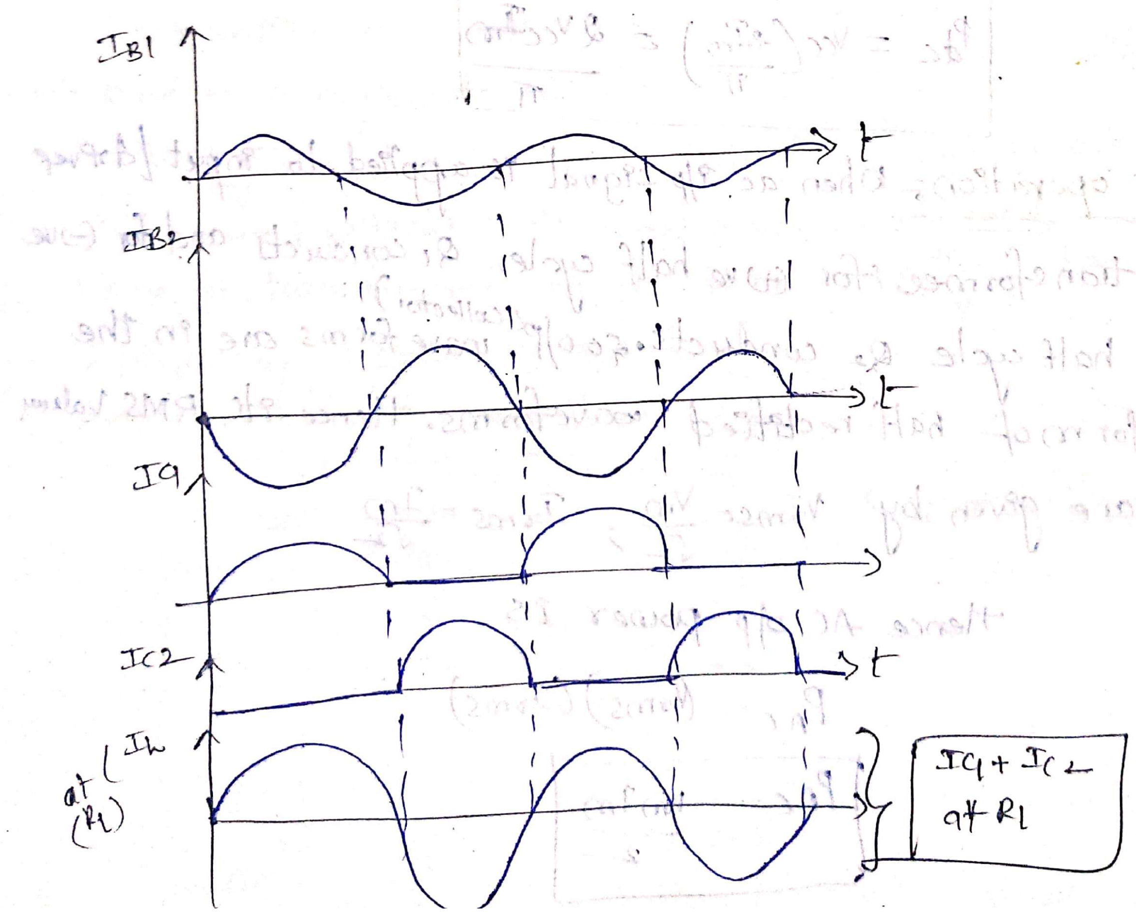
→ Suppose the circuit uses PNP type then the supply voltage must be (−) VCC (i.e +/−) .

→ Here both transistors are configured in CE configuration.

→ w.r.t centre tapped for (+)ve cycle of i/p, the Q_1 (ON) transistor conducts while Q_2 transistor is in cutoff (open) OFF and during (−)ve half cycle the Q_1 transistor (OFF) cutoff and Q_2 transistor is active (ON)

→ so o/p voltage across load is a full cycle of o/p for a full cycle of i/p.

The below fig. shows the waveforms of i/p & o/p currents.



Dc operation: Dc biasing point (Q-point) is adjusted onto the X-axis such that $V_{CEQ} = V_{CC}$ & $I_{CQ} = 0$.

Hence Q-point is $Q(V_{CEQ}, 0) = Q(V_{CC}, 0)$. There is no dc base bias voltage [∵ as $I_C = 0 \Rightarrow I_B = 0$].

Dc input power:

Each transistor o/p is in the form of half wave rectified wave form. Hence if I_m is the peak value of the wave form. Then average DC value output current of each transistor is $\boxed{I_{DC} = \frac{I_m}{\pi}}$ due to half-wave rectified o/p.

→ For full cycle of o/p, $I_{DC} = \frac{I_m}{\pi}$ for half and $I_{DC} = \frac{I_m}{\pi}$ for next half (-)ve cycle.

$$\therefore I_{DC} = \frac{I_m}{\pi} + \frac{I_m}{\pi}$$

$$I_{DC} = \frac{2I_m}{\pi}$$

$$\boxed{P_{dc} = V_{CC}\left(\frac{2I_m}{\pi}\right) = \frac{2V_{CC}I_m}{\pi}}$$

AC operation: When ac i/p signal is applied to input [driver transformer, for (+)ve half cycle, Q_1 conducts and for (-)ve half cycle Q_2 conducts. So o/p (collector) wave forms are in the form of half-rectified waveforms. Hence its RMS values are given by $V_{rms} = \frac{V_m}{\sqrt{2}}$; $I_{rms} = \frac{I_m}{\sqrt{2}}$

Hence AC o/p power is

$$P_{AC} = (V_{rms})(I_{rms})$$

$$\boxed{P_{AC} = \frac{V_m I_m}{2}}$$

Efficiency:- $\eta = \frac{P_{ac}}{P_{dc}}$

$$\eta\% = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{\frac{V_m I_m}{2}}{\frac{2V_{cc}I_m}{\pi}} \times 100$$

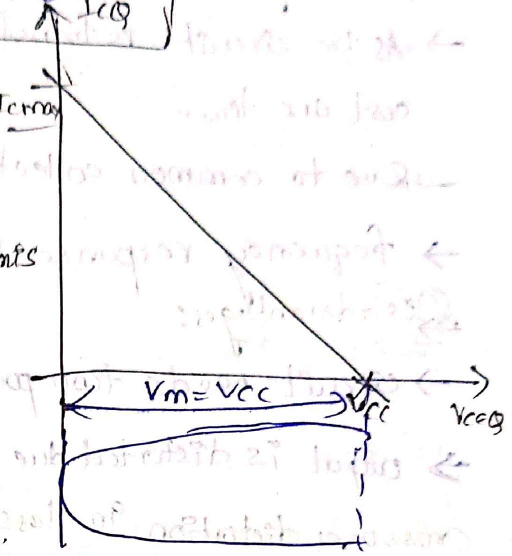
$$\frac{314 \times 2}{6280}$$

$$\eta\% = \frac{V_m I_m}{2} \times \frac{\pi}{2V_{cc}I_m} \times 100$$

$$\eta\% = \frac{\pi}{4}\left(\frac{V_m}{V_{cc}}\right) \times 100$$

$$\boxed{\eta\% = \frac{\pi}{4}\left(\frac{V_m}{V_{cc}}\right) \times 100}$$

Maximum Efficiency:-



$\eta\%_{max} = ?$

For maximum efficiency,

$V_m = V_{cc}$ // Q point is on X-axis

$$\therefore \eta\%_{max} = \frac{\pi}{4} \times 100$$

$$\boxed{\eta\%_{max} = 78.5\%}$$

→ Power dissipation is same.

Advantages:- Efficiency is improved (higher than class A).

→ when there is no i/p signal power dissipation is zero (ie transistors are not working).

→ Due to transformers impedance matching is possible.

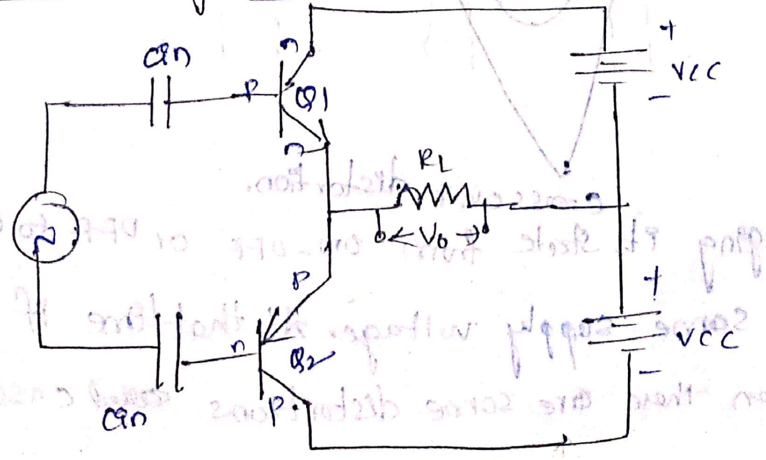
Disadvantages:- Two centre tapped transformers are required (ie we want alternate cycles (+)ve & (−)ve (∴ two centre-tapped)).

→ Due to transformers circuit becomes costly & heavy.

→ Frequency response is poor.

Complementary Symmetry class-B:-

(CE configuration)



→ Transformers are removed.

→ Two supply voltages are required. ((+) for NPN, (−)ve PNP)

→ The two transistors are configured in cc configuration

→ The transistors used are NPN & PNP.

operations all are same as pushpull class-B amplifier.

Efficiency also same.

cc has low o/p impedance so we can connect to loud speakers

Advantages:

→ As the circuit is transformerless. Hence its weight, size, cost are low.

→ Due to common collector, impedance matching is possible

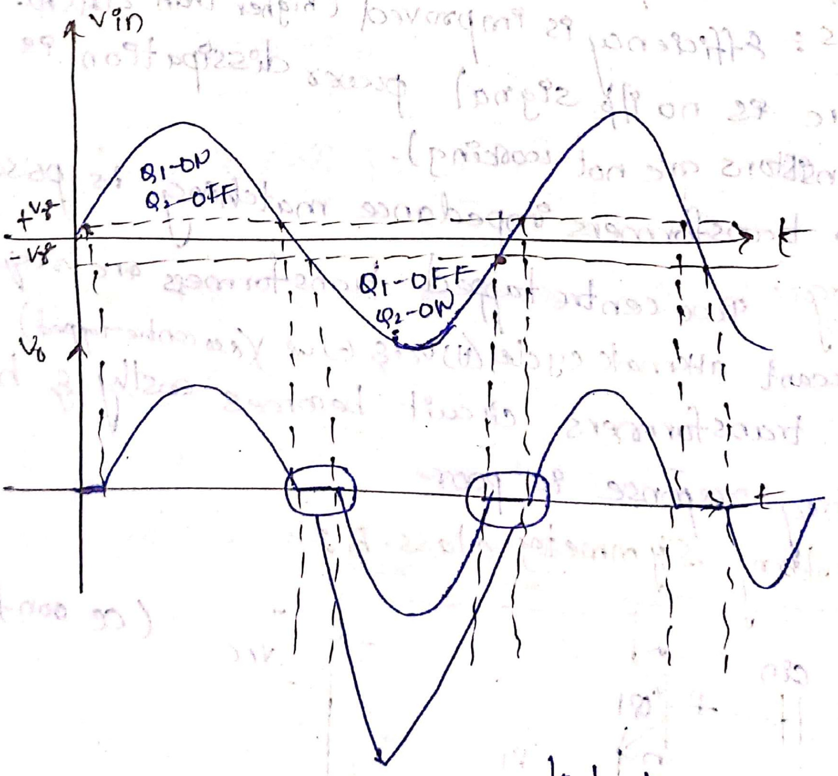
→ frequency response improves.

Disadvantages:

→ circuit needs two power supplies (1 for NPN & 2nd for PNP)

→ output is distorted due to crossover distortion.

Crossover distortion in class B:



crossover distortion.

While changing its state from ON-OFF or OFF to ON it requires some supply voltage. At that time if no supply then there are some distortions called crossover.

junction must be forward bias. The junction can't be made forward bias till the i/p voltage becomes greater than cutin voltage of the junction for which generaley 0.7V for silicon, and 0.3V for Germanium.

Hence aslong as the magnitude of the i/p signal, less than cut in voltage of emitter base junction and greater than cut in voltage ie collector current remains zero and transistor remains in cutoff region. So there is a period / time b/n the crossings of half cycles. for which none of the transistor is in active region & o/p is zero. Such a distored o/p waveform due to cutin voltage as shown in fig is called crossover distortion.

→ To eliminate the Crossover distortion some modifications are necessary in the basic circuit of class-B which is called class-AB power amplifier.

The loudspeaker of 8Ω, is connected to the secondary of o/p transformer of class-A power amplifier. The Q-point collector current is 140mA. The turns ratio of transformer is 3:1. The collector supply voltage is 10V if AC power delivered to the load speak is 0.48 watt. calculate DC power i/p, effeciency, and power dissipation.

Given $I_{CEQ} = 140mA$

$P_{ac} = 0.48$ watts

$V_C = 10V$

$\frac{N_1}{N_2} = 3:1$

$R_L = 8\Omega$

$$Dc\ i/p\ power = V_{CC} \times I_{CEQ}$$

$$= 10 \times 140 \times 10^{-3}$$

$$= 1400 \times 10^{-3}$$

$$\boxed{P(Dc) = 14 \times 10^{-1} = 1.4\ watts.}$$

$$\eta\% = \frac{\text{AC power o/p}}{\text{DC power i/p}} \times 100$$

$$\boxed{\eta\% = 34.28\%}$$

power dissipation = $P_{DC} - P_{ac}$

$$\boxed{(P_D) = 0.92 \text{ watts}}$$

A class-B push pull amplifier supplies power to a resistive load of 12Ω. The o/p transformer as a turns ratio 3:1 and efficiency of 78.5%. calculate (i) Max o/p power (ii) Max power dissipation in each transistor.
P_{ac}

$N_1 : N_2 = 3:1$

$$P_{ac} = \frac{V_m I_m}{2} \qquad \eta\% = 78.5\%$$

$$P_{ac} = \frac{V_m I_m}{2}$$

let as assum = $V_m = V_{cc} = 20V$; $I_m = V_m$

$$P_{ac} = \frac{V_m^2}{2R_L'}$$

$$R_L' = \left(\frac{N_1}{N_2}\right)^2 \times R_L = 108\,\Omega$$

Max power dissipation $(P_{ac}) = \frac{20^2}{2\times 108} = 1.85$ watts

We know that

$$P_{dc} = \frac{P_{ac}}{\text{eff}\%} \times 100 \Rightarrow \frac{1.85}{0.785} = 2.356 \text{ watt}$$

$P_{dc} = 2.356$ watts

∴ Power dissipation (P_d) = $P_{dc} - P_{ac}$ = $2.35 - 1.85 = 0.5$ watts

∴ For each transistor $= \frac{P_d}{2}$ = 0.25 watts.

class-B pushpull delivers a load of 16Ω, connected to the secondary of ideal transformer ($n_1 = n_2 = 1:1$) - supply voltage is 25V, If the no. of turns on secondary is 50. Calculate efficiency?

$R_L = 16\Omega$; $V_{cc} = 25V$; $N_2 = 50 = N_1 = 50$; R_L' also $= 16\Omega$

$$P_{ac} = \frac{V_m I_m}{2}$$

$$P_{dc} = \frac{2\overset{V_{cc}}{V_m}(I_m)}{\pi} = \frac{2 \times 25 \times V_{cc}}{\pi R_L'}$$

$$P_{dc} = \frac{2 \times 25 \times 25}{\pi \times 16}$$

$$P_{dc} = 24.88 \text{ watts.}$$

$$P_{ac} = \frac{\overset{V_{cc}}{V_m} I_m}{2} = \frac{25 \times 25}{2 \times 16} = 19.53 \text{ watts}$$

$$\% \eta = \frac{P_{ac}}{P_{dc}} \times 100 = \frac{19.53}{24.88} \times 100 = \underline{\underline{78.496}}$$

4) A class-B pushpull amplifier supplies power to a loud speaker of 10Ω, the o/p transformer turn ratio of $N_1 : N_2$ of 4:1. and efficiency is 95%. Calculate the (i) Max power o/p (P_{ac}) (ii) Max power dissipation (P_d) (iii) Max Base currents of each transistor.

$$P_{ac} = \frac{V_m I_m}{2}$$

$I_m = I_c$

Let $V_m = V_{cc} = 20V$

$$= \frac{(V_m)^2}{2R_L'} = 1.25 \text{ watts.}$$

$$R_L' = \left(\frac{N_1}{N_2}\right)^2 \times R_L = 160\Omega$$

$$P_{dc} = \frac{P_{ac}}{\eta} \times 100 = \frac{1.25}{0.95} = 1.315 \text{ watts}$$

$$P_d = P_{dc} - P_{ac} = 0.065 \text{ watt}$$

$P_d/2$ = for each transistor = 0.0325 watts.

3) For max Base current

$I_c = \beta I_B$

$P_{dc} = \frac{2V_{CC} I_m}{\pi}$ $(I_m = I_c)$

$I_B = I_c / \beta$

$$\boxed{I_m = 0.10322}$$

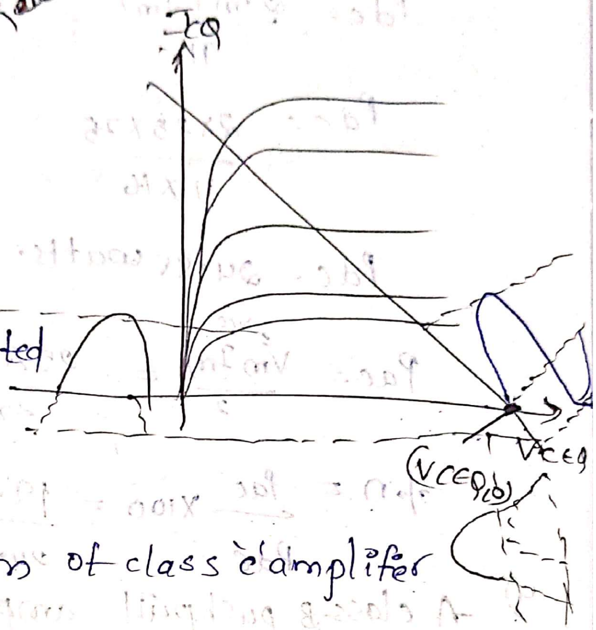
Assume hfe = 25.

$$\boxed{I_{m\,max} = \frac{4.12}{9mA}}$$

22/6/22

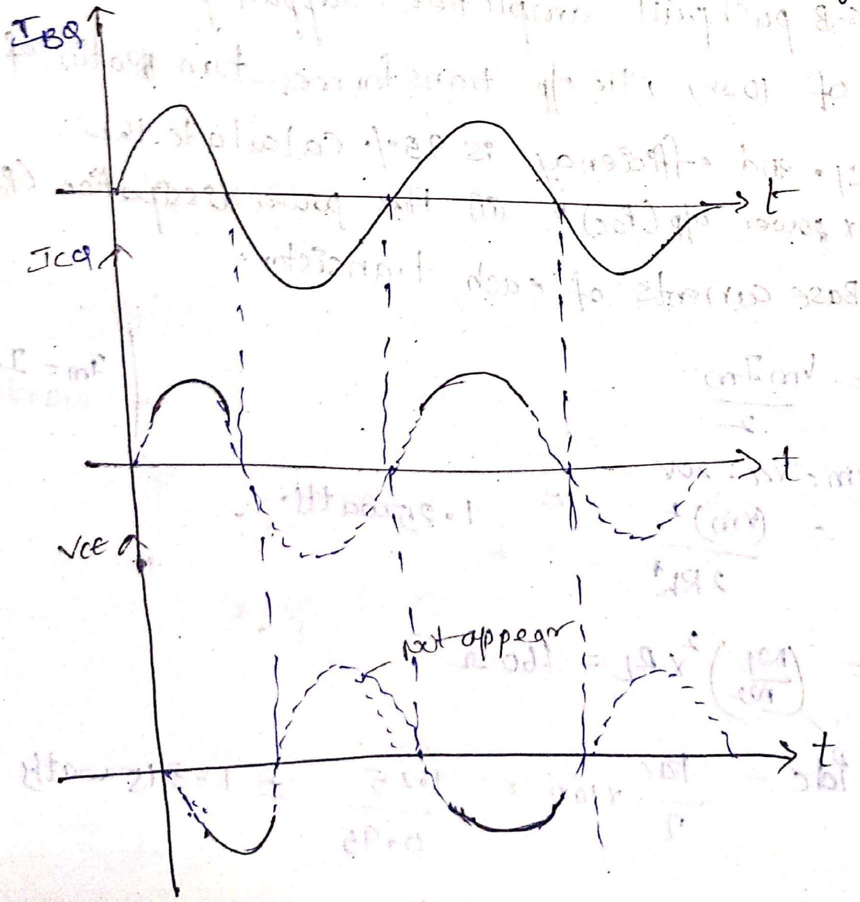
Class-C power amplifier: (used in ~~audio~~ Radio frequency Amplifiers)

Q-point is selected



For this operation, Q-point is shifted below X-axis (or) voltage axis as shown in figure.

The nature of i/p & o/p waveform of class 'c' amplifier



Due to such selection of Q-point transistor remains in active region for less than half cycle. Hence only that much of part is reproduced at the o/p (∩)

→ For remaining cycle of the i/p transistor remains in cutoff and no signal is reproduced, at the o/p.

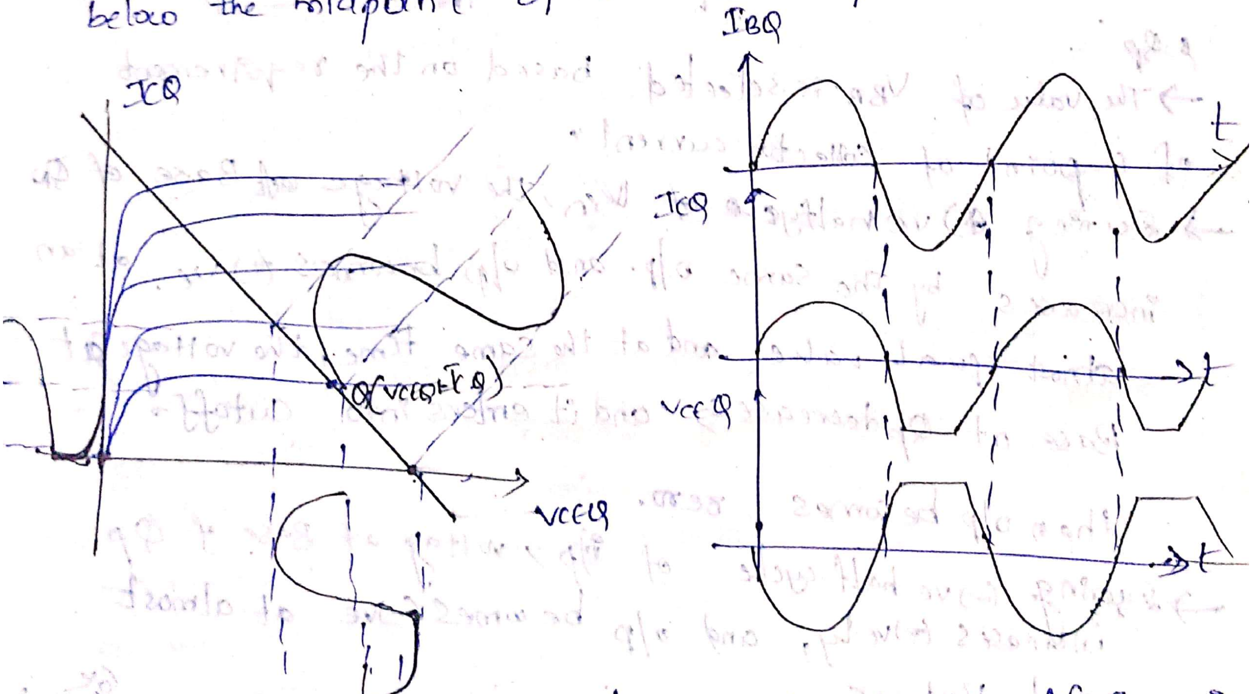
→ So collector current flows less than 180°.

→ In class c-operation, the transistor is biased behind cutoff region so output is more distorted and it is never used for audio frequency power amplifiers. But it is used in radio frequency power amplifiers because efficiency is much higher and can reach very close to 100%.

Class AB power amplifier:

The power amplifier is said to be class AB, if Q-point and the i/p signal are selected such that the o/p signal is obtained for more than 180° but less than 360° for full i/p cycle.

→ For this operation, Q-point is selected above x-axis but below the midpoint of load line.



→ In this operation o/p signal is distorted but efficiency is more than class-A and it is important to eliminate crossover distortion of class-B operation (Amplifier)

→ Definition , Q point, efficiency, Distortion , power dissipation,
} For differences b/n power Amplifiers

Class AB – power dissipation – Moderate.

Analysis of class AB:

class AB o/p stage:

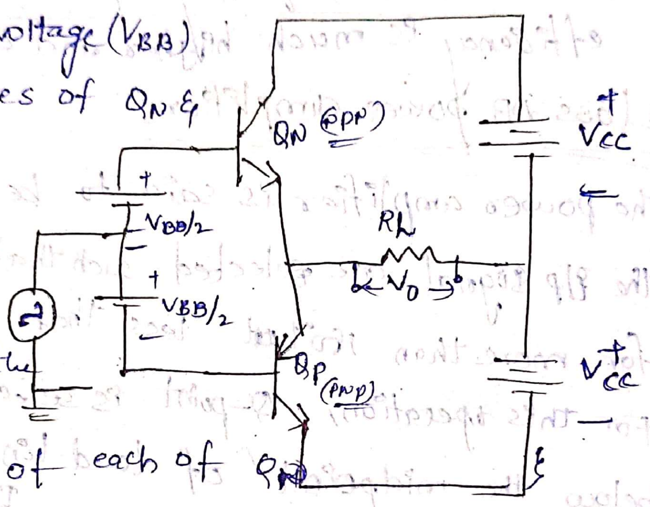
Crossover distortion can be eliminated by biasing complementary transistors at a small, non-zero circuit (current)

→ The resultant circuit is the class AB power amplifier as shown in fig.

→ In the circuit, bias voltage (V_{BB}) is applied b/n the Bases of Q_N & Q_P.

⇒ Suppose for $V_{in}=0$

⇒ ~~and~~ $V_o=0$ and voltage of $\frac{V_{BB}}{2}$ appears across the emitter base junctions of each of Q_N & Q_P.



→ The value of V_{BB} is selected based on the requirement of Q-point of collector current.

→ During (+)ve halfcycle of V_{in}, the voltage at Base of Q_N increases by the same o/p. and o/p becomes (+)ve, at an almost equal value. and at the same time, the voltage at Base of Q_P decreases, and it enters into cutoff.

then o/p becomes zero.

→ During (−)ve half cycle of i/p, voltage at Base of Q_P increases (−)vely, and o/p becomes (−)ve at almost equal values.

→ At the same time, voltage at Base of Q_N decreases (i.e (+)ve) then transistor Q_N enters into cutoff. So o/p ~~volt~~ current I_C or $V_{CC}=0$ (o/p voltage)

→ for full cycle of i/p signal, voltage across Load resistor is also full cycle without any distortion.

Note:- ANALYSIS of Class AB is same as that of class B Amplifier (DC, AC operation, efficiency)

Advantages
crossover distortion is eliminated.

→ efficiency is improved.

Disadvantages:-

More voltage sources are required. (4) same supply.

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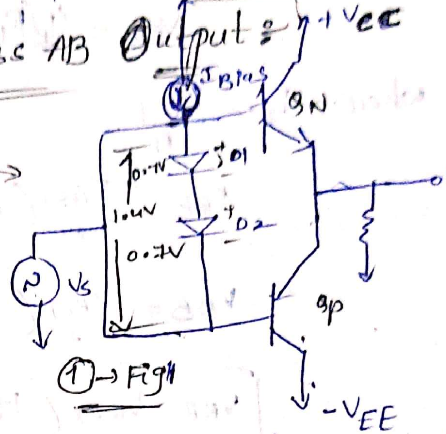
Various Biasing Circuits of class AB Output:-

① Biasing using diodes:- →

② Biasing using V_{BE} amplifier:-

→ In fig1, class AB circuit in which the biasing voltage V_{BB} is generated by passing a constant current source (I_{BIAS}) through a pair of diodes D1 & D2.



① → Fig1

→ In this circuit it supplies large currents of power, even though and biasing diodes are small in size (ie need not be large devices) and Quiescent collector current established in Q_N & Q_P will be

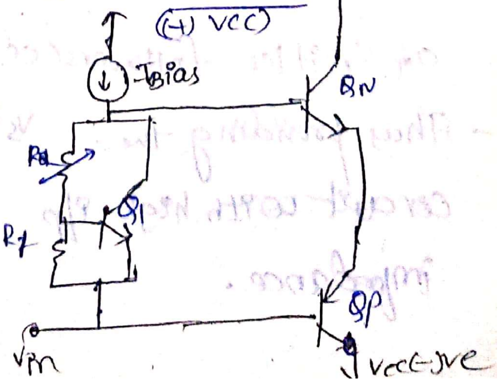
$\boxed{I_{CQ} = nI_{BIAS}}$ where 'n' = Ratio of emitter junction area of the o/p devices to the junction area of the Biasing diodes.

→ Advantage of this arrangement is it can provide thermal stabilisation and it dissipates power under DC ~~press~~ operation also At the same time

Disadvange:- we can provide constant voltage (ie, biasing voltage) In some cases, it is not sufficient to drive Q_N & Q_P.

② Biasing using V_{BE} amplifier:-

The Circuit is alternative biasing arrangement that provides with considerable more flexibility.



to change the biasing voltage for Q_N & Q_P transistors. In the basic circuit consists of Transistor Q_1 with R_1 connected b/n base & Emitter and R_2 is connected b/n collector & base and resulting two terminals is connected with a constant current source I_{Bias}

→ If we neglect base current of Q_1 then R_1 & R_2 resistors will carrying same currents is

$I_R = \frac{V_{BE1}}{R_1}$ and the voltage across V_{BB} across biasing terminals will be

$$V_{BB} = I_R(R_1 + R_2)$$

where $I_R = \frac{V_{BE1}}{R_1}$

$$V_{BB} = \frac{V_{BE1}}{R_1}(R_1 + R_2)$$

$$V_{BB} = \frac{V_{BE1}}{}\left(1 + \frac{R_2}{R_1}\right)$$

$$\boxed{V_{BB} = V_{BE1}\left(1 + \frac{R_2}{R_1}\right)}$$

Thus above circuit simply multiplies V_{BE} by a factor $\left(1 + \frac{R_2}{R_1}\right)$ and is known as V_{BE} multiplier.

→ Here multiplication factor depends on the selection of R_1 & R_2 value

Variations on the class AB o/p:

① Use of i/p emitter follower: (or) ③ Modification of Biasing voltage V_{BE} amplifier

25×~~25~~ = 625w

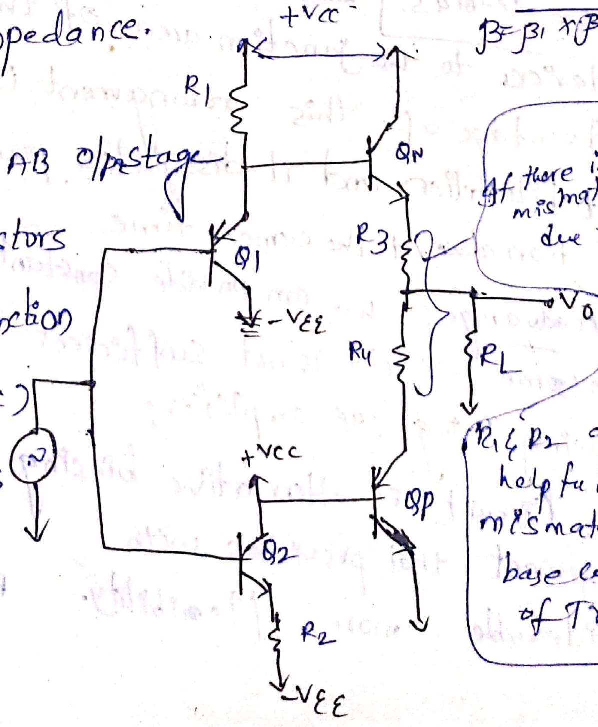
$\beta = \beta_1 \times \beta_2$

CC provides high ~~o/p~~ i/p impedance.

(or) Emitter follower:

→ In this circuit class AB o/p stage is biased using transistors Q_1 & Q_2 which also function as Emitter followers (CC)

→ Thus providing the circuit with high i/p impedance.



If there is any mismatch (cancelled due to (R_3 & R_4)

R_1 & R_2 are helpful in mismatch in base currents of Transistor

→ Here transistors Q_1 & Q_2 circuit function as unity gain power amplifier: ('Buffer amplifier)

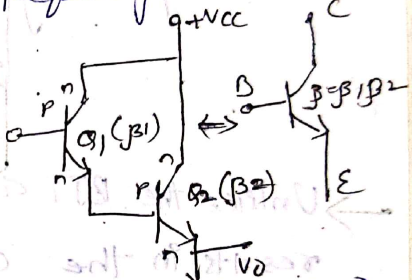
→ Since all 4-transistors are usually matched and neglecting the effect of R_3 & R_4.

→ Quiescent currents of Q_n & Q_p are equal to Q_1 & Q_2.

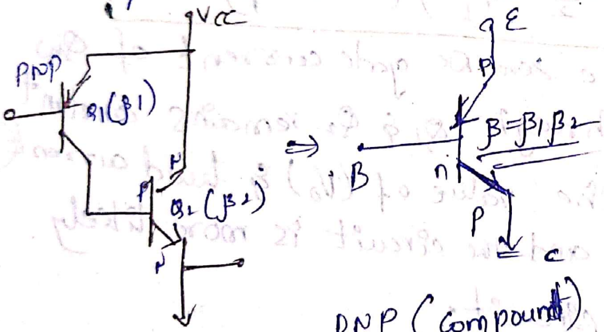
→ The resistors R_1 & R_2 are usually very small and are included to compensate possible mismatch b/n base currents of transistors.

→ Main drawback of this circuit is it requires high quality PNP transistors and it cannot provide high current gains & power gains because of power transistors with low "β" value.

③ Use of compound devices:- To increase the current gain of the o/p stage transistors and reduce the required base current: Darlington pair is frequently used to replace NPN transistor & a compound pair is frequently used to replace PNP transistor.

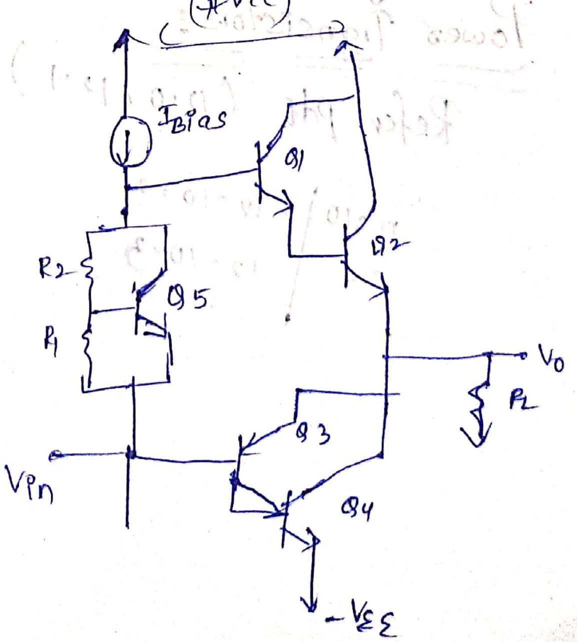


NPN + NPN = NPN.

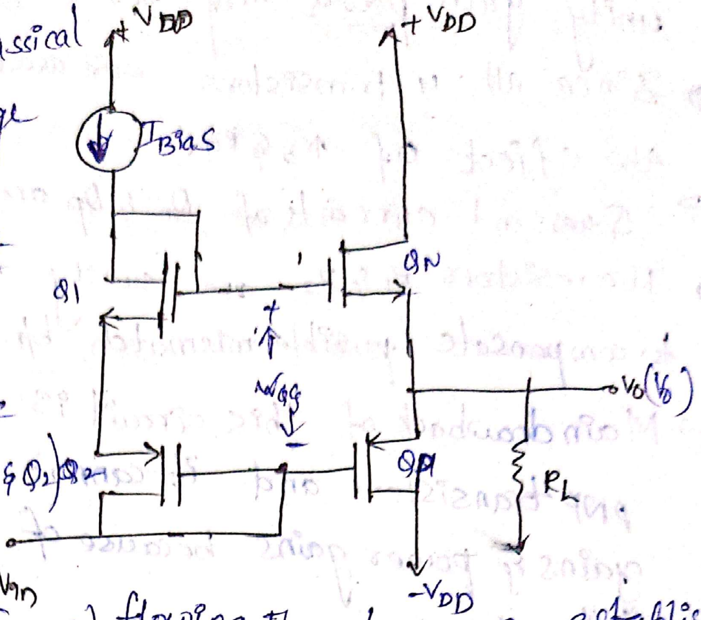


PNP + NPN = PNP (Compound)

– The below fig shows Class AB o/p with the use of compound configurations, and biased by V_{BE} Multiplier.



CMOS Class AB o/p stage:-



The circuit shows the classical CMOS class AB o/p stage

→ The circuit is the exact counter part of BJT circuit with the biasing diodes implemented with diode connected transistors (Q1 & Q2) of same type.

→ The constant current (I_{Bias}) flowing through Q1 & Q2 established a DC bias voltage (V_{QQ}) b/n gates of QN & QP. This voltage in turn establish the Quescent current (I_D) in QN & QP transistors and is given by

$$\boxed{\begin{aligned} I_{D1} &= I_{Bias} = \frac{1}{2} k_n'\left(\frac{W}{L}\right)\left(V_{GS1} - \underset{\sim V_p}{V_{th}}\right)^2 \\ I_{D2} &= I_{Bias} = \frac{1}{2} k_n'\left(\frac{W}{L}\right)\left(V_{GS2} - V_P\right)^2 \end{aligned}}$$

→ Unlike the BJT circuit, here zero DC gate current of QN results in the current through Q1 & Q2 remains constant at I_{Bias}, irrespective of the value of (V_o) & load current (I_L)

→ Thus V_{QQ} remains constant and the circuit is more likely idealy as that of BJT circuit.

Power Transistors:-

Refer pdF (12.0, 12.1) } Refer

12.10 → 12.10.2

12.10.3

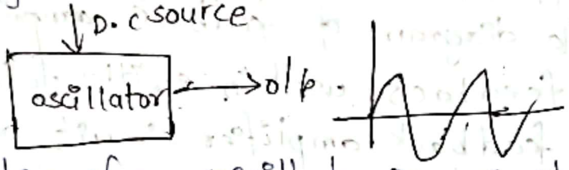
6. OSCILLATORS & TUNED AMPLIFIERS

Introduction to oscillators:- The electronic circuit which produces an alternating voltage (or) current is called an oscillator.

(or) Circuit which generates an AC o/p signal without requiring any externally applied i/p signal.

→ It may also defined the circuit which converts DC signal to AC signal is called an oscillator.

→ It is opposite to that of rectifier. The below fig shows the block diagram of oscillator.



→ The function of an oscillator is similar to that of an amplifier. But the basic difference b/n amplifier & oscillator can be stated as follows.

1) The amplifier takes energy from DC source and converts it into AC source at signal frequency. In this, the frequency waveform and magnitude of AC signal generated is controlled by the AC signal applied at i/p.

2) In oscillator the frequency, waveform & magnitude of AC signal generated is controlled by the circuit itself. i.e) no external controlling voltage is required.

3) In oscillators the frequency, waveform & magntitude of determined by the passive components used in the circuit.

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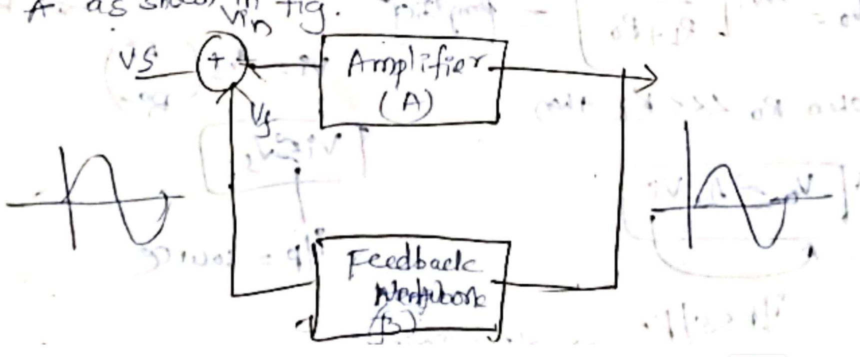
Conditions for Oscillator (or) Barkhausen Criteria:-

1) consider a non-inverting amplifier with a voltage gain of A as shown in fig.



2) In this the o/p voltage (vo) and i/p signal are in face.

Then a part of o/p is feedback to i/p with the help of feedback network then the magnitude of i/p signal increases. Hence it is called positive feedback.

3) From the fig $A = \frac{V_o}{V_{in}}$; $A_f = \frac{V_o}{V_s}$

Due to (+)ve feedback $V_{in} = V_s + V_f$ | $V_f = \beta V_o$

$V_s = V_{in} - V_f$

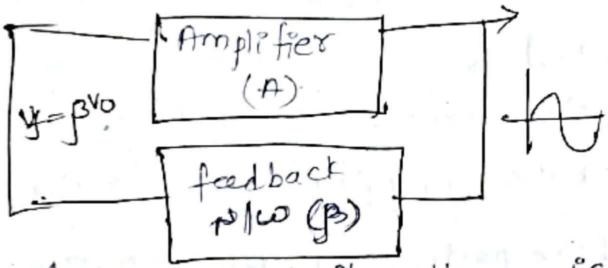
$V_o = \beta A V_{in}$

$V_s = V_{in} - \beta A V_{in}$

$V_s = V_{in}(1 - A\beta)$

$$\boxed{A_f = \frac{V_o}{(1-A\beta)V_{in}} = \frac{A}{1-A\beta}} \rightarrow \text{gain of amplifier with (+)ve feedback.}$$

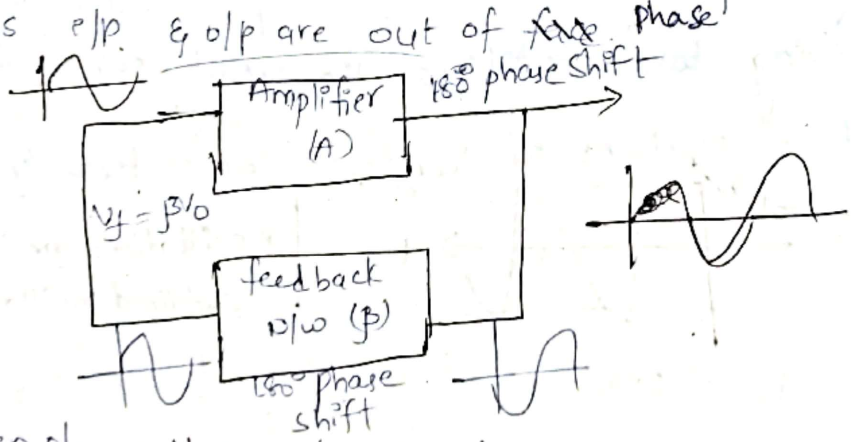
Now consider the various values of (β) and corresponding values of A_f for constant amplifier gain A, then at some value of β, then A_f becomes α, This indicates that the circuit can produce o/p without external i/p voltage (ie $V_s = 0$) just be feeding the part of o/p as its own i/p and it is shown in below fig. which is called as an basic block diagram of an oscillator.



(Block diagram of an Oscillator)

$V_i = V_f$ In this circuit i/p voltage is V_f

From the above circuit if the basic amplifier is inverting amplifier means i/p & o/p are out of ~~face~~ phase



Then o/p voltage (vo) = AV_{in}

Then the feedback signal $V_f = -\beta V_o$ then $V_f = -\beta A V_{in}$

$$\boxed{V_f = -A\beta V_{in}}$$

From the above circuit

$V_f = V_{in}$

$\cancel{V_{in}} = -A\beta \cancel{V_{in}}$

$-A\beta = 1$

$A\beta = -1$ → $\boxed{|A\beta| = 1}$ is called Magnitude of loop gain.

The above eqn indicates the magnitude of loop gain is equal to 1 i.e) (The product of $\underbrace{\text{open loop gain}}_{A}$ & $\underbrace{\text{feedback ratio}}_{\beta}$ is equal to 1

$\boxed{A\beta = 1}$

From circuit the phase shift of V_f & V_o are same (i.e) the feedback n/w should produce 180° of phase shift in addition to 180° phase shift introduced by inverting amplifier. It indicates the total phase shift around the loop is 360°, It is called as necessary & sufficient condition.

$A\beta = 1$ is only sufficient condition.

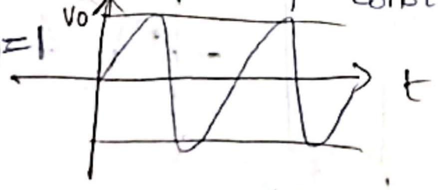
→ The two conditions are required to work circuit as an oscillator are called Barkhausen criteria for oscillations and they maybe stated as

1) The total phase shift around the loop is 0° or 360°. This phase shift is due to basic amplifier and feedback networks.

2) The magnitude of the product of open loop gain of the amplifiers and feedback n/w (β) is unity (i.e) $|A\beta| = 1$

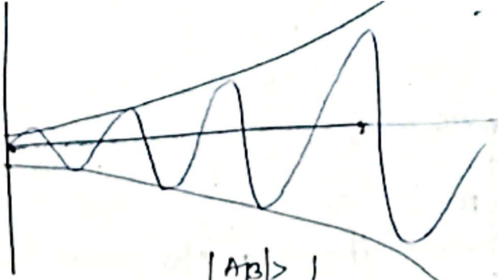
By satisfying above conditions the circuit is able to produce sustained oscillations of constant amplitude & frequency

i.e $(A\beta) = 1$



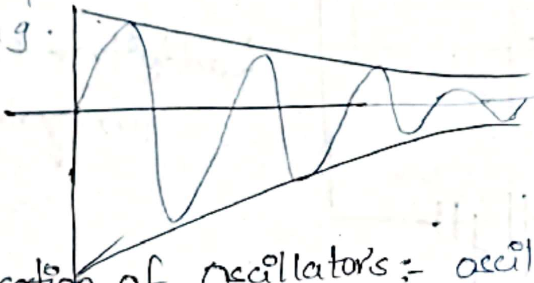
oscillations are called sustained oscillations

→ when the total phase shift around the loop is 360° and $|A\beta| > 1$ then the circuit produces oscillations but the oscillations are exponentially increasing.



These are called unsustainedoscillations

→ when the total phase shift is 360° & |Aβ| < 1 then the circuit produces oscillations but they are exponentially decaying.



unsustained Oscillations.

classification of Oscillators :- oscillators are classified base on different parameters.

① Based on o/p signal (waveform) :-

(a) sinusoidal oscillators (b) Non-sinusoidal oscillators. Ex(square, triangle, sawtooth)

② Based on feedback network :-

(i) RC - oscillators — RC phaseshift oscillator.
— wien bridge oscillators

(ii) LC oscillators — Hartley oscillators
— Colpitts oscillators.

(iii) crystal oscillators

③ Based on o/p frequency :-

(i) Audio oscillators (or) low frequency oscillators)(20Hz - 20KH

(ii) Radio oscillators (or) High frequency oscillators (20K - 20MHz

(iii) Very high frequency oscillators (20H - 200 MHZ)

(iv) ultra-high frequency oscillators(200M - 3GHZ)

(v) Microwave frequency oscillators (Above 3GHZ)

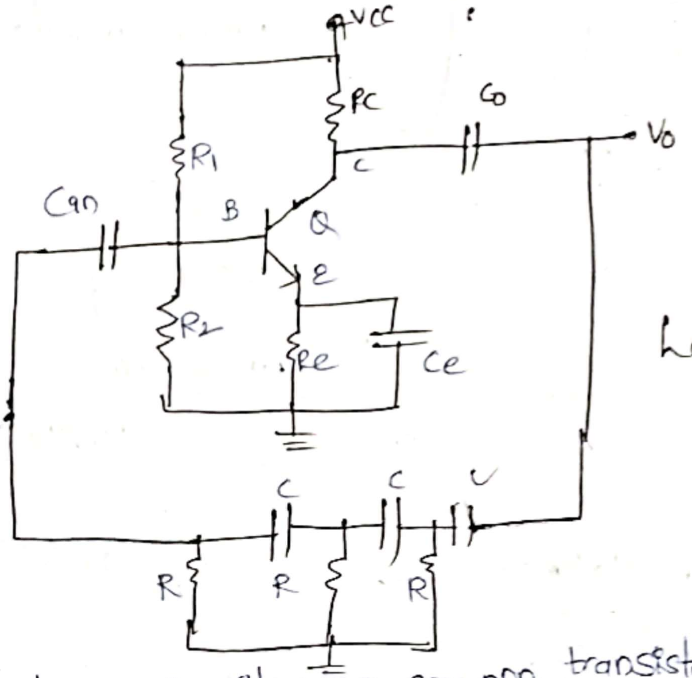
④ Based on type of feedback :-

(i) positive feedback oscillators.

(ii) Non-feedback oscillators Ex :- Tunnel diode, UJT)
(The circuit which operates in -ve resistance region)

① RC phase shift Oscillator :-

It is commonly used sinusoidal low frequency oscillator the below figure shows the circuit diagram of RC phase shift oscillator.



Ladder type RC N/w arrangement

In above circuit, uses an npn transistor in common emitter configuration with voltage divider bias of an amplifier and in feedback network consists of 3 identical RC sections connected in ladder fashion.

→ In the above circuit, CE amplifier provides 180° of phase shift and the feedback n/w provides another 180° of phase shift so the total phase shift is 0° or 360°.

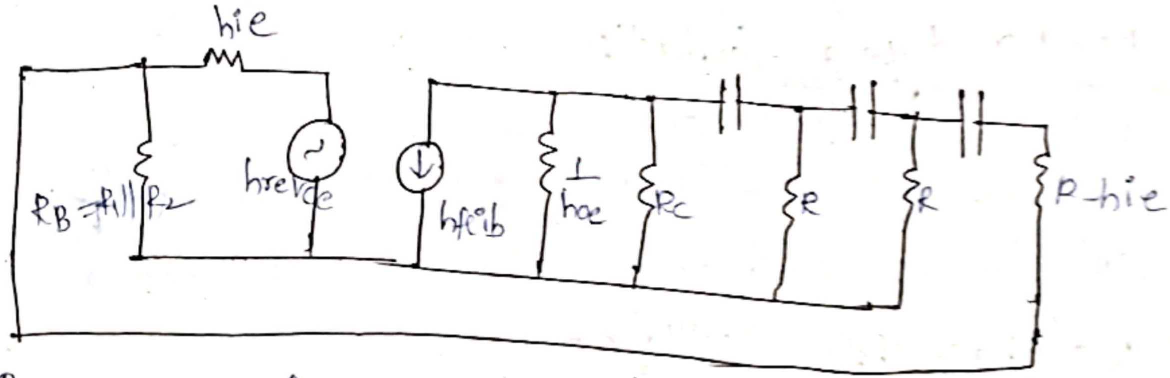
In feedback n/w we can choose the suitable values of R & C to get the phase shift as 60°

i.e, $\theta = \tan^{-1}\left[\frac{X_C}{R}\right]$ where X_C is reactance of Capacitor

$X_C = \frac{1}{2\pi f C}$, R-resistance

Expression for frequency of Oscillations:

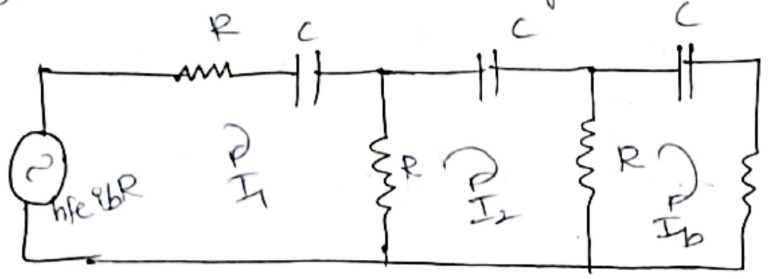
The equivalent circuit of Rc phase shift oscillator is below.



By making following assumptions we can simplify the above equivalent circuit.

Make $R_C = R$, Neglect biasing resistors (R_1, R_2)

Replace current source voltage source



By applying kvl to 3 loops we get

loop1 ; $\Rightarrow$ $h_{fe} i_b R + RI_1 + \frac{1}{j\omega C} I_1 + R(I_1 - I_2) = 0.$

$$\left[2R + \frac{1}{j\omega C}\right] I_1 - RI_2 + Rh_{fe} i_b = 0 \longrightarrow ①$$

For loop2:- $(I_2 - I_1) R + \frac{1}{j\omega C} I_2 + (I_2 - I_b) R = 0$

$$-RI_1 + \left(2R + \frac{1}{j\omega C}\right) I_2 - RI_b = 0 \longrightarrow ②$$

For loop3:-

$$(I_b - I_2) R + \frac{1}{j\omega C} I_b + RI_b = 0$$

$$0I_1 - RI_2 + \left(2R + \frac{1}{j\omega C}\right) I_b = 0 \rightarrow ③$$

From eqn ①, ②, ③ the currents I_1, I_2, I_b are non-Vanishing means those does not becomes zero. So the determinants of coefficients of I_1, I_2, I_b must be '0' and

put $\frac{1}{j\omega C} = -jX_c$

The coefficient matrix is

$$\begin{bmatrix} 2R - jX_c & -R & h_{fe}R \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{bmatrix}$$

Then det $\begin{vmatrix} 2R - jX_c & -R & h_{fe}R \\ -R & 2R - jX_c & -R \\ 0 & -R & 2R - jX_c \end{vmatrix} = 0$

$$2R - jX_c\left[(2R - jX_c)^2 - R^2\right] + R\left[-R(2R - jX_c) - 0\right] + h_{fe}R\left[R^2 - 0\right] = 0$$

$$(2R - jX_c)^3 - R^2(2R - jX_c) - R^2(2R - jX_c) + R^3 h_{fe} = 0$$

$$(2R)^3 - 3(2R)^2 jX_c + 3(2R)(jX_c)^2 - (jX_c)^3 - 2R^3 + R^2 jX_c - 2R^3$$
$$+ R^2 jX_c + R^3 h_{fe} = 0$$

$$\Rightarrow 8R^3 - 12R^2 jX_c + 6R\underset{=-1}{j^2}X_c^2 - j^3X_c^3 - 4R^3 + 2R^2 jX_c + R^3 h_{fe} = 0$$

$$\Rightarrow 4R^3 - 10R^2 jX_c - 6RX_c^2 + jX_c^3 + h_{fe}R^3 = 0$$

$$4R^3 - 10R^2 jX_c - 6RX_c^2 + jX_c^3 + R^3 h_{fe} = 0$$

$$(4R^3 - 6RX_c^2 + h_{fe}R^3) + j(X_c^3 - 10R^2X_c) = 0$$

By equating imaginary part to "0".

$$X_c^3 - 10R^2X_c = 0$$

$$X_c^3 = 10R^2X_c$$

$$\boxed{X_c^2 = 10R^2}$$

$$X_c = \sqrt{10}R$$

$$\frac{1}{2\pi fC} = \sqrt{10}R$$

$$f = \frac{1}{2\pi RC\sqrt{10}}$$

By equating real to zero

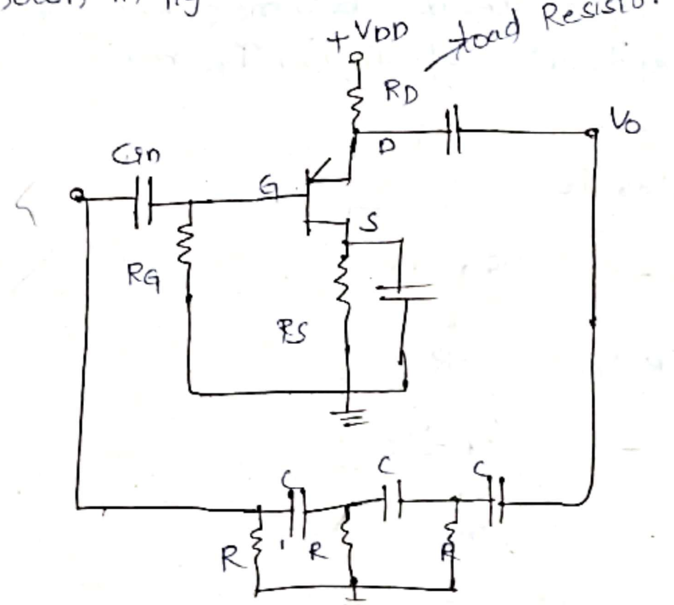
$$4R^3 - 6R(10R^2) + h_{fe}R^3 = 0$$

$$4 - 60 + h_{fe} = \frac{0}{R^3}$$

$$h_{fe} = 56$$

FET RC phase shift Oscillators :-

The practical circuit of FET RC phase shift oscillator is shown in fig.



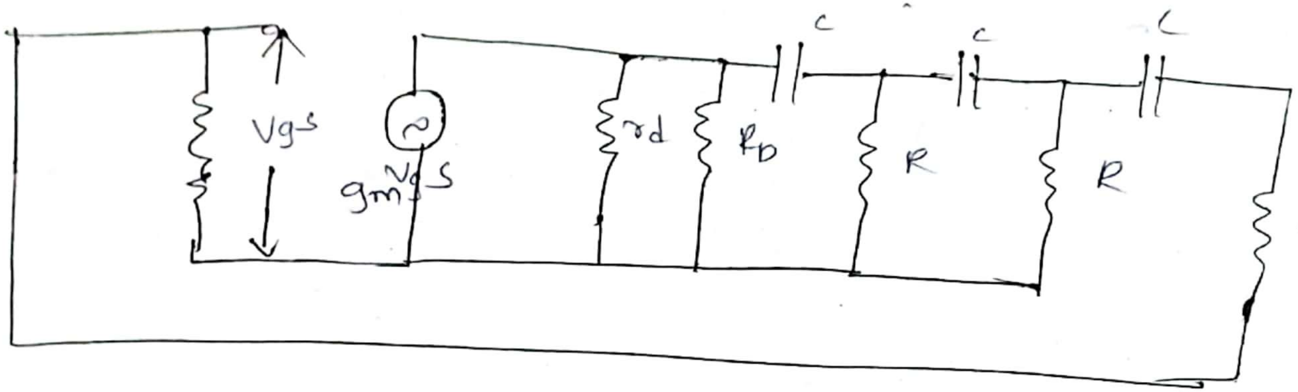
In the above circuit for the amplifier stage FET is used in self bias with capacitor bypassed source resistance Rs and the drain resistance (RD) acts as load resistor. The important parameters of FET are

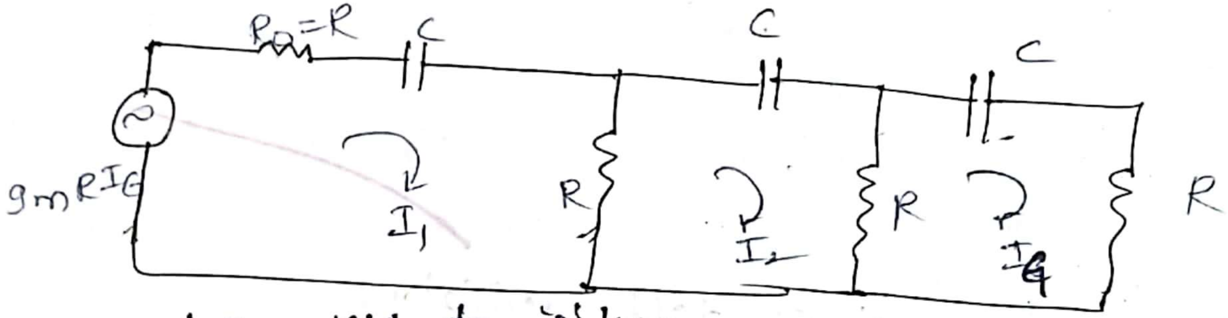
Gm & r_d then the gain of the amplifier is given by

$$\boxed{\hat{A} = g_m R_L}$$

where $R_L = r_d \parallel R_D$ $\quad R_L = \frac{r_d R_D}{r_d + R_D}$

For the derivation of frequency the equivalent circuit





$R_D = R$
r_d is neglected
R_G is "
$f = \frac{1}{2\pi\sqrt{6} RC}$
$|A| \geq 29$

By applying KVL to '3' loops,

Loop 1: $g_m I_q R + R I_1 + \frac{1}{j\omega c} I_1 + R(I_1 - I_2) \Rightarrow$

Advantages of RC phase shift oscillator :-

1) The circuit is simple to design.✓

2) It can produce o/p over audio frequency range.

3) It can produce sinusoidal o/p wave form.

4) It is a fixed frequency oscillator.

Disadvantages :-

1) By changing the values of R & C, the frequency of the oscillator can be changed but the values of R & C of all the 3 sections must be changed simultaneously to satisfy the oscillation conditions.

2) But this is practically impossible. Hence the RC phase shift oscillator is consider as a fixed oscillator for all practical cases.

2) The frequency stability is poor due to changes in the values of various components due to effect of temp. on Ageing, humidity and so on.

Problem For the RC phase shift oscillator, the feedback n/w uses R= 6KΩ & C= 1500pF. The transitorized amplifier uses as a collector resistance of 18KΩ calculate the frequency of oscillations & minimum value of hfe of transistor?

We know that in RC phase shift oscillator,

$$f = \frac{1}{2\pi RC\sqrt{10}}$$

Given that

$$R = 6K\Omega, \quad C = 1500pF, \quad R_C = 18K\Omega$$

$$f = \frac{1}{2\pi RC\sqrt{6+4K}}$$

$$\overline{RC\sqrt{6+4k}}$$

$$k = \frac{R_C}{R}$$

$$K = \frac{R_C}{R} = \frac{18\times10^3}{6\times10^3} = 3$$

$$f = \frac{1}{2\times3.14\times6\times10^3\times1500\times10^{-12}\sqrt{6+4(3)}}$$

$$\boxed{f = 4.17\ KHz}$$

$$h_{fe} = 23+4K+\frac{29}{K} = 4(3)+23+\frac{29}{3} = 44.66$$

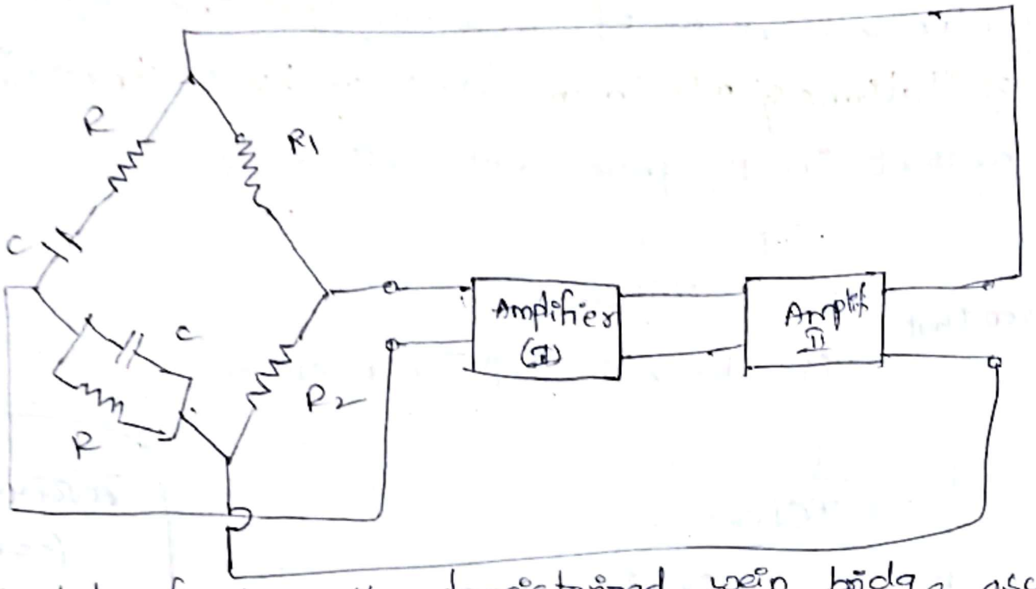
$$\boxed{h_{fe} \geq 45}$$

Wein Bridge Oscillator [Audio frequency].

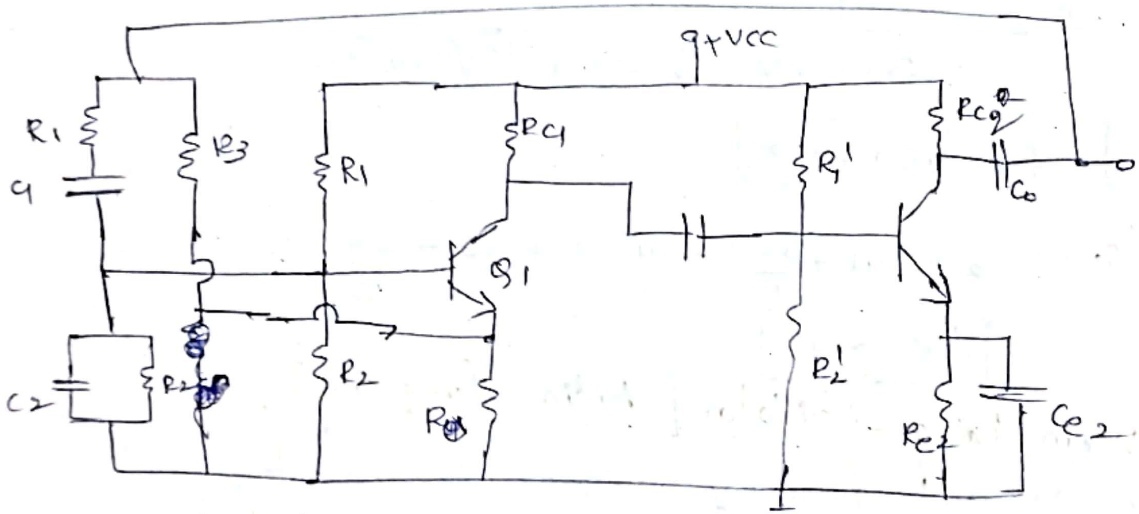
This is audio frequency oscillator. The advantage of this is the frequency may be varied in the range of 10Hz to 1MHz. Hence it is a variable frequency oscillator. Generally in an oscillator amplifier stage introduce 180° of phase shift and feedback n/w introduces another 180° of phase shift, to obtain a phase shift of 360°. But in wein bridge does not produce feedback n/w, i.e; wein bridge does not produce any phase shift. Because of its series and parallel ~~arg~~ RC n/w in the bridge circuit.

Series n/w acts as lead n/w, parallel n/w acts as lag n/w, They both get cancelled. Inorder to produce 0° & 360° phaseshift we use two stage CE amplifier.

The below fig shows the block diagram of wein bridge oscillator.



The below fig. shows the transistorized wein bridge oscillator.



Contined after $X_c^2 = 10R^2$

$$X_c = \sqrt{10}\,R$$

$$\frac{1}{\omega C} = \sqrt{10}\,R$$

$$\frac{1}{2\pi f C} = \sqrt{10}\,R$$

$$\boxed{f = \frac{1}{2\pi RC\sqrt{10}}}$$

If $R_C \neq R$, $f = \frac{1}{2\pi RC\sqrt{6+4K}}$ $\quad \left| K = \frac{R_C}{R} \right.$

By equating real part $=0$

$4R^3 - 6RX_c^2 + h_{fe}R^3 = 0$

$4R^3 - 6R(10R^2) + h_{fe}R^3 = 0$

$4 - 60 + h_{fe} = 0$

$\boxed{h_{fe} = 56}$ indicates to get the sustain values.

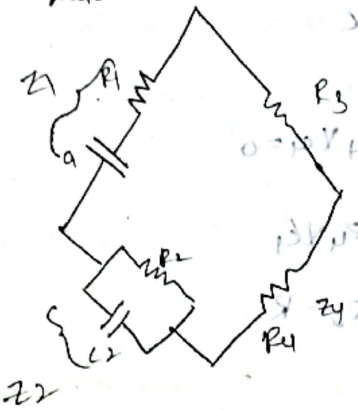
if $R_C = R$, $\boxed{h_{fe} > 4K + 23 + \frac{29}{K}}$ where $K = \frac{R_c}{R}$

Derivation for frequency of oscillation:-

As w.k.t the frequency of oscillations on an oscillator depends on the feedback n/w.

In wienn bridge oscillator the frequency of oscillation depends on based on balancing condition of the bridge.

If the bridge is balanced means the product of opposite arms impedances are equal or the ratio of adjacents arms are equal.



$\frac{Z_1}{Z_2} = \frac{Z_3}{Z_4}$

$\boxed{Z_2Z_3 = Z_1Z_4}$

The impedance of the bridge are given $Z_1 = R_1 + X_{C1}$

$Z_2 = R_2 || X_{C2} = \frac{-jR_2X_{C2}}{R_2 - jX_{C2}}$

$Z_3 = R_3$; $Z_4 = R_4$

$Z_2Z_3 = Z_1Z_4$

$\frac{\frac{1}{j\omega C_2} \times R_2}{R_2 + \frac{1}{j\omega C_2}} = \frac{-jR_2X_{C2}}{R_2 - jX_{C2}}$

$\frac{-jR_2X_{C2}}{R_2 - jX_{C2}} \times R_3 = (R_1 - jX_{C1})R_4$

$(R_2 - jX_{C2}) - jX_{C2}R_2R_3 = (R_1 - jX_{C1})R_4$

$(R_2 - jX_{C2})R_2R_3 = (R_1 - jX_{C1})(R_2 - jX_{C2})R_4$

$-jR_2X_{C2} \times R_2R_3 - jR_3X_{C2} = R_1 - jX_{C1}\ (R_2R_4 - jR_4X_{C2})$

$(-jR_2X_{C2} - jR_3X_{C2})R_2R_3 = R_1R_2R_4 - jR_2R_4X_{C2} - jX_{C1}R_2R_4 - X_{C1}X_{C2}R_4)$

$$-jR_2^2R_3X_{C2} - jR_3^2R_2X_{C2} = R_1R_2R_4 - jR_1R_4X_{C2} - jX_{C1}R_2R_4$$
$$- X_{C1}X_{C2}R_4$$

By equating Real part $=0$

$$R_1R_2R_4 - X_{C1}X_{C2}R_4 = 0$$

$$R_1R_2 = X_{C1}X_{C2}$$

$$R_1R_2 = \frac{1}{\omega C_1 \times \omega C_2}$$

$$R_1R_2C_1C_2 = \frac{1}{\omega^2}$$

$$\frac{1}{\omega} = \sqrt{R_1R_2C_1C_2}$$

$$\frac{1}{2\pi f} = \sqrt{R_1R_2C_1C_2}$$

$$\frac{1}{f} = 2\pi\sqrt{R_1R_2C_1C_2} \qquad R_1R_2 = R,\ C_1 = C_2 = C$$

$$f = \frac{1}{2\pi\sqrt{R_1R_2C_1C_2}}$$

$$f = \frac{1}{2\pi\sqrt{R^2C^2}} = \frac{1}{2\pi RC}$$

By making; Img $=0$

$$R_2R_3X_{C2} - R_1R_4X_{C2} - R_2R_4X_{C1} = 0$$

$$\cancel{X}_{C2}(R_2R_3 - R_1R_4) = R_2R_4\cancel{X}_{C1}$$

if $X_{C1} = X_{C2} = X_C$; $R_1 = R_2 = R$

$$\cancel{R}(R_3 - R_4) = \cancel{R}R_4$$

$$R_3 = 2R_4$$

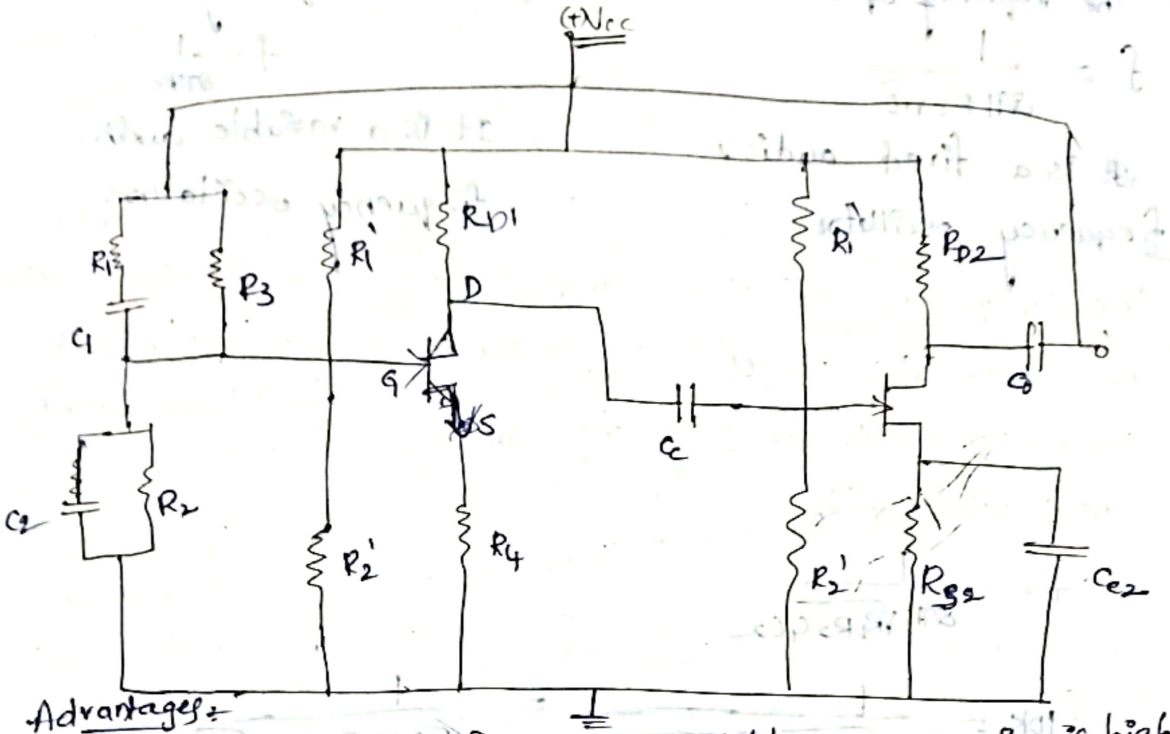
$$\frac{R_3}{R_4} = 2$$

The above eqn indicates the condition for sustained oscillations

Here R_3 & R_4 contools the gain of the amplifier which means

$A = 2$ & $\beta = 1/2$ $[\because |A\beta| = 1]$

FET Wien bridge oscillator:-



Advantages:-

It gives good frequency stability ,overall gain is high because of two transistors ,2) ·overall gain is high because of two transistors, 3) It gives. It gives constant sign wave o/p · frequency of oscillation can be changed. 4) Frequency of oscillations can be changed

Disadvantages:- It requires two transistors and more no. of components circuit becomes complex.

It can't generate radio (or high frequency.

Difference b/n RC phase shift & Wienn bridge

RC phase shift	Wienn bridge
1) It consists single stage CE	1) It consists (double) two stage RC
2) It uses three (3) RC sections arranged in ladder fashion.	2) The fedback n/w consists of bridge circuit with series and parallel RC in two arms and the remaining two arms are resistive.
3) In this the amplifier produces 180 ~~360~~	3) In this the amplifier section produces $\overset{360^\circ}{360}$ ~~180~~ phaseshift
4) In this the fedback n/w produces 180° phase shift	4) The feedback n/w doesnot produce any shift ie (0°).

RC phase shift

5) The frequency of oscillation

$$f = \frac{1}{2\pi R C\sqrt{10}}$$

6) It is a fixed audio frequency oscillator

Wienn bridge

5) The frequency is

$$f = \frac{1}{2\pi RC}$$

6) It is a variable audio-frequency oscillator.

① The frequency sensitive arms of the wienn bridge oscillator uses $C_1 = C_2 = 0.001\mu F$ & $R_1 = 10K\Omega$, R_2 is kept variable. The frequency is to varied from 10KHz to 50KHz. Find min & max value of R_2?

$$f = \frac{1}{2\pi\sqrt{R_1 R_2 C_1 C_2}}$$

$$10K = \frac{1}{2\pi\sqrt{10K \times R_2 \times 0.001 \times 10^{-6}}} = \frac{1}{50329212 \cdot \sqrt{R_2}}$$

$$\sqrt{R_2} = \frac{1}{50329212 \cdot 1 \times 10K}$$

$$\sqrt{R_2} = 5.032 \times 10^{11}$$

R_2

$$10 \times 10^3 = 15911549.43 \frac{1}{\sqrt{R_2}}$$

$$10 \times 10^3 = \frac{15.91 \times 10^6}{\sqrt{R_2}}$$

$$\sqrt{R_2} = \frac{15.91 \times 10^3}{10}$$

$$\sqrt{R_2} = 15.91 \times 10^2$$

3/5/22

LC Oscillators:

Oscillators which use the elements L & C to produce oscillations are called LC oscillators.

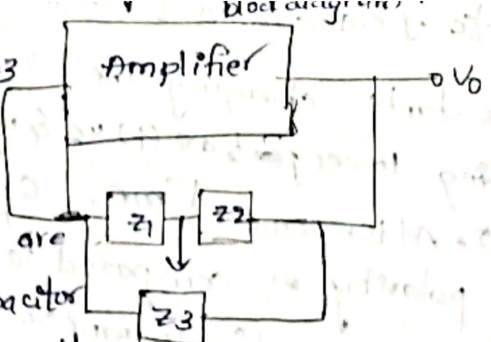
⇒ The circuit using the elements (L & C) are called Tank (or) oscillatory circuit, which is an important part in LC oscillator.

⇒ This circuit is also called Resonating / Tuned Circuit.

⇒ This oscillators are used for very high frequency range from (200KHz to 10GHz).

⇒ Due to this (High) frequency range this oscillators are used in Radio receivers (or) Transmitters circuit.

→ In the fig, z1,z2,z3 are inductor (or) capacitor.



z_1,

→ suppose if z_1, z_2 are Inductors & z_3 is capacitor then it is called heartly oscillator.

→ If z_1, z_2 are capacitors & z_3 (L) Inductor it is called Colpits oscillator.

→ In the above fig. the amplifier provides 180° phase shift and the LC circuit feedback another 180° phase shift. Then overall phase shift around any loop either 0° (or) 360°

Operation of LC Tank circuit :-

consider LC circuit as shown in fig 1, consists of L&C are connected in parallel.

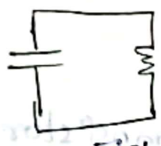


Fig1

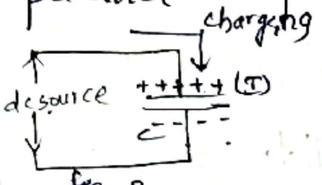


fig-2

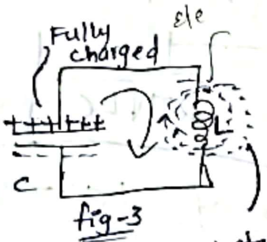


fig-3

It starts charging so Then discharging

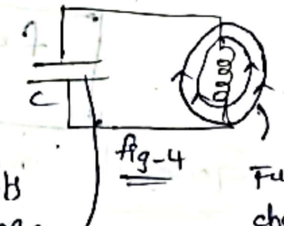


fig-4

Fully charged

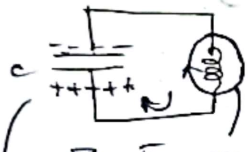


Fig-5 discharged

discharging in reverse polarities

Fig-6 Fully discharged

capacitor fully charged

→ capacitor discharged → Inductor charged (continously with (+)ve & (-)ve charging indicates the produce oscillations)

$$f = \frac{1}{2\pi\sqrt{LC}}$$

Let capacitor is initially charged from DC source with the polarities (±) as shown in fig 2. when the capacitor gets fully charged the energy stored in capacitor is called electro-static energy. when such a charged capacitor is connected across inductor in a Tank circuit, then the capacitor discharges to (L) as shown in fig 3. The arrow indicates the direction of flow of conventional Current. Due to such current flow the magnetic field gets setup around the inductor. Thus, inductor starts storing the energy (i.e) magnetic static energy. Then capacitor is fully discharged. The maximum current flows through the circuit. At that time all the electrostatic energy get stored as a e~~lect~~ magnetic energy in the inductor as shown in fig 4).

Now, the magnetic field around L starts collapsing as per Lenz's law. This starts charging the capacitor with opposite direction making lower plate as (+) ve & upperplate as (-) ve as shown in fig 5. After some time, capacitor is fully charged with opposite polarity as compared to initial polarity as shown in fig 6. Now, entire magnetic energy gets converted back to electrostatic energy.

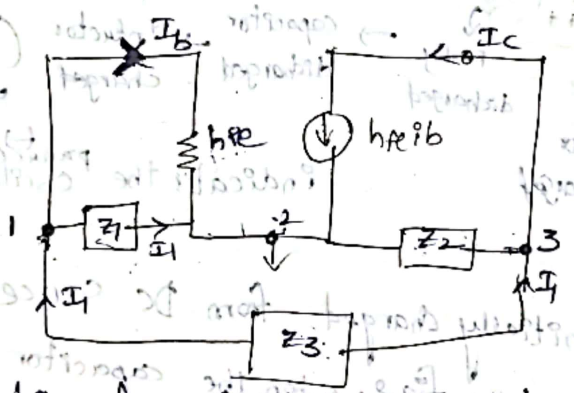
→ The above process repeats by the proper care of polarities is taken in feedback b/w the LC circuit along with amplifier can be used to obtain oscillations called as LC oscillations.

→ The frequency of oscillations generated by LC Tank ckt depends on the values of L & C.

$$\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$$

General form of LC oscillators:-

consider simplified Equivalent circuit of a transistor with LC Tank circuit as a feedback as shown in fig.



→ The load impedance (Z_L) b/n o/p terminals (2 & 3) nodes.

Here Z_1 & hie are in parallel, Its resultant is in series with Z_3 & it is parallel to Z_2.

→ $\frac{1}{Z_1'} = \frac{1}{Z_1} + \frac{1}{hie}$ ⇒ $\boxed{Z_1' = \frac{Z_1 hie}{Z_1 + hie}}$

Then $Z_1' + Z_3$ (series) $= \frac{Z_1 hie}{Z_1 + hie} + Z_3$

$$= \frac{Z_1 hie + Z_3(Z_1 + hie)}{Z_1 + hie}$$

$$Z_1' + Z_3 = \frac{hie(Z_1 + Z_3) + Z_1 Z_3}{Z_1 + hie}$$

equivalent load impedance

$$\frac{1}{z_L} = \frac{1}{z_1'+z_3} + \frac{1}{z_2}$$

$$\frac{1}{z_L} = \frac{(z_1'+z_3)(z_2)}{z_2+z_1'+z_3}$$

$$\frac{1}{z_L} = \frac{1}{\frac{hie(z_1+z_3)+z_1z_3}{z_1+hie}} + \frac{1}{z_2}$$

$$\frac{1}{z_L} = \frac{(z_1+hie)}{hie(z_1+z_3)+z_1z_3} + \frac{1}{z_2}$$

$$z_2(hie(z_1+z_3))$$

$$z_1z_2 + z_2 hie + hie z_3 + hie z_1$$

$$\frac{1}{z_L} = \frac{(z_2(z_1+hie) + hie(z_1+z_3) + z_1z_3))}{z_2[hie(z_1+z_3) + z_1z_3]}$$

$$\boxed{z_L = \frac{z_2[hie(z_1+z_3)+z_1z_3]}{hie(z_1+z_2+z_3)+z_1z_2+z_1z_3}}$$

⇒ voltage gain (A_V) : $A_V = \frac{-hfe R_L}{hie} = \frac{-hfe z_L}{hie}$

$$z_2 hie + z_1z_2 + z_2z_3$$

$$A_V = \frac{-hfe z_L}{hie}$$

$\therefore \beta = \frac{V_f}{V_0}$

o/p voltage b/n 2 & 3 terminals is given by

$$V_0 = (z_1' + z_3) I_1$$

$$V_0 = \left[\frac{z_1(hie)}{z_1+hie} + z_3\right] I_1$$

$$V_0 = \left[\frac{z_1(hie) + z_3(z_1+hie)}{z_1+hie}\right] I_1$$

$$V_0 = \left[\frac{hie(z_1+z_3)+z_1z_3}{(z_1+hie)}\right] I_1$$

The feedback voltage b/n i/p terminals 1 & 2. is

$$V_f = z_1' I_1$$

$$V_f = \frac{z_1 hfe}{(z_1+hre)} I_1 - \frac{z_1 hre}{(z_1+hre)} I_1$$

$$\beta = -\frac{V_f}{V_0}$$

$$\beta = -\frac{\frac{1}{\left(\frac{h_{ie}(z_1+z_3)+z_1z_3}{\cancel{(z_1+h_{ie})}}\right)} \cancel{I_1}}{\left(\frac{z_1 h_{ie}}{\cancel{z_1+h_{ie}}}\right)\cancel{I_1}}$$

$$\beta = \frac{1}{-\left[\frac{h_{ie}(z_1+z_3)+z_1z_3}{(z_1 h_{ie})}\right]} = \frac{-z_1 h_{ie}}{h_{ie}(z_1+z_3)+z_1z_3}$$

$$A\beta = -1$$

$$\therefore \quad A_v\beta = -1$$

$$\frac{-h_{fe}z_1}{h_{ie}} = \frac{\left[\frac{-h_{fe}z_2\left[\cancel{h_{ie}(z_1+z_3)+z_1z_3}\right]}{h_{ie}(z_1+z_2+z_3)+z_1z_2+z_1z_3} \times \frac{-z_1 \cancel{h_{ie}}}{\cancel{h_{ie}(z_1+z_3)+z_1z_3}}\right]}{h_{ie}}$$

$$\Rightarrow$$

$$\frac{h_{fe}z_1z_2}{h_{ie}(z_1+z_2+z_3)+z_1z_2+z_1z_3} = -1$$

$$h_{fe}z_1z_2 = -\left[h_{ie}(z_1+z_2+z_3)+z_1z_2+z_1z_3\right]$$

$$h_{fe}z_1z_2 + h_{ie}(z_1+z_2+z_3)+z_1z_2+z_1z_3 = 0$$

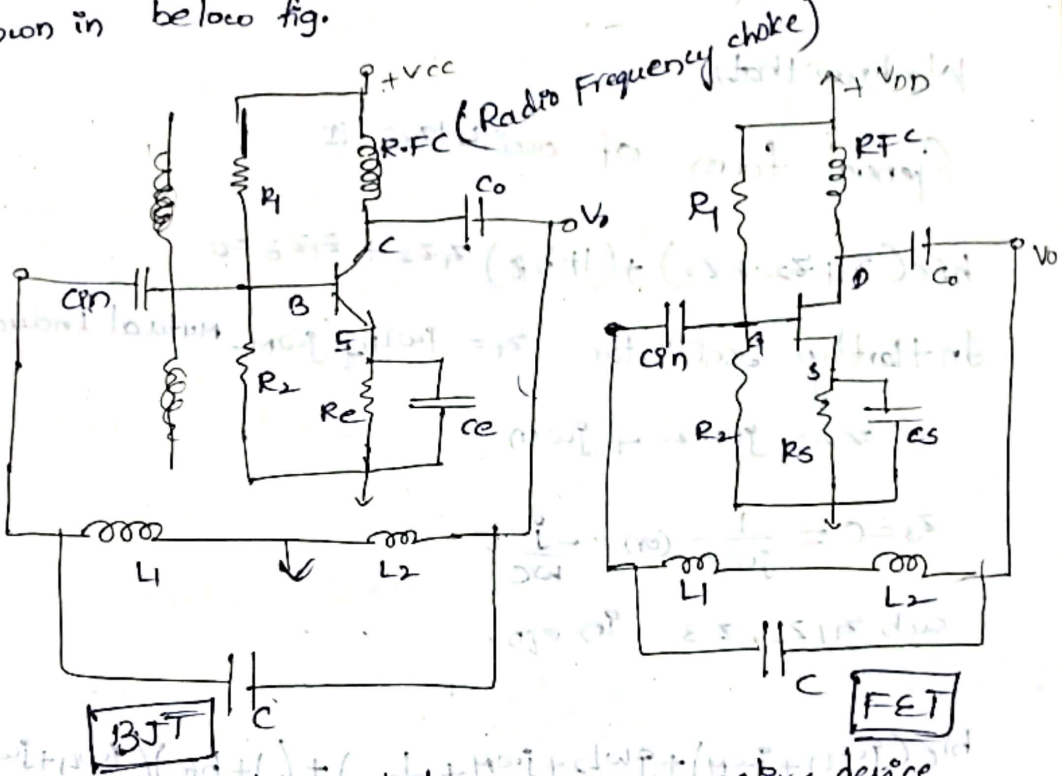
$$\boxed{z_1z_2(1+h_{fe})+z_1z_3+h_{ie}(z_1+z_2+z_3)=0}$$

For Hartly, $z_1 = j\omega L_1$, $z_2 = j\omega L_2$; $z_3 = \frac{1}{j\omega C}$

For colpott, $z_1 = \frac{1}{j\omega C_1}$, $z_2 = \frac{1}{j\omega C_2}$, $z_3 = j\omega L$

The above eqn is general form of an LC oscillator that deriving frequency of oscillations & condition for sustained oscillations.

Hartly Oscillator:- It is an Example of LC oscillator, which consists of two Inductors & one capacitor as feedback as shown in below fig.



In fig1, the amplifier stage uses an active device called BJT in CE configuration with voltage divider bias.

→ Here R1, R2 are biasing resistors, the RFC is the Radio frequency choke, its reactance value is very high for high frequencies. Hence it can withstand at Large voltages (or) currents.

→ It also provides isolation b/w AC & DC operation.

→ Re-resistor provides stabilization and Cin, Co are coupling capacitors.

→ The feedback n/w consists of L1 & L2 and one capacitor C which are arrange in the form of Tank ckt.

→ The CE amplifier provides a phase shift of 180° as the Emitter is Ground, the Base & Collector voltages are out of phase by 180°.

→ As the centre of L1 & L2 are grounded, then upper end becomes (+)ve & lower end becomes (−)ve & vice-versa

→ So LC feedback n/w gives an additional phase shift of 180°

necessary to satisfy oscillation conditions.

Derivation for frequency of oscillations:-

We know that,

General form of oscillations is

$$h_{ie}(Z_1+Z_2+Z_3)+(1+h_{fe})Z_1Z_2+Z_1Z_3=0$$

In Hartly oscillator $Z_1 = j\omega L_1 + j\omega M$ — Mutual Inductance

$$Z_2 = j\omega L_2 + j\omega M$$

$$Z_3 = C = \frac{1}{j\omega C} \text{ (or) } -\frac{j}{\omega C}$$

sub Z_1, Z_2, Z_3 in eqn.

$$h_{ie}(j\omega L_1 + j\omega M) + j\omega L_2 + j\omega M + \frac{1}{j\omega C}) + (1+h_{fe})(j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M)$$

$$+(j\omega L_1 + j\omega M)\left(\frac{1}{j\omega C}\right) = 0$$

$$= h_{ie}\left(j\omega(L_1+L_2) + 2j\omega M + \frac{1}{j\omega C}\right) + (1+h_{fe})\left(j^2\omega^2 L_1L_2 + j^2\omega^2 L_1 M + j^2\omega^2 M L_2 + j^2\omega^2 M^2\right)$$

$$+ j\omega(L_1+M)\left(\frac{1}{j\omega C}\right) = 0$$

$$= h_{ie}^{j\omega}\left[L_1+L_2+2M - \frac{1}{\omega^2 C}\right] + (1+h_{fe})(-\omega^2)\left[L_1L_2 + L_1M + ML_2 + M^2\right]$$

$$+ (L_1+M)\left(\frac{1}{C}\right) = 0$$

Equate imaginary to zero

$$\omega\, h_{ie}\left[L_1+L_2+2M - \frac{1}{\omega^2 C}\right] = 0$$

$$\omega\left(L_1+L_2+2M - \frac{1}{\omega^2 C}\right) = 0$$

$$\frac{1}{\omega^2 C} = L_1+L_2+2M$$

$$\frac{1}{\omega^2} = L_{eq}C$$

Two Inductors are in series

$$= \frac{1}{\omega} = \sqrt{L_{eq} C}$$

$$\frac{1}{2\pi f} = \sqrt{L_{eq} C}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{L_{eq} C}}}$$ where $L_{eq} = L_1 + L_2 + 2M$

Equating real part to zero.

$$(-\omega^2)(1+hfe)\left[(L_1+M)(L_2+M)\right] + \frac{L_1+M}{C} = 0$$

$$-\omega^2 (L_1+M)\left[(1+hfe)(L_2+M) - \frac{1}{\omega^2 C}\right] = 0$$

$$(1+hfe)(L_2+M) - \frac{1}{\omega^2 C} = 0$$

$$(1+hfe)' = \frac{1}{\omega^2 C (L_2+M)}$$

$$\frac{1}{\omega^2 C} = L_1 + L_2 + M$$

$$\therefore (1+hfe) = \frac{L_1+L_2+2M}{L_2+M}$$

$$(1+hfe) = 1 + \frac{L_1+M}{L_2+M}$$

$$\boxed{hfe = \frac{L_1+M}{L_2+M}}$$ Gives condition for sustained oscillations.

Colpitts oscillators

$Z_1 = \frac{-j}{\omega C_1}$; $Z_2 = \frac{-j}{\omega C_2}$; $Z_3 = j\omega L$

∴ sub Z_1, Z_2, Z_3 in general form of oscillators.

$$hie(Z_1+Z_2+Z_3) + (1+hfe)(Z_1 Z_2) + Z_1 Z_3 = 0$$

$$hie\left(\frac{-j}{\omega C_1} \text{[illegible]} \frac{-j}{\omega C_2} + j\omega L\right) + (1+hfe)\left(\left(\frac{-j}{\omega C_1}\right)\left(\frac{-j}{\omega C_2}\right)\right) + \left(\frac{-j}{\omega C_1}\right)(j\omega L) = 0$$

$$hie\left(\frac{j}{\omega}\right)\left(\frac{-1}{C_1} - \frac{1}{C_2} + \omega^2 L\right) \text{[illegible]} (1+hfe)\left(\frac{+j}{\omega}\right)\left(\frac{1}{C_1}\right)\left(\frac{1}{C_2}\right) - \frac{j}{\omega C_1}(j\omega L) = 0$$

$$hie\left(\frac{j}{\omega}\right)\left(\frac{-1}{C_1} - \frac{1}{C_2} + \omega^2 L\right) \text{[illegible]} (1+hfe)\left(\frac{+j}{\omega}\right)\left(\frac{1}{C_1}\right)(1/C_2) + \frac{L}{C_1} = 0$$

$$\frac{j\,hie}{\omega}\left[\frac{-1}{C_1} - \frac{1}{C_2} + \omega^2 L\right] \text{[illegible]} \frac{\text{[illegible]}}{\omega^2}\left\{(1+hfe)\left(\frac{1}{C_1}\right)(1/C_2)\right] + \frac{L}{C_1} = 0$$

Equating imaginary to zero

$$\frac{\varphi}{\omega}\left[\frac{hie}{\omega}\left(\frac{1}{C_1}-\frac{1}{C_2}+\omega^2 L\right)\right]+(1+hfe)\left(\frac{1}{C_1}\right)\left(\frac{1}{C_2}\right)\Bigg]=0$$

~~$hie\left(\frac{1}{C_1}-\frac{1}{C_2}+\omega^2 L\right)-(1+hfe)\left(\frac{1}{C_1}\right)\left(\frac{1}{C_2}\right)=0$~~

$$-hie\left(\omega\frac{1}{C_1}+\frac{1}{\omega C_2}-\omega L\right)=0$$

$$\frac{1}{\omega C_1}+\frac{1}{\omega C_2}=\omega L$$

$$\omega=\frac{1}{L}\left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}\right) \quad \Bigg| \; L=\frac{1}{\omega^2}\left[\frac{1}{C_1}+\frac{1}{C_2}\right]$$

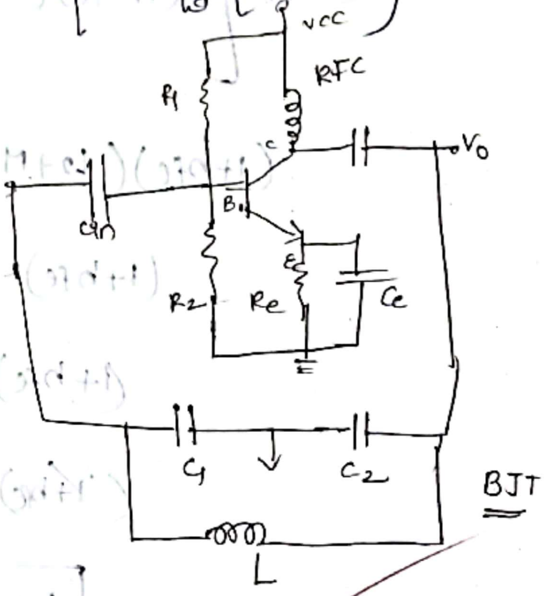
$$\therefore \underset{\omega}{2\pi f}=\frac{1}{L}\left(\frac{1}{\omega C_1}+\frac{1}{\omega C_2}\right)$$

$$\omega^2=\frac{1}{LC_1}+\frac{1}{LC_2}$$

$$\omega=\sqrt{\frac{1}{LC_1}+\frac{1}{LC_2}}$$

$$2\pi f=\sqrt{\frac{1}{LC_1}+\frac{1}{LC_2}}$$

$$\boxed{f=\frac{1}{2\pi}\sqrt{\frac{1}{LC_1}+\frac{1}{LC_2}}}$$



Equating real part to zero.

$$-\frac{(1+hfe)}{\omega^2}\left(\frac{1}{C_1}\right)\left(\frac{1}{C_2}\right)+\frac{L}{C_1}=0$$

$$\frac{1}{C_1}\left[L-\frac{(1+hfe)}{\omega}\left(\frac{1}{C_2}\right)\right]=0$$

$$L=(1+hfe)\left(\frac{1}{C_2}\right)$$

$$-\frac{1}{\omega^2}\left(\frac{1}{C_1C_2}\right)-\frac{hfe}{\omega^2(C_1C_2)}+\frac{L}{C_1}=0$$

$$\frac{hfe}{\omega^2 C_1C_2}=\frac{1}{\omega C_1}\left(\omega L-\frac{1}{\omega C_2}\right)$$

$$hfe=\omega C_2\left(\omega L-\frac{1}{\omega C_2}\right)$$

$$hfe=\omega^2 C_2 L-1$$

$$hfe=\frac{C_1+C_2}{LC_1C_2}\times C_2L-1$$

$$\omega^2=\frac{1}{LC_1}+\frac{1}{LC_2}$$

$$\omega^2=\frac{C_1+C_2}{LC_1C_2}$$

$$\frac{C_1+C_2}{LC_1C_2}\times C_2L$$

$$\frac{C_1+C_2}{C_1}-1$$

$$\frac{C_1+C_2-C_1}{C_1}$$

$$h_{fe} = \frac{C_1+C_2}{\sqrt{C_1C_2}} \times \varepsilon_2 L - 1$$

$$h_{fe} = \frac{C_1+C_2-C_1}{C_1}$$

$$\boxed{h_{fe} = \frac{C_2}{C_1}}$$

Advantages & disadvantages of Hartly (LC)(or) Colpits (or) oscillator:-

→ It generates very high frequencies (200KHz - 2GHz)

→ It produces sinusoidal signal at radio frequency.

→ It has a variable oscillator by varying (C) (or) (L)

Disadvantages:- The circuit becomes costly and H bulky colpits due to Inductors.

→ It provides poor frequency stability.

(**) Diff. b/n RC & LC oscillators:-

RC oscillators (wien (or) bridge)	LC oscillators (Hartley & Colpitts oscillators)
The feedback n/w uses resistor and capacitor	The feedback n/w uses inductor & capacitor.
Frequency of oscillations depends on R & C $f = \frac{1}{2\pi\sqrt{RC}}$	Frequency of oscillations depends on L & C. $f = \frac{1}{2\pi\sqrt{LC}}$
→ It produces audio/low frequency signals.	It produces Radio/very high frequency signals.
→ Load Resistor is RC	Load is RFC (Inductor)

Find the frequency of a transistor hartly oscillator if Mutual inductance (M) = 20μH and $L_1 = 100\mu H$, $L_2 = 1$[illegible]H, $c = 20pF$. Find the freq

$$L_{eq} = L_1 + L_2 + 2M = 100\times10^{-6} + 1\times10^{-3} + 2(20\times10^{-6})$$

$$C = 20\times10^{-12}$$

$$f = \frac{1}{2\pi\sqrt{L_{eq}C}} = \frac{1}{2\pi\sqrt{(100\times10^{-6}+10^{-3}+40\times10^{-6})\,20\times10^{-12}}}$$

$$\boxed{f = 1054.029\ kHz}$$

Find the frequency of transistor colpits oscillators, $C_1 = 0.001\mu F$, $C_2 = 0.01\mu F$, $L = 15\mu H$

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC_1}+\frac{1}{LC_2}} = \frac{1}{2\pi}\sqrt{\frac{1}{15\times10^{-6}\times0.001\times10^{-6}} + \frac{1}{15\times10^{-6}\times0.01\times10^{-6}}}$$

$$\boxed{f = 1363.612\ KHz}$$

In a transistorized hartly oscillator, two inductances are 2mH & 20μH, while frequency is to be varied from 950KHZ 2050KHz Calculate the range over which the capacitor is to be varied?

$M = 0$

$$f = \frac{1}{2\pi\sqrt{L_{eq}C}} \qquad L_{eq} = L_1 + L_2$$

$$L_{eq} = 0.00202$$

$$950KH = \frac{1}{2\pi\sqrt{L_{eq}C_1}}$$

$$\sqrt{L_{eq}C} = \frac{1}{2\pi(950K)} \quad C = \frac{1}{(2\pi(950k))^2 \times 0.00202} = 13.894PF$$

$C_1 =$ ~~0.0091~~ $\quad C_2 =$ ~~0.0062~~

$$2050KHZ = \frac{1}{2\pi\sqrt{L_{eq}C_2}}$$

$$C_2 = \frac{1}{(2\pi)^2 \times L_{eq} \times (2050K\,HZ)^2} = \text{~~0.0062~~} \quad 2.98 \times 10^{-12} F = 2.98pF$$

2.98 pF to 13.8pF

∴ capacitor range is (~~0.0062~~ to ~~0.0091~~)

In a colpitts oscillator $C_1 = 0.001μF$, $C_2 = 0.01μF$, $L = 10μH$, Find the frequency of oscillations, (β), voltage gain (Av)?

$$f = \frac{1}{2\pi}\sqrt{\frac{1}{LC_1} + \frac{1}{LC_2}} = \frac{1}{2\pi}\sqrt{\frac{1}{10\times10^{-6}\times0.001\times10^{-6}} + \frac{1}{10\times10^{-6}\times0.01\times10^{-6}}}$$

$f = 1670.077KHZ$

$$\text{Gain}_{(h_{fe})} = \frac{C_2}{C_1} = 10$$

we know that $A\beta = 1 \Rightarrow \beta = \frac{1}{A} = 0.1$

A FET RC phase shift oscillator has $g_m = 5m℧$, $r_D = 50K\Omega$ Feedback resistance is $(R) = 100K\Omega$ and capacitance value is 64.79pF. Calculate the frequency of oscillations & $R_D = ?$

R_o

$R = 100$

$$f = \frac{1}{2\pi RC\sqrt{10}} = \frac{1}{2\pi \times 64.79\times10^{-12} \times 100\times10^{3}\sqrt{10}} = 7.779KHz$$

$R_D =$

$|A| \geq 29 \quad A = g_m R_L$

$R_L = r_d \parallel R_D$

$g_m R_L > 29 \Rightarrow R_L > \frac{29}{g_m}$

$R_L > 5.8\,k\Omega$

let $R_L = 6k\Omega$

$\therefore$ ~~By~~ $R_L = r_d \parallel R_D$

$$R_L = \frac{r_d \times R_D}{r_d + R_D}$$

$$(r_d + R_D)6k\Omega = r_d \times R_D$$

$$50\times10^3 \times 6\times10^3 + R_D \times 6k\Omega = 50\times10^3 \times R_D$$

$$6\times10^3 R_D = 50\times10^3 \times R_D$$

$$44\times10^3 R_D = 300\times10^6$$

$$R_D = \frac{300\times10^6}{44\times10^3}$$

$$R_D = 6.818\,k\Omega$$

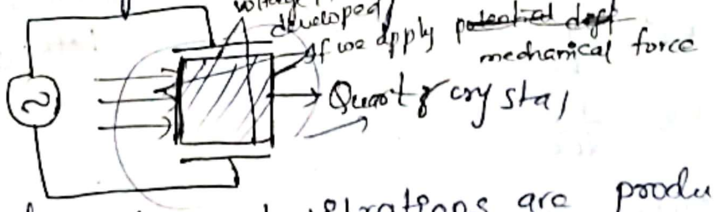
Drawbacks of RC & LC oscillators.

Crystal Oscillators:- Incase of RC & LC oscillators, the frequency of operations doesnot remains strictly constant.

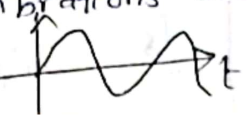
→ The reason behind this is the values of R, C & L which are frequency determining factors. They maybe changed due to so many reasons & they are not able to generate microwave frequencies

→ To overcome the above disadvantages crystal oscillators are used, And its principle depends on $\boxed{\text{piezo electric effect.}}$

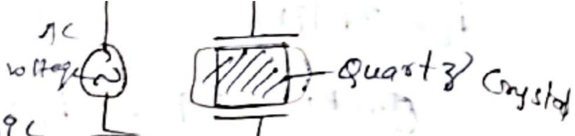
Piezoelectric effect:- It means when a mechanical stress/strain is applied across one faces of the crystal then a potential difference is developed across the opposite faces of the crystal, conversely when a potential difference



is applied mechanical vibrations are produced along the opposite faces, and that vibrations are in the form of oscillations



Working of Quartz crystal:-



Inorder to use crystal in electronic circuit it is placed b/n two metals. This arrangement is equivalent to a capacitor with crystal as a dielectric as Shown in fig. above.

⇒ When an AC voltage is applied crystal starts vibrating with the frequency of applied voltage. If frequency of applied voltage is equal to natural frequency of a crystal, resonance takes place, and crystal starts vibrating with maximum amplitude.

⇒ The electrical equivalent of a crystal is shown in fig. b when the crystal is not vibrating it is equivalent to capacitance Cm & When a crystal starts vibrating, it can be represented by a series RLC circuit, shunted (parallel) to Cm.

→ In this L is electrically equivalent to mass of the vibrating crystal.

→ C is equivalent to mechanical compliance and R is electrically equivalent to mechanical friction.

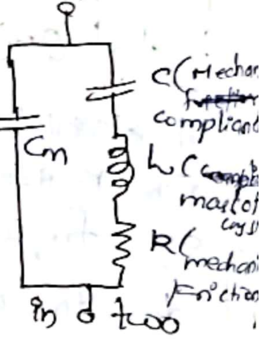


fig b

The above electrical equivalent crystal operates in two frequencies resonance conditions.

1) Series Resonance frequency:-

Under this the reactance of Inductance (X_L) is equivalent to reactance of capacitance (X_C) in series RLC circuit

$$X_L = X_C$$

$$\omega_s L = \frac{1}{\omega_s C}$$

$$\omega_s^2 = \frac{1}{LC}$$

$$\omega_s = \frac{1}{\sqrt{LC}}$$

$$2\pi f_s = \frac{1}{\sqrt{Lc}}$$

$$\boxed{f_s = \frac{1}{2\pi\sqrt{LC}}}$$ Series resonance frequency.

} Working of Resonance write both ① & ②

(2) parallel Resonance frequency:- Under this frequency the total reactance of series RLC circuit is equal to Reactance of (Cm) mounting capacitance i.e) $\omega_p L - \frac{1}{\omega_p C} = \frac{1}{\omega_p C_m}$

$$\frac{\omega_p^2 LC - 1}{C} = \frac{1}{C_m}$$

$$\omega_p^2 L - \frac{1}{C} = \frac{1}{C_m}$$

$$\omega_p^2 L = \frac{1}{C_m} + \frac{1}{C}$$

$$\omega_p^2 = \frac{1}{L}\left[\frac{1}{C_m} + \frac{1}{C}\right]$$

$\frac{1}{C_m} + \frac{1}{C}\}$
= parallel
$C_{eq} = \frac{CC_m}{C+C_m}$

$$\omega_p^2 = \frac{1}{L}\left(\frac{1}{C_{eq}}\right)$$

$$\omega_p = \frac{1}{\sqrt{LC_{eq}}}$$

$$2\pi f_p = \frac{1}{\sqrt{LC_{eq}}}$$

$$\boxed{f_p = \frac{1}{2\pi\sqrt{LC_{eq}}}}$$

The below fig. shows the transistorized Crystal Oscillator with voltage divider bias:-

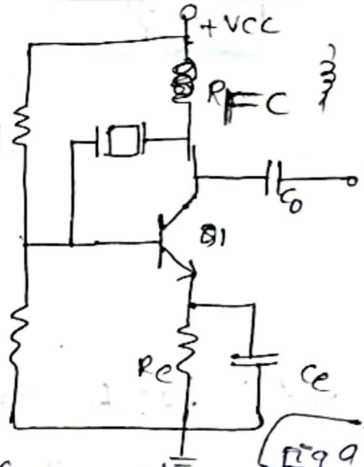
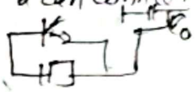


Fig a

⇒ This transistorized crystal oscillator is suggested by "pierce".

⇒ In fig a, NPN transistor in CE configuration with voltage divider bias is used.

⇒ Here R1 & R2 provides biasing, ReCe provides stabilization, RFC provides very high reactance path for Radio frequency signals, Co acts as output coupling capacitor to block DC voltages and the crystal is connected in b/n collector to Base so it acts as feedback (or u can connect as



) and it operates in series resonance frequency because it is connected in a series element in feedback path from Collector to Base.

The frequency of oscillations is given by $\boxed{f = \frac{1}{2\pi\sqrt{LC}}}$

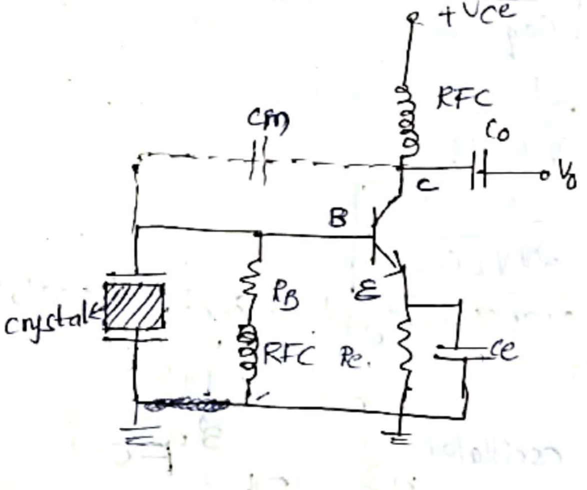
Advantages:-

- ⇒ As frequency of crystal is independent of temperature.
- ⇒ This oscillators have higher order frequency (GHz) stability.
- ⇒ It is a fixed oscillator for generating microwave frequencies
- ⇒ Quality factor of crystal is very high.

Disadvantages:-

- ⇒ we cannot vary the oscillator because it is fixed.
- ⇒ frequency of oscillations cannot be changed.
- ⇒ It ~~leasis~~ cost circuit

Miller Crystal Oscillator:-



Crystal is connected in parallel to RFC. So it is called parallel resonance.

A crystal has L = 0.4 Henry, C = 0.0805 PF, Cm = 1 PF with series Resistance (Rs) = 5kΩ, calculate series resonant frequency (f_s) (f_p) parallel Resonant Frequency, Quality factor (Q) and by what percent that the parallel resonant frequency exceeds the series resonant frequency.

1) $$f_s = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.055\times10^{-12}\times0.4}} = \cancel{4.683\,PHz}$$

863.576 KHz

$$f_p = \frac{1}{2\pi\sqrt{C_{eq}\cdot L}} = \frac{1}{2\pi\sqrt{\frac{C\,C_m}{C+C_m}\times0.4}} = 899.530\ KHz$$

3) $Q = \frac{\omega_s L}{R}$ (or) $\frac{2\pi f_s L}{R} = \frac{2\pi \times 863.576K \times 0.4}{5 \times 10^3} = 433.880$

$= \frac{1}{\omega_s CR}$ (or)

4) $\% \text{ change} = \frac{f_p - f_s}{f_p} \times 100 = \frac{0.899 \times 10^6 - 0.863 \times 10^6}{0.899 \times 10^6} \times 100 = 4.004$

$= 4\%$

✗✗✗✗

10M Frequency stability of oscillators:-

The ability of the circuit (oscillator) provides const. frequency over a period of time is called frequency stability.

(or)

⇒ The ability of an oscillator to maintain the required frequency constant over a long time interval possible

→ In transistor oscillators, the frequency of oscillations doesnot remains stable during long time because circuit parameters on which the oscillator frequency depends doesnot remains constant in time.

→ The frequency stability is affected due to following factors

1) change in temperature:- The values of the components of feedback networks get affected. so changes in the values of R, L and C due to change in temp. is the main cause to which frequency doesnot remains stable.

2) Due to change in temp, the parameters of the active devices such as BJT (or) FET get affected, which changes frequency of oscillations.

3) Due to change in power supply:- It affects the frequency.

4) Due to changes in atmospheric conditions, aging, unstable transistor parameters:- It affects the frequency.

5) Due to changes in load connection:- It affects the effective Resistance of the feedback network.

6) Due to changes in capacitive effect in transistor at high frequencies such as stray capacitance (or) junction capacitances. It effects the capacitance of fedback circuit.

Based on change in temperature, frequency stability is defined as

$$S_{\omega \cdot T} = \frac{\Delta\omega/\omega}{\Delta T/T}$$ parts per million per °c.

$\Delta\omega$ is change in frequency. ($\omega = 2\pi f$)

ω is desired frequency

ΔT is change in temperature

T is operating temperature.

→ freq-stability

$S_\omega = \frac{d\theta}{d\omega}$ where $d\theta$ is change in phase shift (or) phase shift introduced by small change in frequency and $d\omega$ is change in frequency.

frequency stability

⇒ The frequency stability can be improved by the following Precauti

1) Enclosing the circuit in a constant temperature chamber.

2) Maintain constant power supply (supply voltage) by using Zener diode.

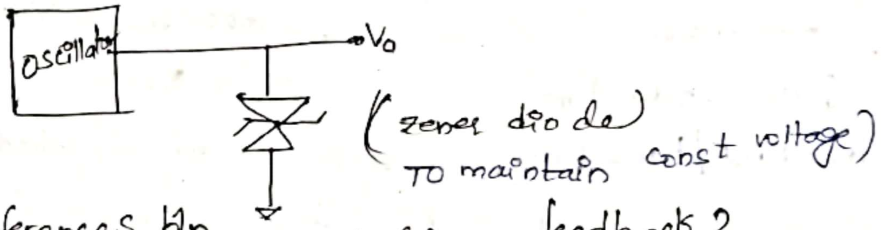
3) Load Effect is reduced, by loosely connected to load. (or) with the help of a circuit having high i/p impedance & low output impedance.

Amplitude stability: It is defined as the ability of the oscillator to maintain constant amplitude over a long tim interval as possible.

→ The oscillator o/p amplitude if not limited/constant means which attains the extreme levels of saturation and it causes the destortion in output waveform due to either clipping of some portion/part of the wave form (or) it may drive amplifier into saturation.

→ TO overcome above problem we can use circuit called "amplitude limiting circuit" two back to back zener diodes at the o/p of oscillator as shown in fig.

→ This circuit makes the oscillations as a constant if the amplitude increases the behind limit..



Assign Write the differences b/n (+)ve & (−)ve feedback?

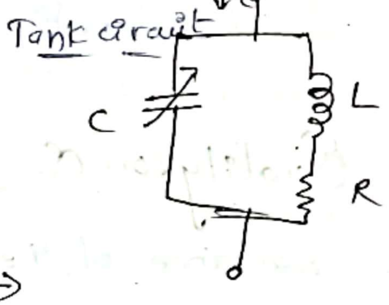
Diff b/n normal Tuned amplifier (search)

Tuned Amplifiers:- To amplify the selective range of frequencies the resistive load (Rc) is replaced by a tuned circuit (or tank circuit). The tuned circuit is capable of amplifying a signal over a narrow band of frequencies centered at resonance frequency.

→ The amplifier with such a tuned circuit as a load are known as "tuned amplifiers".

Below fig. shows the tuned parallel LC circuit which resonates at a particular frequency called as resonance frequency. $\boxed{f_r = \frac{1}{2\pi\sqrt{LC}}}$ and impedance of tank circuit is

$\boxed{Z_r = \frac{L}{CR}}$.



At resonance frequency

frequency response of tuned circuit is shown in fig1:-

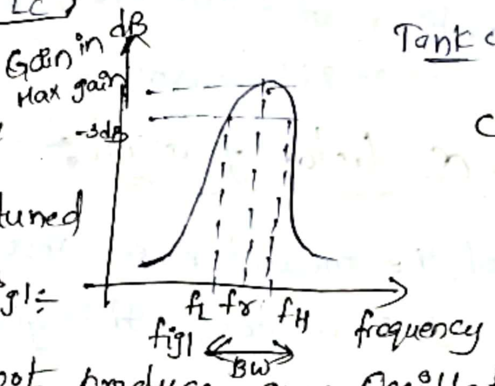


fig1

Q Why tuned circuit doesnot produce any Oscillations?

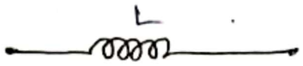
{ when the applied signal frequency and tuned circuit frequency becomes, then reactance of inductance & reactance of capacitor cancelled, so circuit acts as pure resistive n/w, so no oscillations.

→ The frequency response of tuned circuit is shown in fig1-

→ It is observed that max. gain is at Resonant frequency shortly below and above the resonant frequency (fr)

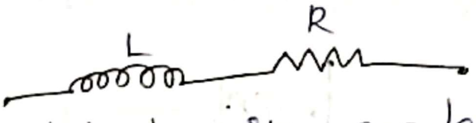
→ At resonance the inductive and capacitive effect of tuned circuit cancelled each other as a result the tank circuit is acts like a resistive n/w, and it is able to amplify the i/p signal without oscillations.

Coil Losses:- (Inductor losses)



Pure Inductor

⟺



Inductor with series leakage resistor

In a tank/tuned circuit consists of coil/Inductor, practically coil is not a purely inductive. It consists of few losses and they are represented in the form of leakage resistance in series with the inductor.

→ The losses in the coil are:- copper, Eddy current, Hysteresis losses

copper losses (CL) → It appears at low frequencies and the coil is equivalent to DC resistance. This losses are inversely proportional to frequency. $CL \propto \frac{1}{f}$

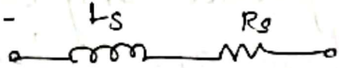
Eddy current losses:- These are due to current flowing within the coil. As a result of eddy current, a current is loss due to heating the coil. This losses are ∝ (directlly pro) to frequency (ELf)

Hysteresis losses:- It is proportional to area enclosed by the hysteresis loop and ~~to~~ the rate at which the loop is transferse

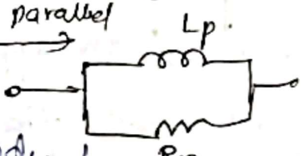
→ It is a function of signal level, and increases with frequency and howeves it is independent of frequency.

Quality (or) Q- factor of a coil:- It is defined as the ratio of reactance of the inductor at resonant frequency to its resistance. It is unitless. It is given by $Q = \frac{\omega L_s}{R_s}$ or $\frac{R_p}{\underset{2\pi f}{\omega} L_p}$

$Q = \frac{\omega L_s}{R_s}$ series →



| $Q = \frac{R_p}{\omega L_p}$ parallel →



→ It is the measure of how much pure inductor, ie) Inductor contains only reactance.

→ The higher the Q-value of Inductor, few/less losses are there in inductor.

→ It is also defined as the measure of efficiency with which inductor can store the energy. } (Q-factor)

Classification of Tuned amplifiers

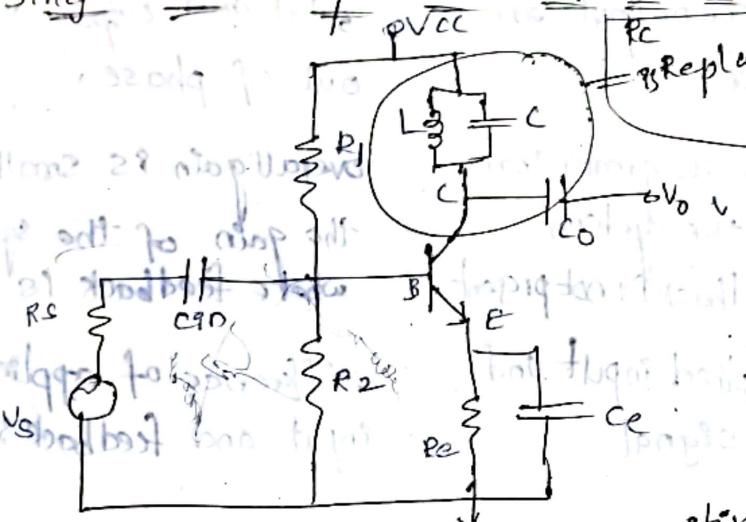
① Based on No. of turning Stages

- a) single Tuned Amplifier
- b) Double Tuned Amplifier
- c) stagger tunned / synchronous

② Based on Couplingelement

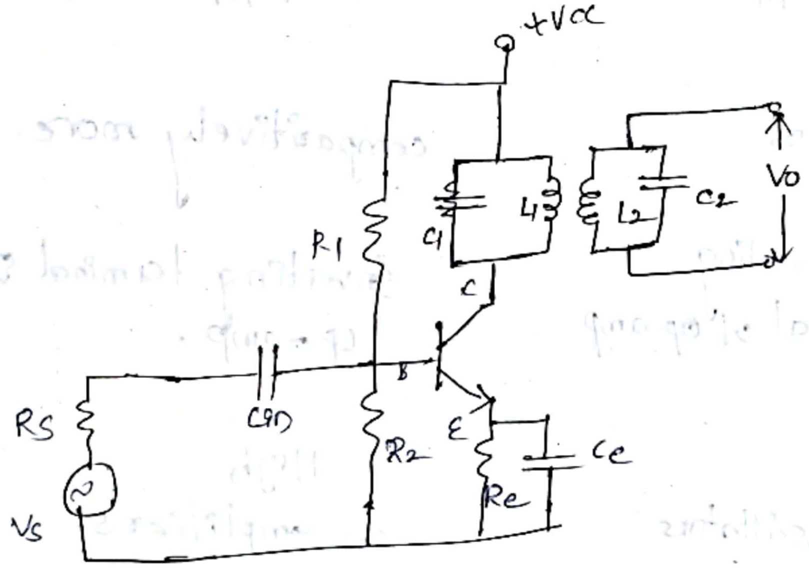
- a) capacitive coupled tuned amp.
- b) Inductive coupled tuned amplifier
- c) Transformer Coupled tuned amplifier

Ex of single Tuned capacitive Amplifier:-



Rc Replaced with tank (ie Tuned circuit) in CE amplifier.

Example of Double Tuned capacitive Amplifier.



Basis for comparision	Positive Feedback	Negative feedback
	It is also called as regenerative feedbacks	It is also called as degenerative feedbacks.
Relation b/n i/p & o/p.	Input and output are in phase	Input and output are out of phase.
Overallgain	overall gain is greater than the gain of the system where feedback is not present	overallgain is smaller than the gain of the system where feedback is absent
Effective input	Sum of applied input and feedback signal	Difference of applied input and feedback signal.
Transfer function of system with respective feedbacks	$\frac{G}{1-GH}$	$\frac{G}{1+GH}$
stability	Less	comparitively more.
phaseshift		
feedback is taken from	Non-inverting terminal of op-amp	Inverting terminal of op-amp.
Sensitivity	Low	High
Use	In oscillators	In amplifiers
	In increases the gain of the amplifier	It decreases the gain of the amplifier.
	It is regenerative or direct feedback	It is degenerative or inverse feedback.
	It makes the amplifier unstable	It makes the amplifier stable
	It reduces the bandwidth	It increases the bandwidth
	It is used in the Oscillators	It is used in the small signal amplifiers.

Rajeev Gandhi Memorial College of Engineering & Technology

Autonomous
NANDYAL-518501

Department of Electronics & Communication Engineering

Academic Year: 2022-23

Subject: Electronic Circuits-Analysis & Design (ECA&D)

Class: II B. Tech, II Sem

The following topics are covered beyond the syllabus as prescribed by RGM-R20 regulations:

1. Discrete- Circuit Amplifiers
2. Some useful transistor pairing in multistage amplifiers.
3. Effect of feedback on amplifier poles.
4. Amplifiers with Multiple Tuned Circuits

7.5 Discrete-Circuit Amplifiers

With our study of transistor amplifier basics complete, we now put everything together by presenting practical circuits for discrete-circuit amplifiers. These circuits, which utilize the amplifier configurations studied in Section 7.3 and the biasing methods of Section 7.4, can be assembled using off-the-shelf discrete transistors, resistors, and capacitors. Though practical and carefully selected to illustrate some important points, the circuits presented in this section should be regarded as examples of discrete-circuit transistor amplifiers. Indeed, there is a great variety of such circuits, a number of which are explored in the end-of-chapter problems.

As mentioned earlier, the vast majority of discrete-circuit amplifiers utilize BJTs. This is reflected in this section where all the circuits presented except for one utilize BJTs. Of course, if desired, one can utilize MOSFETs in the same amplifier configurations presented here. Also, the MOSFET is the device of choice in the design of integrated-circuit (IC) amplifiers. We begin our study of IC amplifiers in Chapter 8.

As will be seen shortly, the circuits presented in this section utilize large capacitors (in the μF range) to couple the signal source to the input of the amplifier, and to couple the amplifier output signal to a load resistance or to the input of another amplifier stage. As well, a large capacitor is employed to establish a signal ground at the desired terminal of the transistor (e.g., at the emitter of a CE amplifier). The use of capacitors for these purposes simplifies the design considerably: Since capacitors block dc, one is able to first carry out the dc bias design and then connect the signal source and load to the amplifier without disturbing the dc design. There amplifiers are therefore known as **capacitively coupled amplifiers.**

7.5.1 A Common-Source (CS) Amplifier

As mentioned in Section 7.3, the common-source (CS) configuration is the most widely used of all MOSFET amplifier circuits. A common-source amplifier realized using the bias circuit of Fig. 7.48(c) is shown in Fig. 7.55(a). Observe that to establish a **signal ground**, or an **ac ground** as it is sometimes called, at the source, we have connected a large capacitor, C_S, between the source and ground. This capacitor, usually in the microfarad range, is required to provide a very small impedance (ideally, zero impedance—i.e., in effect, a short circuit) at all signal frequencies of interest. In this way, the signal current passes through C_S to ground and thus *bypasses* the resistance R_S; hence, C_S is called a **bypass capacitor**. Obviously, the lower the signal frequency, the less effective the bypass capacitor becomes. This issue will be studied in Section 10.1. For our purposes here we shall assume that C_S is acting as a perfect short circuit and thus is establishing a zero signal voltage at the MOSFET source.

To prevent disturbances to the dc bias current and voltages, the signal to be amplified, shown as voltage source v_{sig} with an internal resistance R_{sig}, is connected to the gate through a large capacitor C_{C1}. Capacitor C_{C1}, known as a **coupling capacitor**, is required to act as a perfect short circuit at all signal frequencies of interest while blocking dc. Here again, we note that as the signal frequency is lowered, the impedance of C_{C1} (i.e., $1/j\omega C_{C1}$) will increase and its effectiveness as a coupling capacitor will be correspondingly reduced. This problem, too, will be considered in Section 10.1 in connection with the dependence of the amplifier

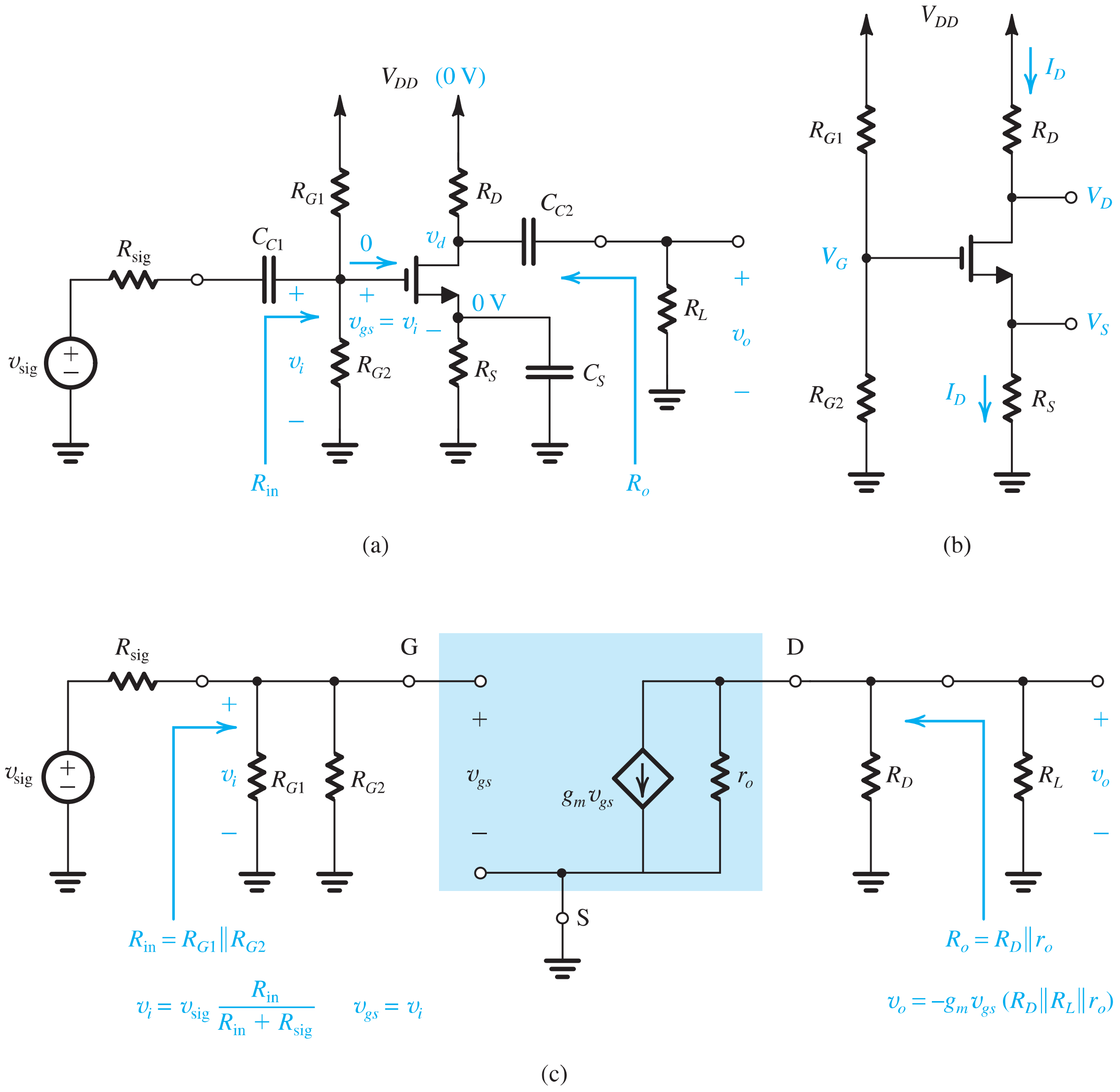


Figure 7.55 (**a**) A common-source amplifier using the classical biasing arrangement of Fig. 7.48(c). (**b**) Circuit for determining the bias point. (**c**) Equivalent circuit and analysis.

operation on frequency. For our purposes here we shall assume that C_{C1} is acting as a perfect short circuit as far as the signal is concerned.

The voltage signal resulting at the drain is coupled to the load resistance R_L via another coupling capacitor C_{C2}. We shall assume that C_{C2} acts as a perfect short circuit at all signal frequencies of interest and thus that the output voltage $v_o = v_d$. Note that R_L can be either an actual load resistor, to which the amplifier is required to provide its output voltage signal, or it can be the input resistance of another amplifier stage in cases where more than one stage of amplification is needed. (We will study multistage amplifiers in Chapter 9).

Since a capacitor behaves as an open circuit at dc, the circuit for performing the dc bias design and analysis is obtained by open-circuiting all capacitors. The resulting circuit is shown in Fig. 7.55(b) and can be designed as discussed in Section 7.4.1.

To determine the terminal characteristics of the CS amplifier of Fig. 7.55(a)—that is, its input resistance, voltage gain, and output resistance—we replace the MOSFET with its hybrid-π small-signal model, replace V_{DD} with a signal ground, and replace all coupling and bypass capacitors with short circuits. The result is the circuit in Fig. 7.55(c). Analysis is straightforward and is shown on the figure, thus

$$R_{\text{in}} = R_{G1} \parallel R_{G2} \tag{7.149}$$

which shows that to keep R_{in} high, large values should be used for R_{G1} and R_{G2}, usually in the megohm range. The overall voltage gain G_v is

$$G_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} g_m (R_D \parallel R_L \parallel r_o) \tag{7.150}$$

Observe that we have taken r_o into account, simply because it is easy to do so. Its effect, however, is usually small (this is not the case for IC amplifiers, as will be explained in Chapter 8). Finally, to encourage the reader to do the small-signal analysis directly on the original circuit diagram, with the MOSFET model used implicitly, we show some of the analysis on the circuit of Fig. 7.55(a).

EXERCISES

D7.37 Design the bias circuit in Fig.7.55(b) for the CS amplifier of Fig. 7.55(a). Assume the MOSFET is specified to have $V_t = 1$ V, $k_n = 4$ mA/V^2, and $V_A = 100$ V. Neglecting the Early effect, design for $I_D = 0.5$ mA, $V_S = 3.5$ V, and $V_D = 6$ V using a power-supply $V_{DD} = 15$ V. Specify the values of R_S and R_D. If a current of 2 µA is used in the voltage divider, specify the values of R_{G1} and R_{G2}. Give the values of the MOSFET parameters g_m and r_o at the bias point.
Ans. $R_S = 7$ kΩ; $R_D = 18$ kΩ; $R_{G1} = 5$ MΩ; $R_{G2} = 2.5$ MΩ; $g_m = 2$ mA/V; $r_o = 200$ kΩ

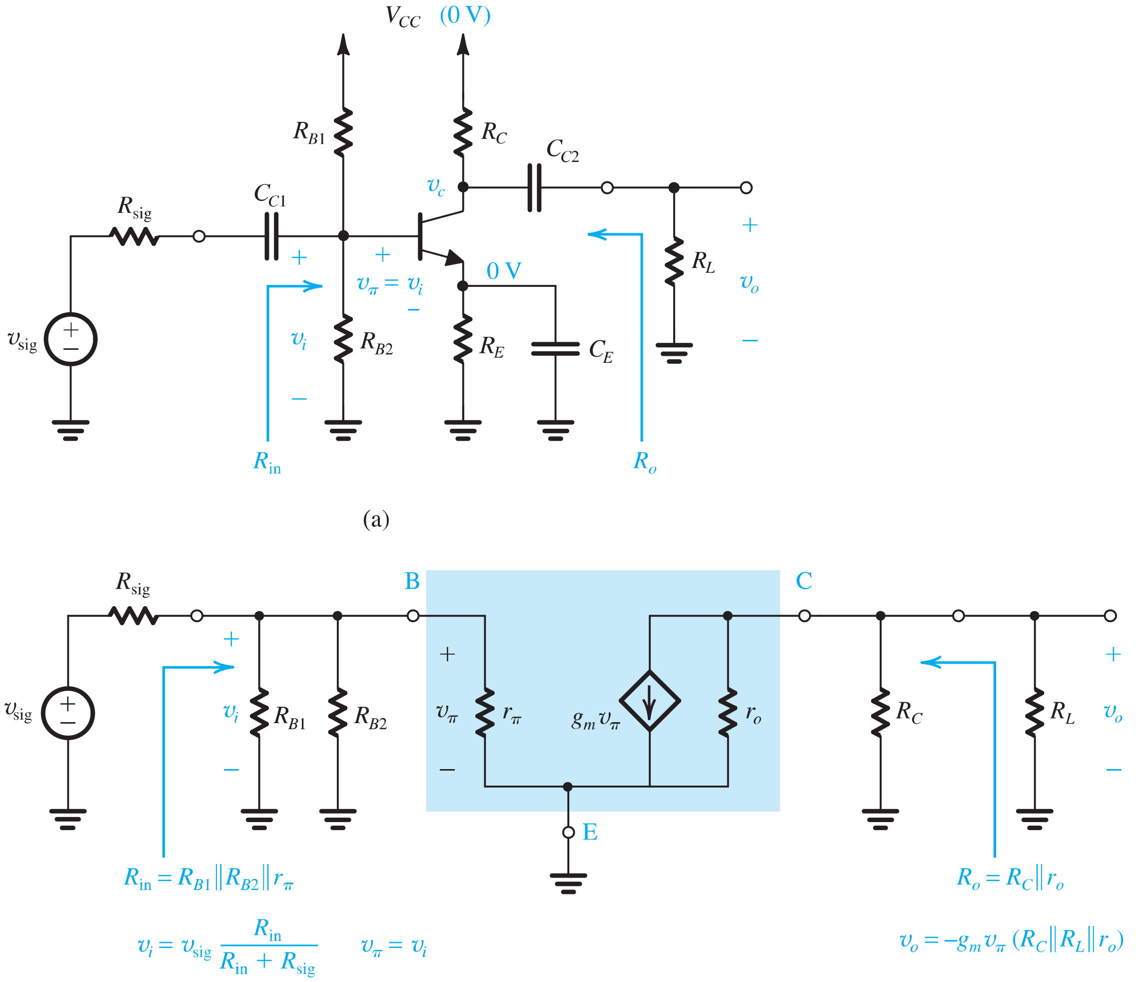
7.38 For the CS amplifier of Fig. 7.55(a) use the design obtained in Exercise 7.37 to determine R_{in}, R_o, and the overall voltage gain G_v when $R_{\text{sig}} = 100$ kΩ and $R_L = 20$ kΩ.
Ans. 1.67 MΩ; 16.5 kΩ; −17.1 V/V

D7.39 As discussed in Section 7.3, beneficial effects can be realized by having an unbypassed resistance R_s in the source lead of the CS amplifier. This can be implemented in the circuit of Fig. 7.55(a) by splitting the resistance R_S into two resistances: R_s, which is left unbypassed, and $(R_S - R_s)$, across which the bypass capacitor C_S is connected. Now, if in order to improve linearity of the amplifier in Exercises 7.37 and 7.38, v_{gs} is to be reduced to half its value, what value should R_s have? What would the amplifier gain G_v become? Recall that when R_s is included it becomes difficult to include r_o in the analysis, so neglect it.
Ans. $R_s = 500$ Ω; $G_v = -8.9$ V/V

7.5.2 A Common-Emitter Amplifier

The common-emitter (CE) amplifier is the most widely used of all BJT amplifier configurations. Figure 7.56(a) shows a CE amplifier utilizing the classical biasing arrangement of Fig. 7.48(c), the design of which was considered in Section 7.4. The CE circuit in Fig. 7.54(a) is the BJT counterpart of the CS amplifier of Fig. 7.55(a). It utilizes coupling capacitors C_{C1} and C_{C2} and bypass capacitor C_E. Here we assume that these capacitors, while blocking dc, behave as perfect short circuits at all signal frequencies of interest.

To determine the characteristic parameters of the CE amplifier, we replace the BJT with its hybrid-π model, replace V_{CC} with a short circuit to ground, and replace the coupling and bypass capacitor with short circuits. The resulting small-signal equivalent circuit of the CE amplifier is shown in Fig. 7.56(b). The analysis is straightforward and is given in the



(a)

(b)

Figure 7.56 (**a**) A common-emitter amplifier using the classical biasing arrangement of Fig. 7.52(a). (**b**) Equivalent circuit and analysis.

figure, thus

$$R_{\text{in}} = R_{B1} \| R_{B2} \| r_\pi \tag{7.151}$$

which indicates that to keep R_{in} relatively high, R_{B1} and R_{B2} should be selected large (typically in the range of tens or hundreds of kilohms). This requirement conflicts with the need to keep R_{B1} and R_{B2} low so as to minimize the dependence of the dc current I_C on the transistor β. We discussed this design trade-off in Section 7.4.

The voltage gain G_v is given by

$$G_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} g_m (R_C \| R_L \| r_o) \tag{7.152}$$

Note that we have taken r_o into account because it is easy to do so. However, as already mentioned, the effect of this parameter on discrete-circuit amplifier performance is usually small.

EXERCISES

D7.40 Design the bias circuit of the CE amplifier of Fig. 7.56(a) to obtain $I_E = 0.5$ mA and $V_C = +6$ V. Design for a dc voltage at the base of 5 V and a current through R_{B2} of 50 μA. Let $V_{CC} = +15$ V, $\beta = 100$, and $V_{BE} \simeq 0.7$ V. Specify the values of R_{B1}, R_{B2}, R_E, and R_C. Also give the values of the BJT small-signal parameters g_m, r_π, and r_o at the bias point. (For the calculation of r_o, let $V_A = 100$ V.)

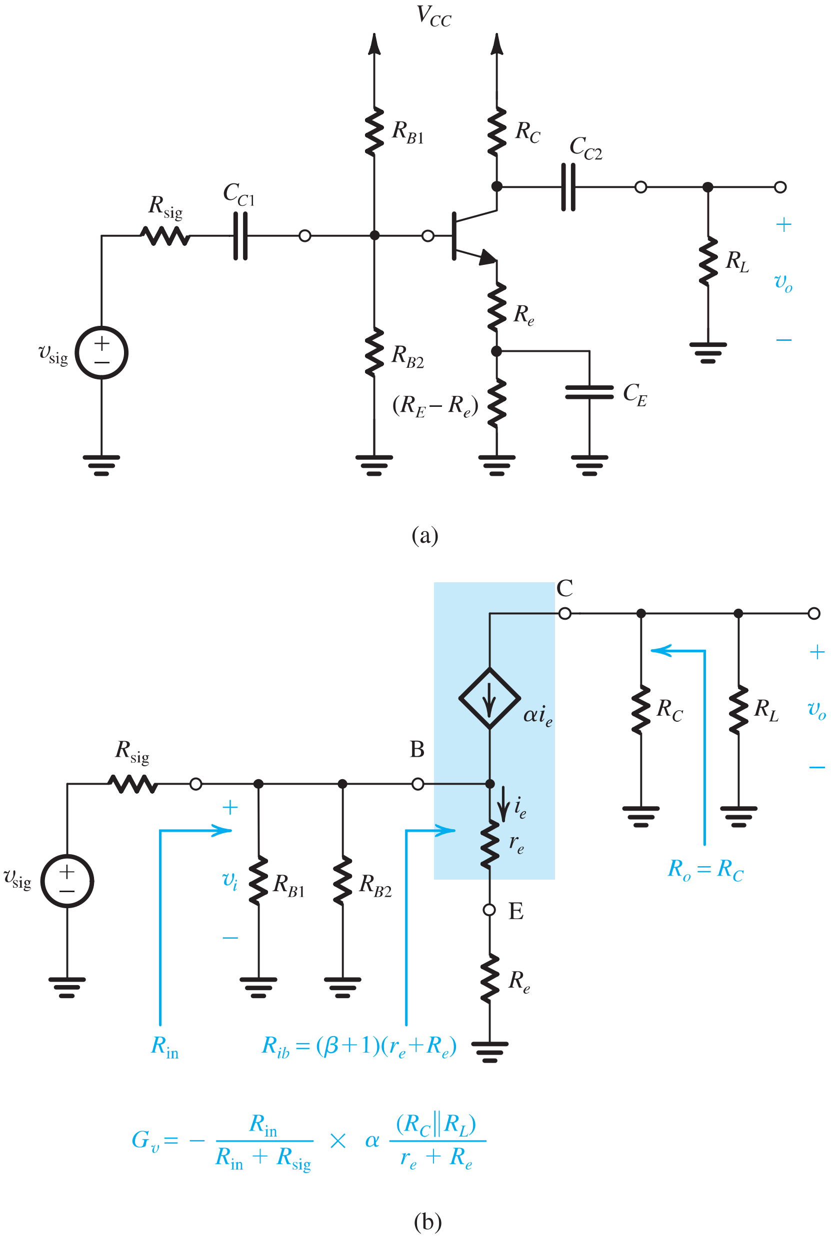
Ans. $R_{B1} = 182\text{ k}\Omega$; $R_{B2} = 100\text{ k}\Omega$; $R_E = 8.6\text{ k}\Omega$; $R_C = 18\text{ k}\Omega$; $g_m = 20\text{ mA/V}$, $r_\pi = 5\text{ k}\Omega$, $r_o = 200\text{ k}\Omega$

7.41 For the amplifier designed in Exercise 7.40, find R_{in}, R_o, and G_v when $R_{\text{sig}} = 10\text{ k}\Omega$ and $R_L = 20\text{ k}\Omega$.

Ans. $R_{\text{in}} = 4.64\text{ k}\Omega$; $R_o = 16.51\text{ k}\Omega$; $G_v = -57.3$ V/V

7.5.3 A Common-Emitter Amplifier with an Emitter Resistance R_e

As discussed in Section 7.3.4, it is beneficial to include a small resistance in the transistor emitter lead. This can be implemented in the circuit of Fig. 7.56(a) by splitting the emitter bias resistance R_E into two components: an unbypassed resistance R_e, and a resistance $(R_E - R_e)$ across which the bypass capacitor C_E is connected. The resulting circuit is shown in Fig. 7.57(a) and its small-signal model is shown in Fig. 7.57(b). In the latter we utilize the T model of the BJT because it results in much simpler analysis (recall that this is always the case when a resistance is connected in series with the emitter). Also note that we have not included r_o, for doing so would complicate the analysis significantly. This burden would not be justified given that r_o has little effect on the performance of discrete-circuit amplifiers.



$$G_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \times \alpha \frac{(R_C \| R_L)}{r_e + R_e}$$

Figure 7.57 (**a**) A common-emitter amplifier with an unbiased emitter resistance R_e. (**b**) The amplifier small-signal model and analysis.

Analysis of the circuit in Fig. 7.57(b) is straightforward and is shown in the figure. Thus,

$$\begin{aligned} R_{\text{in}} &= R_{B1} \| R_{B2} \| (\beta + 1)(r_e + R_e) \\ &= R_{B1} \| R_{B2} \| [r_\pi + (\beta + 1)R_e] \end{aligned} \tag{7.153}$$

from which we note that including R_e increases R_{in} because it increases the input resistance looking into the base by adding a component $(\beta + 1)R_e$ to r_π. The overall voltage gain G_v is

$$G_v = -\frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \times \alpha \frac{\text{Total resistance in collector}}{\text{Total resistance in emitter}}$$

$$= -\alpha \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \frac{R_C \parallel R_L}{r_e + R_e} \tag{7.154}$$

EXERCISE

7.42 For the amplifier designed in Exercise 7.40 and analyzed in Exercise 7.41, let it be required to raise R_{in} to 10 kΩ. What is the required value of R_e, and what does the overall voltage gain G_v become?
Ans. $R_e = 67.7\ \Omega$; $G_v = -39.8$ V/V

7.5.4 A Common-Base (CB) Amplifier

Figure 7.58(a) shows a CB amplifier designed using the biasing arrangement of Fig. 7.53. Note that the availability of two power supplies, V_{CC} and $-V_{EE}$, enables us to connect the base directly to ground, obviating the need for a large bypass capacitor to establish a signal ground at the base.

The small-signal equivalent circuit of the CB amplifier is shown in Fig 7.58(b). As expected, we have utilized the T model of the BJT and have not included r_o. Including r_o would complicate the analysis significantly without making much difference to the results in the case of discrete-circuit amplifiers. From the circuit in Fig. 7.58(b) we find

$$R_{\text{in}} = r_e \parallel R_E \simeq r_e \simeq 1/g_m$$

which as expected can be very small, causing v_i to be a small fraction of v_{sig},

$$v_i = v_{\text{sig}} \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}}$$

Now,

$$i_e = -\frac{v_i}{r_e}$$

and

$$v_o = -\alpha i_e (R_C \parallel R_L)$$

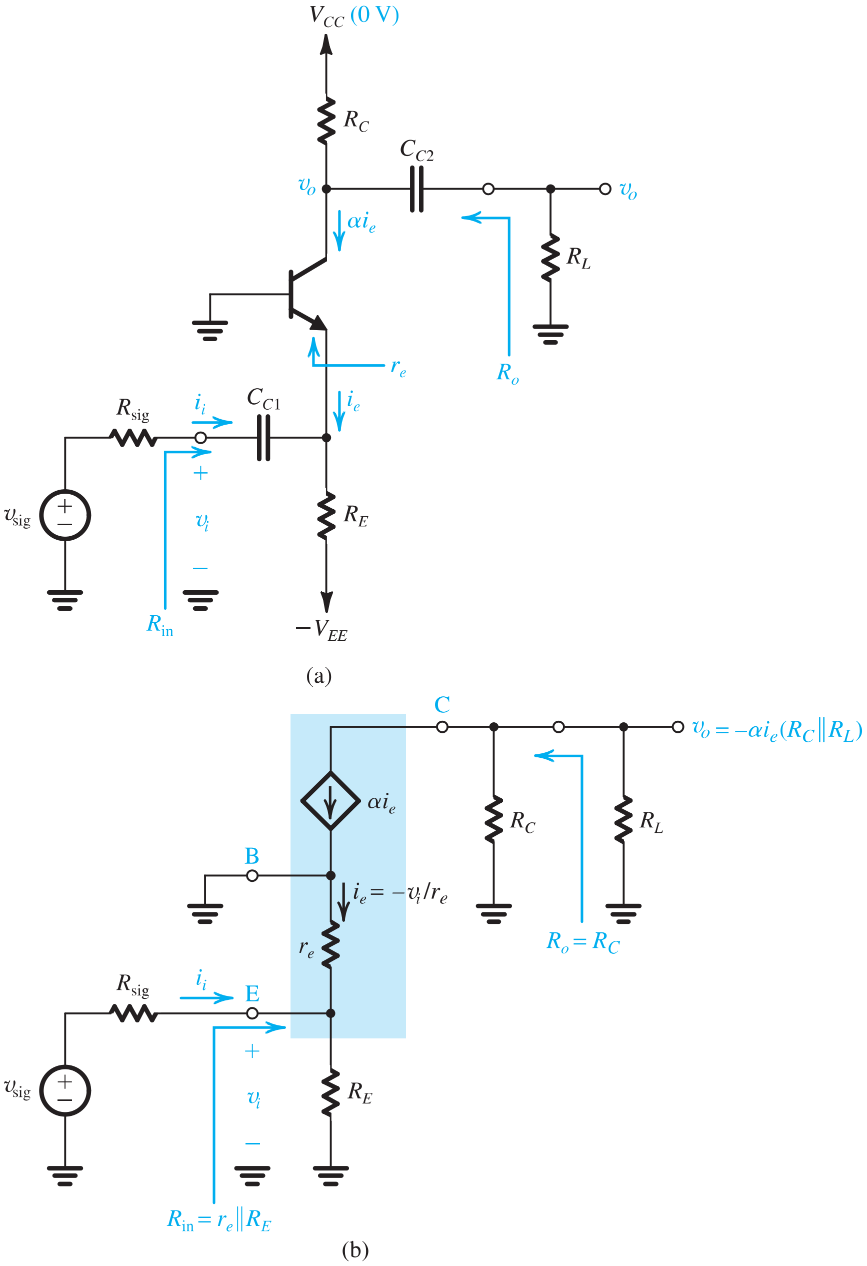


Figure 7.58 (**a**) A common-base amplifier using the structure of Fig. 7.53 with R_B omitted (since the base is grounded). (**b**) Equivalent circuit obtained by replacing the transistor with its T model.

Thus, the overall voltage gain is given by

$$G_v = \alpha \frac{R_{in}}{R_{in} + R_{sig}} \frac{R_C \| R_L}{r_e} = \frac{R_{in}}{R_{in} + R_{sig}} g_m (R_C \| R_L) \tag{7.155}$$

EXERCISE

D7.43 Design the CB amplifier of Fig. 7.58(a) to provide an input resistance R_{in} that matches the source resistance of a cable with a characteristic resistance of 50 Ω. Assume that $R_E \gg r_e$. The available power supplies are ±5 V and $R_L = 8\ \text{k}\Omega$. Design for a dc collector voltage $V_C = +1$ V. Specify the values of R_C and R_E. What overall voltage gain is obtained? If v_{sig} is a sine wave with a peak amplitude of 10 mV, what is the peak amplitude of the output voltage? Let $\alpha \simeq 1$.
Ans. $R_C = 8\ \text{k}\Omega$; $R_E = 8.6\ \text{k}\Omega$; 40 V/V; 0.4 V

7.5.5 An Emitter Follower

Figure 7.59(a) shows an emitter follower designed using the bias arrangement of Fig. 7.53 and two power supplies, V_{CC} and $-V_{EE}$. The bias resistance R_B affects the input resistance of the follower and should be chosen as large as possible while limiting the dc voltage drop across it to a small fraction of V_{EE}; otherwise the dependence of the bias current I_C on β can become unacceptably large.

Figure 7.59(b) shows the small-signal equivalent circuit of the emitter follower. Here, as expected, we have replaced the BJT with its T model and included r_o (since this can be done very simply). The input resistance of the emitter follower can be seen to be

$$R_{\text{in}} = R_B \parallel R_{ib} \tag{7.156}$$

where R_{ib}, the input resistance looking into the base, can be obtained by using the resistance-reflection rule. Toward that end, note that r_o appears in parallel with R_E and R_L (which is why it can be easily taken into account). Thus,

$$R_{ib} = (\beta + 1)[r_e + (R_E \parallel r_o \parallel R_L)] \tag{7.157}$$

The overall voltage gain can be determined by tracking the signal transmission from source to load,

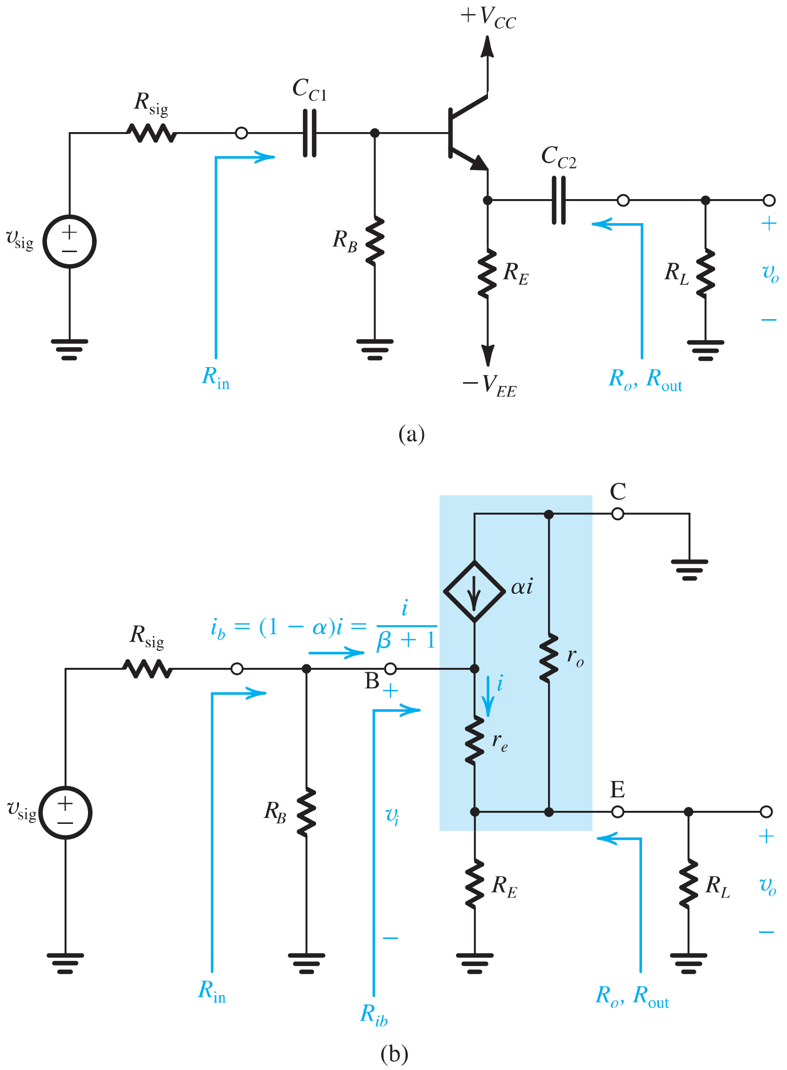
$$v_i = v_{\text{sig}} \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \tag{7.158}$$

and

$$v_o = v_i \frac{R_E \parallel r_o \parallel R_L}{r_e + (R_E \parallel r_o \parallel R_L)} \tag{7.159}$$

Thus,

$$G_v \equiv \frac{v_o}{v_{\text{sig}}} = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}} \frac{(R_E \parallel r_o \parallel R_L)}{r_e + (R_E \parallel r_o \parallel R_L)} \tag{7.160}$$



(a)

(b)

Figure 7.59 (**a**) An emitter-follower circuit. (**b**) Small-signal equivalent circuit of the emitter follower with the transistor replaced by its T model. Note that r_o is included because it is easy to do so. Normally, its effect on performance is small.

Finally, the output resistance R_{out} can be obtained by short-circuiting v_{sig} and looking back into the output terminal, excluding R_L, as

$$R_{out} = r_o \| R_E \| \left[r_e + \frac{R_B \| R_{sig}}{\beta + 1} \right] \tag{7.161}$$

Note that we have used the inverse resistance-reflection rule, namely, dividing the total resistance in the base, $(R_B \| R_{sig})$, by $(\beta + 1)$.

From the above example we observe that using the Widlar circuit allows the generation of a small constant current using relatively small resistors. This is an important advantage that results in considerable savings in chip area. In fact the circuit of Fig. 8.43(a), requiring a 942-kΩ resistance, is totally impractical for implementation in IC form because of the very high value of resistor R_1.

Another important characteristic of the Widlar current source is that its output resistance is high. The increase in the output resistance, above that achieved in the basic current source, is due to the emitter-degeneration resistance R_E. To determine the output resistance of Q_2, we assume that since the base of Q_2 is connected to ground via the small resistance r_e of Q_1, the incremental voltage at the base will be small. Thus we can use the formula in Eq. (8.70) and adapt it for our purposes here as follows:

$$R_{\text{out}} \simeq [1 + g_m(R_E \| r_\pi)]r_o \tag{8.102}$$

Thus the output resistance is increased above r_o by a factor that can be significant.

EXERCISE

8.27 Find the output resistance of each of the two current sources designed in Example 8.6. Let $V_A = 100$ V and $\beta = 100$.
Ans. 10 MΩ; 54 MΩ

8.7 Some Useful Transistor Pairings

A

The cascode configuration studied in Section 8.5 combines CS and CG MOS transistors (CE and CB bipolar transistors) to great advantage. The key to the superior performance of the resulting combination is that the transistor pairing is done in a way that maximizes the advantages and minimizes the shortcomings of each of the two individual configurations. In this section we present a number of other such transistor pairings. In each case the transistor pair can be thought of as a compound device; thus the resulting amplifier may be considered as a single stage.

8.7.1 The CC–CE, CD–CS, and CD–CE Configurations

Figure 8.44(a) shows an amplifier formed by cascading a common-collector (emitter-follower) transistor Q_1 with a common-emitter transistor Q_2. This circuit has two main advantages over the CE amplifier. First, the emitter follower increases the input resistance by a factor equal to $(\beta_1 + 1)$. As a result, the overall voltage gain is increased, especially if the resistance of the signal source is large. Second, it will be shown in Chapter 10 that the CC–CE amplifier can exhibit much wider bandwidth than that obtained with the CE amplifier.

The MOS counterpart of the CC–CE amplifier, namely, the CD–CS configuration, is shown in Fig. 8.44(b). Here, since the CS amplifier alone has an infinite input resistance, the

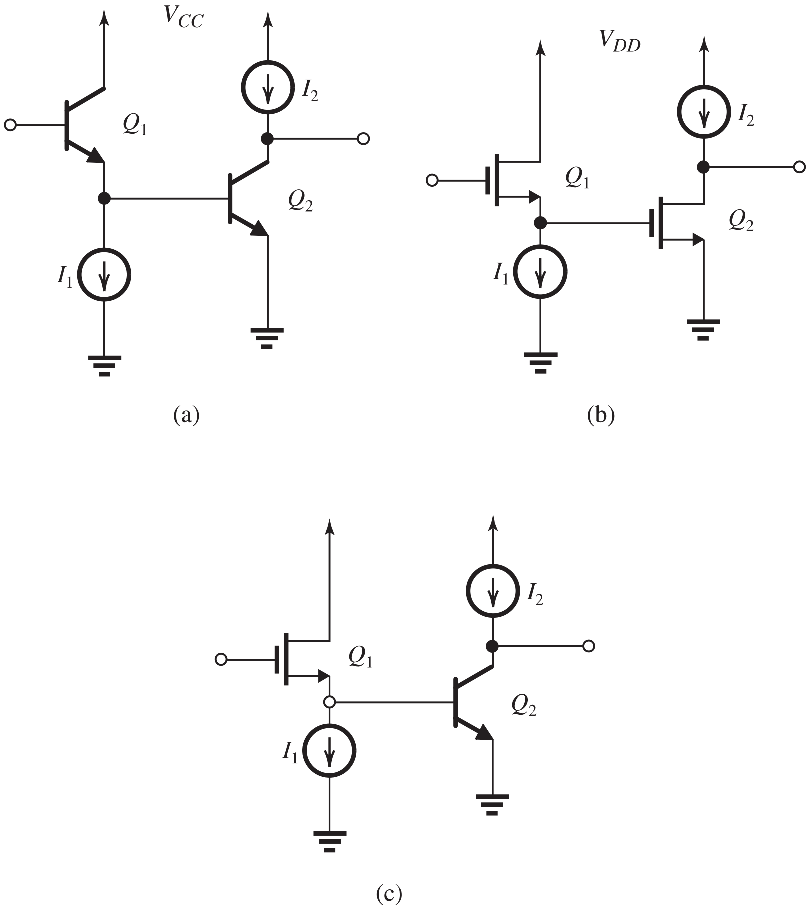


Figure 8.44 (**a**) CC–CE amplifier; (**b**) CD–CS amplifier; (**c**) CD–CE amplifier.

sole purpose for adding the source-follower stage is to increase the amplifier bandwidth, as will be seen in Chapter 10. Finally, Fig. 8.44(c) shows the BiCMOS version of this circuit type. Compared to the bipolar circuit in Fig. 8.44(a), the BiCMOS circuit has an infinite input resistance. Compared to the MOS circuit in Fig. 8.44(b), the BiCMOS circuit typically has a higher g_{m2}.

The IC Source Follower Since a number of the circuit configurations discussed in this section utilize an input source follower, we digress briefly to consider the IC source follower (the discrete-circuit source follower was studied in Section 7.3.6). Figure 8.45(a) shows a source follower formed by transistor Q_1 and biased by a constant-current supplied by the current mirror Q_2–Q_3. Observe that since the source of Q_1 cannot be connected to the body (which is at signal ground potential) a voltage signal v_{bs} develops between body and source and gives rise to a current signal $g_{mb}v_{bs}$, as indicated in the equivalent circuit in Fig. 8.45(b). The equivalent circuit shows also the output resistance r_{o3} of the bias current source Q_3, which acts as a load resistance for the follower Q_1.

An important observation to make from the equivalent circuit is that the controlled source $(g_{mb}v_{bs})$ appears across its control voltage v_{bs}. Thus we can use the source-absorption theorem (Appendix G) to replace the controlled source with a resistance $1/g_{mb}$. Next, note that the three

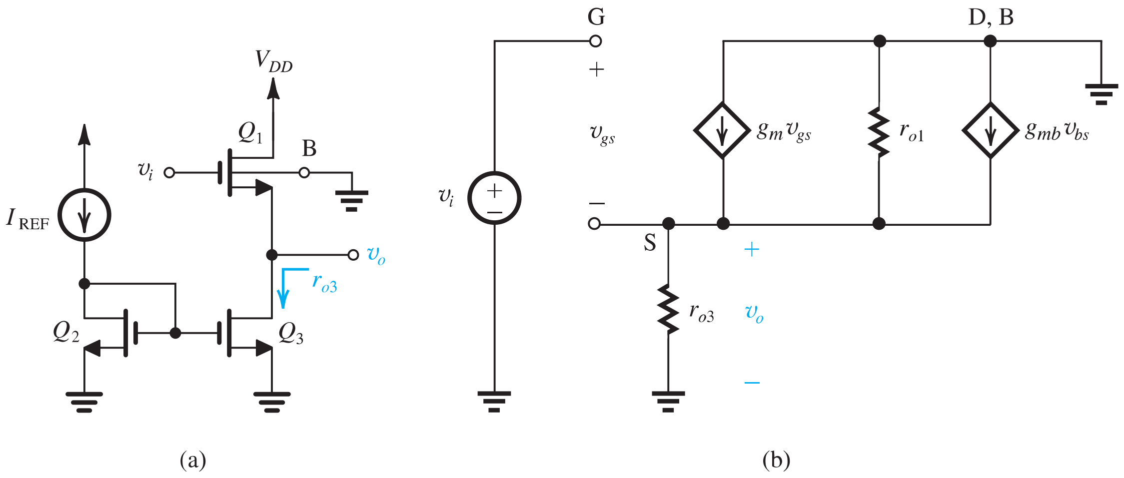


Figure 8.45 (**a**) A source follower biased with a current mirror Q_2–Q_3 and with the body terminal indicated. Note that the source cannot be connected to the body and thus the body effect should be taken into account. (**b**) Equivalent circuit.

resistances $1/g_{mb}$, r_{o1}, and r_{o3} appear in parallel between the source and ground. If we denote their parallel equivalent R_L, we can easily show that the voltage gain of the source follower is given by

$$\frac{v_o}{v_i} = \frac{R_L}{R_L + \frac{1}{g_m}} \tag{8.103}$$

where

$$R_L = r_{o1} \| r_{o3} \| \frac{1}{g_{mb}} \tag{8.104}$$

In cases where $\frac{1}{g_{mb}} \ll r_{o1}, r_{o3}$,

$$R_L \simeq \frac{1}{g_{mb}}$$

and

$$\frac{v_o}{v_i} \simeq \frac{g_{mb}}{g_m + g_{mb}} \tag{8.105}$$

Substituting for $g_{mb} = \chi g_m$ where $\chi = 0.1$ to 0.2,

$$\frac{v_o}{v_i} \simeq \frac{1}{1+\chi} \tag{8.106}$$

This is the maximum possible gain obtained from an IC source follower. The actual gain realized will usually be lower because of the effect of r_{o1} and r_{o3}.

EXERCISE

8.28 For the source follower in Fig. 8.45(a), let the bias current of Q_1 be 200 μA and assume Q_1 is operating at $V_{OV} = 0.2$ V. If $V_A = 5$ V and $\chi = 0.2$, find the voltage gain of the source follower.
Ans. 0.81 V/V

Example 8.7

For the CC–CE amplifier in Fig. 8.44(a) let $I_1 = I_2 = 1$ mA and assume identical transistors with $\beta = 100$. Find the input resistance R_{in} and the overall voltage gain obtained when the amplifier is fed with a signal source having $R_{sig} = 4\ \text{k}\Omega$ and loaded with a resistance $R_L = 4\ \text{k}\Omega$. Compare the results with those obtained with a common-emitter amplifier operating under the same conditions. Ignore r_o.

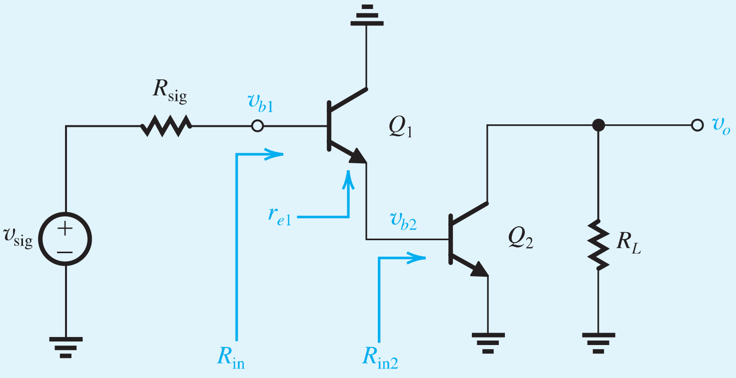
Solution

At an emitter current of 1 mA, Q_1 and Q_2 have

$$g_m = 40\ \text{mA/V}$$

$$r_e = 25\ \Omega$$

$$r_\pi = \frac{\beta}{g_m} = \frac{100}{40} = 2.5\ \text{k}\Omega$$



(c)

Figure 8.46 Circuit for Example 8.7.

Referring to Fig. 8.46 we can find

$$R_{in2} = r_{\pi 2} = 2.5\ \text{k}\Omega$$

$$R_{in} = (\beta_1 + 1)(r_{e1} + R_{in2})$$

$$= 101(0.025 + 2.5) = 255\ \text{k}\Omega$$

$$\frac{v_{b1}}{v_{sig}} = \frac{R_{in}}{R_{in} + R_{sig}} = \frac{255}{255+4} = 0.98\ \text{V/V}$$

$$\frac{v_{b2}}{v_{b1}} = \frac{R_{in2}}{R_{in2} + r_{e1}} = \frac{2.5}{2.5+0.025} = 0.99\ \text{V/V}$$

$$\frac{v_o}{v_{b2}} = -g_{m2}R_L = -40 \times 4 = -160\ \text{V/V}$$

Thus,

$$G_v = \frac{v_o}{v_{\text{sig}}} = -160 \times 0.99 \times 0.98 = -155\ \text{V/V}$$

For comparison, a CE amplifier operating under the same conditions will have

$$R_{\text{in}} = r_\pi = 2.5\ \text{k}\Omega$$

$$G_v = \frac{R_{\text{in}}}{R_{\text{in}} + R_{\text{sig}}}(-g_m R_L)$$

$$= \frac{2.5}{2.5+4}(-40 \times 4)$$

$$= -61.5\ \text{V/V}$$

EXERCISE

8.29 Repeat Example 8.7 for the CD–CE configuration of Fig. 8.44(c). Let $I_1 = I_2 = 1$ mA, $\beta_2 = 100$, $R_L = 4\ \text{k}\Omega$, and $k_{n1} = 8\ \text{mA/V}^2$; neglect the body effect in Q_1 and r_o of both transistors. Find R_{in} and G_v when $R_{\text{sig}} = 4\ \text{k}\Omega$ (as in Example 8.7) and $R_{\text{sig}} = 400\ \text{k}\Omega$. What would G_v of the CC–CE amplifier in Example 8.7 become for $R_{\text{sig}} = 400\ \text{k}\Omega$?

Ans. $R_{\text{in}} = \infty$; $G_v = -145.5$ V/V, independent of R_{sig}; -61.7 V/V

8.7.2 The Darlington Configuration[5]

Figure 8.47(a) shows a popular BJT circuit known as the **Darlington configuration**. It can be thought of as a variation of the CC–CE circuit with the collector of Q_1 connected to that of Q_2. Alternatively, the **Darlington pair** can be thought of as a composite transistor with $\beta = \beta_1\beta_2$. It can therefore be used to implement a high-performance voltage follower, as illustrated in Fig. 8.47(b). Note that in this application the circuit can be considered as the cascade connection of two common-collector transistors (i.e., a CC–CC configuration).

Since the transistor β depends on the dc bias current, it is possible that Q_1 will be operating at a very low β, rendering the β-multiplication effect of the Darlington pair rather ineffective. A simple solution to this problem is to provide a bias current for Q_1, as shown in Fig. 8.47(c).

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[5] Named after Sidney Darlington, a pioneer in filter design and transistor circuit design.

factor β is less than a critical value β_{cr} and unstable if $\beta \geq \beta_{\text{cr}}$, and find the value of β_{cr}. Hence, find the minimum value of the closed-loop gain for which the amplifier is stable.

Ans. $\omega_{180} = \sqrt{3} \times 10^4$ rad/s; $\beta_{\text{cr}} = 0.008$; $A_{f\,\text{min}} = 111.1$

HARRY NYQUIST— A DIVERSE ELECTRONICS FUNDAMENTALIST:

Harry Nyquist, a Swedish-born electrical engineer working for Bell Labs and its predecessor, was responsible for developments in communications electronics involving thermal noise, feedback-amplifier stability, telegraphy, facsimile, television, and many other areas.

In *The Idea Factory*, an excellent book on the history of Bell Labs, Jon Gertner notes that

> [S]ome lawyers in the patent office of the Bell Labs decided to study whether there was an organizing principle that could explain why certain individuals were more productive than others. They discerned only one common thread: Workers with the most patents often shared lunch or breakfast with a Bell Labs electrical engineer named Harry Nyquist. It wasn't the case that Nyquist gave them specific ideas. Rather, as one scientist recalled, "he drew people out, got them thinking." More than anything, Nyquist asked good questions.

11.8 Effect of Feedback on the Amplifier Poles

The amplifier frequency response and stability are determined directly by its poles. Therefore we shall investigate the effect of feedback on the poles of the amplifier.[7]

11.8.1 Stability and Pole Location

We shall begin by considering the relationship between stability and pole location. For an amplifier or any other system to be stable, its poles should lie in the left half of the s plane. A pair of complex-conjugate poles on the $j\omega$ axis gives rise to sustained sinusoidal oscillations. Poles in the right half of the s plane give rise to growing oscillations.

To verify the statement above, consider an amplifier with a pole pair at $s = \sigma_0 \pm j\omega_n$. If this amplifier is subjected to a disturbance, such as that caused by closure of the power-supply switch, its transient response will contain terms of the form

$$v(t) = e^{\sigma_0 t}\left[e^{+j\omega_n t} + e^{-j\omega_n t}\right] = 2e^{\sigma_0 t}\cos(\omega_n t) \tag{11.60}$$

This is a sinusoidal signal with an envelope $e^{\sigma_0 t}$. Now if the poles are in the left half of the s plane, then σ_0 will be negative and the oscillations will decay exponentially toward zero, as shown in Fig. 11.29(a), indicating that the system is stable. If, on the other hand, the poles are in

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[7] For a brief review of poles and zeros and related concepts, refer to Appendix F.

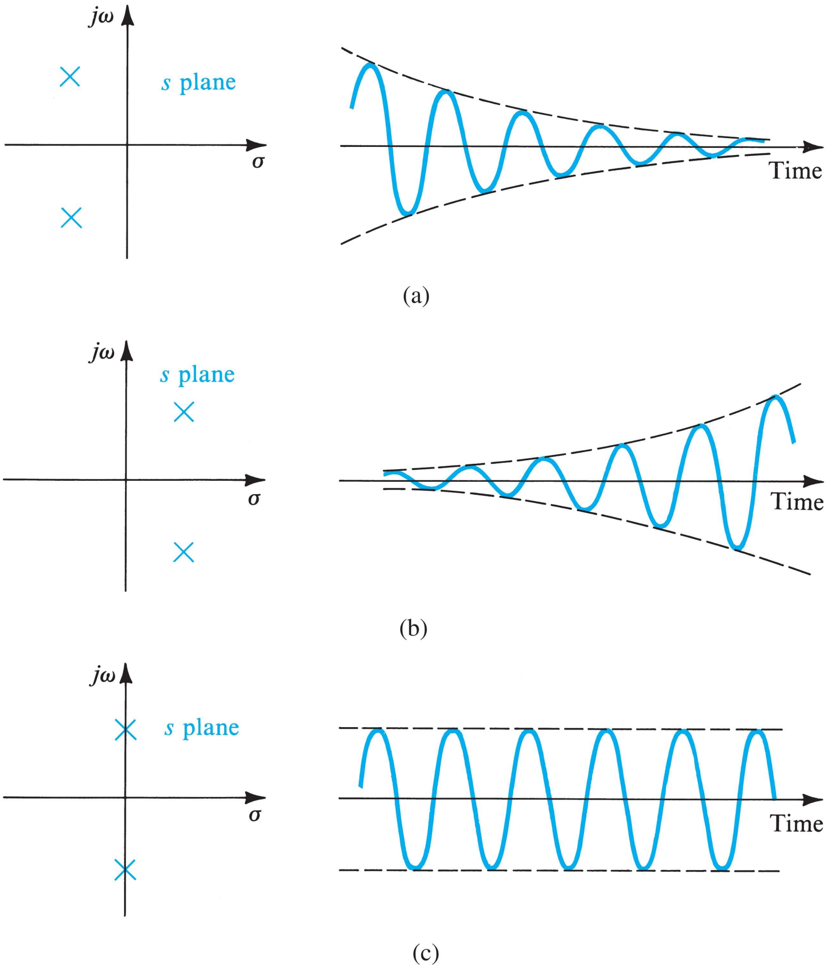


Figure 11.29 Relationship between pole location and transient response.

the right half-plane, then σ_0 will be positive, and the oscillations will grow exponentially (until some nonlinearity limits their growth), as shown in Fig. 11.29(b). Finally, if the poles are on the $j\omega$ axis, then σ_0 will be zero and the oscillations will be sustained, as shown in Fig. 11.29(c).

Although the discussion above is in terms of complex-conjugate poles, it can be shown that the existence of any right-half-plane poles results in instability.

11.8.2 Poles of the Feedback Amplifier

From the closed-loop transfer function in Eq. (11.57), we see that the poles of the feedback amplifier are the zeros of $1 + A(s)\beta(s)$. That is, the feedback amplifier poles are obtained by solving the equation

$$1 + A(s)\beta(s) = 0 \qquad (11.61)$$

which is called the **characteristic equation** of the feedback loop. It should therefore be apparent that applying feedback to an amplifier changes its poles.

In the following, we shall consider how feedback affects the amplifier poles. For this purpose we shall assume that the open-loop amplifier has real poles and no finite zeros (i.e., all the zeros are at $s = \infty$). This will simplify the analysis and enable us to focus our attention on the fundamental concepts involved. We shall also assume that the feedback factor β is independent of frequency.

11.8.3 Amplifier with a Single-Pole Response

Consider first the case of an amplifier whose open-loop transfer function is characterized by a single pole:

$$A(s) = \frac{A_0}{1+s/\omega_P} \tag{11.62}$$

The closed-loop transfer function is given by

$$A_f(s) = \frac{A_0/(1+A_0\beta)}{1+s/\omega_P(1+A_0\beta)} \tag{11.63}$$

Thus the feedback moves the pole along the negative real axis to a frequency ω_{Pf},

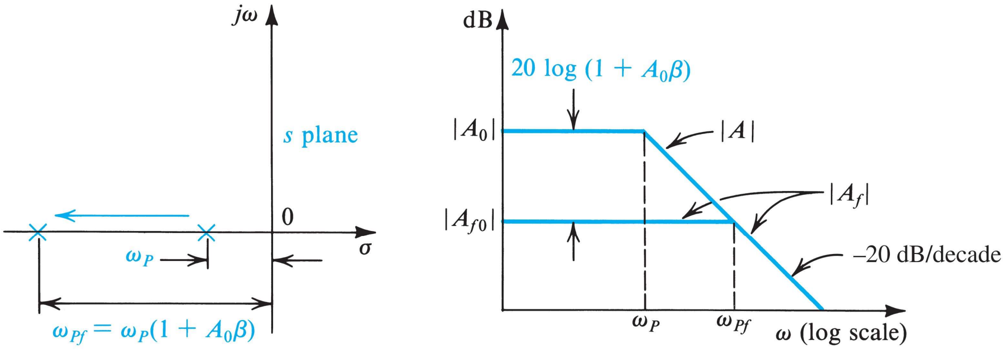
$$\omega_{Pf} = \omega_P(1+A_0\beta) \tag{11.64}$$

This process is illustrated in Fig. 11.30(a). Figure 11.30(b) shows Bode plots for $|A|$ and $|A_f|$. Note that while at low frequencies the difference between the two plots is $20 \log(1 + A_0\beta)$, the two curves coincide at high frequencies. One can show that this indeed is the case by approximating Eq. (11.63) for frequencies $\omega \gg \omega_P(1 + A_0\beta)$:

$$A_f(s) \simeq \frac{A_0\omega_P}{s} \simeq A(s) \tag{11.65}$$

Physically speaking, at such high frequencies the loop gain is much smaller than unity and the feedback is ineffective.

Figure 11.30(b) clearly illustrates the fact that applying negative feedback to an amplifier results in extending its bandwidth at the expense of a reduction in gain. Since the pole of the



(a) (b)

Figure 11.30 Effect of feedback on **(a)** the pole location and **(b)** the frequency response of an amplifier having a single-pole, open-loop response.

17.12.4 Amplifiers with Multiple Tuned Circuits

The selectivity achieved with the single tuned circuit of Fig. 17.42 is not sufficient in many applications—for instance, in the IF amplifier of a radio or a TV receiver. Greater selectivity is obtained by using additional tuned stages. Figure 17.46 shows a BJT with tuned circuits at both the input and the output.[12] In this circuit the bias details are shown, from which we note that biasing is quite similar to the classical arrangement employed in low-frequency, discrete-circuit design. However, to avoid the loading effect of the bias resistors R_{B1} and R_{B2} on the input tuned circuit, a **radio-frequency choke** (RFC) is inserted in series with each resistor. Such chokes have low resistance but high impedances at the frequencies of interest. The use of RFCs in biasing tuned RF amplifiers is common practice.

The analysis and design of the double-tuned amplifier of Fig. 17.46 is complicated by the Miller effect[13] due to capacitance C_μ. Since the load is not simply resistive, as was the case in the amplifiers studied in Section 10.3.3, the Miller impedance at the input will be complex. This reflected impedance will cause detuning of the input circuit as well as "skewing" of the response of the input circuit. Needless to say, the coupling introduced by C_μ makes tuning (or aligning) the amplifier quite difficult. Worse still, the capacitor C_μ can cause oscillations to occur (see Gray and Searle, 1969, and Problem 17.101).

Methods exist for **neutralizing** the effect of C_μ, using additional circuits arranged to feed back a current equal and opposite to that through C_μ. An alternative, and preferred, approach is to use circuit configurations that do not suffer from the Miller effect. These are discussed later. Before leaving this section, however, we wish to point out that circuits of the type shown in Fig. 17.46 are usually designed utilizing the *y*-parameter model of the BJT (see

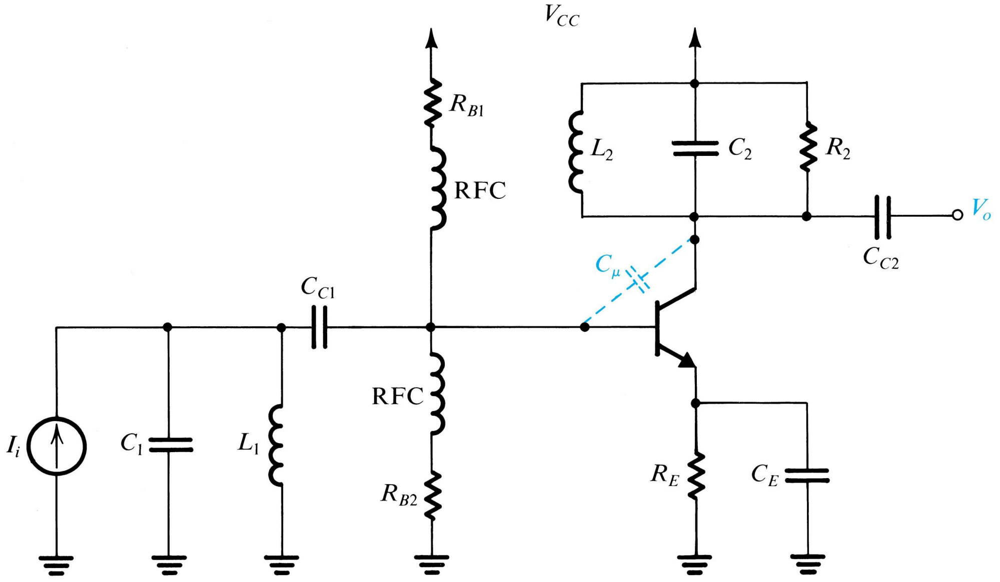


Figure 17.46 A BJT amplifier with tuned circuits at the input and the output.

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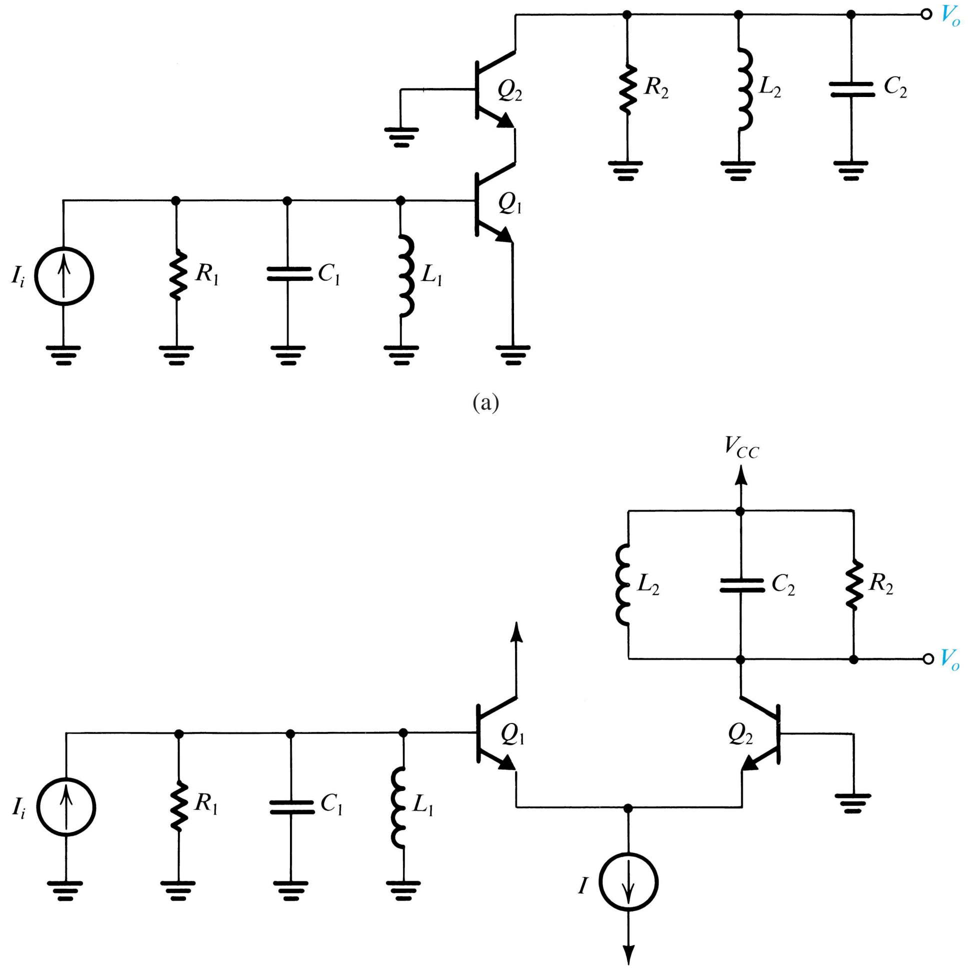
[12] Note that because the input circuit is a parallel resonant circuit, an input current source (rather than voltage source) signal is utilized.

[13] Here we use "Miller effect" to refer to the effect of the feedback capacitance C_μ in reflecting back an input impedance that is a function of the amplifier load impedance.

Appendix C). This is done because here, in view of the fact that C_μ plays a significant role, the y-parameter model makes the analysis simpler (in comparison to that using the hybrid-π model). Also, the y parameters can easily be measured at the particular frequency of interest, ω_0. For narrow-band amplifiers, the assumption is usually made that the y parameters remain approximately constant over the passband.

17.12.5 The Cascode and the CC–CB Cascade

From our study of amplifier frequency response in Chapter 10, we know that two amplifier configurations do not suffer from the Miller effect. These are the cascode configuration and the common-collector, common-base cascade. Figure 17.47 shows tuned amplifiers based on these two configurations. The CC–CB cascade is usually preferred in IC implementations because its differential structure makes it suitable for IC biasing techniques. (Note that the biasing details of the cascode circuit are not shown in Fig. 17.47(a). Biasing can be done using arrangements similar to those discussed in earlier chapters.)



(a)

(b)

Figure 17.47 Two tuned-amplifier configurations that do not suffer from the Miller effect: **(a)** cascode and **(b)** common-collector, common-base cascade. (Note that bias details of the cascode circuit are not shown.)

17.12.6 Synchronous Tuning and Stagger Tuning

In the design of a tuned amplifier with multiple tuned circuits, the question of the frequency to which each circuit should be tuned arises. The objective, of course, is for the overall response to exhibit high passband flatness and skirt selectivity. To investigate this question, we shall assume that the overall response is the product of the individual responses: in other words, that the stages do not interact. This can easily be achieved using circuits such as those in Fig. 17.47.

Consider first the case of N identical resonant circuits, known as the **synchronously tuned** case. Figure 17.48 shows the response of an individual stage and that of the cascade. Observe the bandwidth "shrinkage" of the overall response. The 3-dB bandwidth B of the overall amplifier is related to that of the individual tuned circuits, ω_0/Q, by (see Problem 17.102)

$$B = \frac{\omega_0}{Q}\sqrt{2^{1/N} - 1} \tag{17.123}$$

The factor $\sqrt{2^{1/N} - 1}$ is known as the **bandwidth-shrinkage factor**. Given B and N, we can use Eq. (17.123) to determine the bandwidth required of the individual stages, ω_0/Q.

EXERCISE

D17.36 Consider the design of an IF amplifier for an FM radio receiver. Using two synchronously tuned stages with $f_0 = 10.7$ MHz, find the 3-dB bandwidth of each stage so that the overall bandwidth is 200 kHz. Using 3-μH inductors find C and R for each stage.
Ans. 310.8 kHz; 73.7 pF; 6.95 kΩ

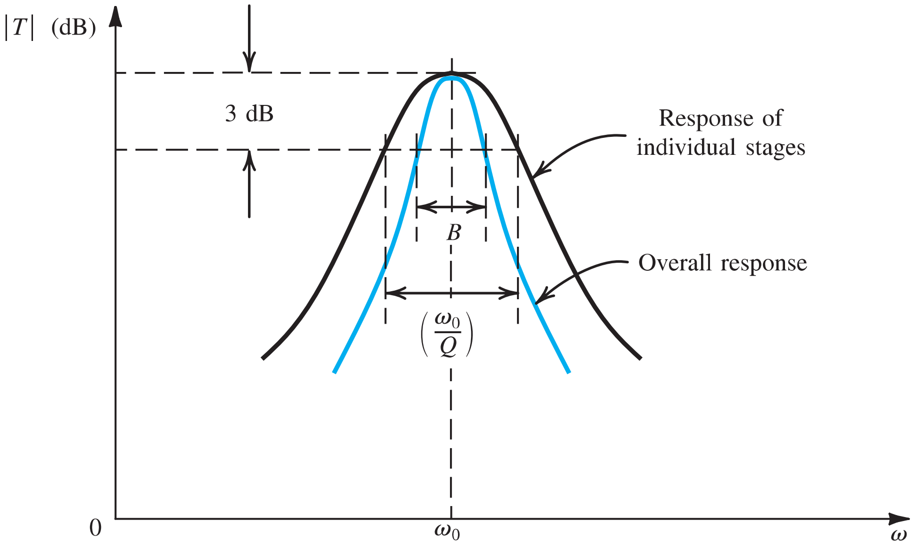


Figure 17.48 Frequency response of a synchronously tuned amplifier.

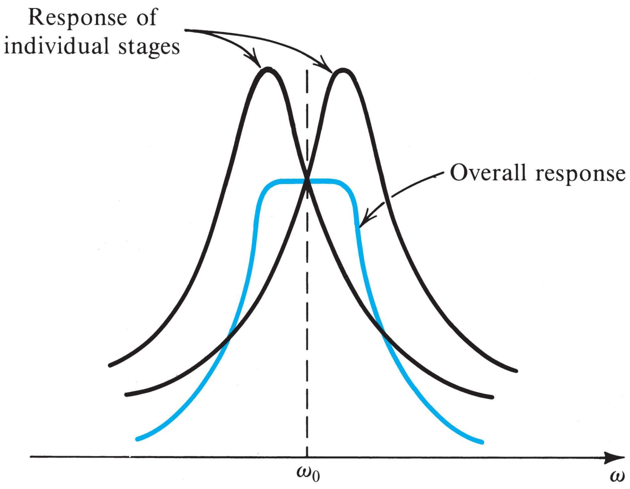


Figure 17.49 Stagger-tuning the individual resonant circuits can result in an overall response with a passband flatter than that obtained with synchronous tuning (Fig. 17.48).

A much better overall response is obtained by stagger-tuning the individual stages, as illustrated in Fig. 17.49. Stagger-tuned amplifiers are usually designed so that the overall response exhibits *maximal flatness* around the center frequency f_0. Such a response can be obtained by transforming the response of a maximally flat (Butterworth) low-pass filter up the frequency axis to ω_0. Appendix H shows how this can be done.

Summary

- A filter is a linear two-port network with a transfer function $T(s) = V_o(s)/V_i(s)$. For physical frequencies, the filter transmission is expressed as $T(j\omega) = |T(j\omega)|e^{j\phi(\omega)}$. The magnitude of transmission can be expressed in decibels using either the gain function $G(\omega) \equiv 20\log|T|$ or the attenuation function $A(\omega) \equiv -20\log|T|$.

- The transmission characteristics of a filter are specified in terms of the edges of the passband(s) and the stopband(s); the maximum allowed variation in passband transmission, $A_{\max}$ (dB); and the minimum attenuation required in the stopband, $A_{\min}$ (dB). In some applications, the phase characteristics are also specified.

- The filter transfer function can be expressed as the ratio of two polynomials in s; the degree of the denominator polynomial, N, is the filter order. The N roots of the denominator polynomial are the poles (natural modes).

- To obtain a highly selective response, the poles are complex and occur in conjugate pairs (except for one real pole when N is odd). The zeros are placed on the $j\omega$ axis in the stopband(s) including $\omega = 0$ and $\omega = \infty$.

- The Butterworth filter approximation provides a low-pass response that is maximally flat at $\omega = 0$. The transmission decreases monotonically as ω increases, reaching 0 (infinite attenuation) at $\omega = \infty$, where all N transmission zeros lie. Eq. (17.11) gives $|T|$, where ϵ is given by Eq. (17.14) and the order N is determined using Eq. (17.15). The poles are found using the graphical construction of Fig. 17.10, and the transfer function is given by Eq. (17.16).

- The Chebyshev filter approximation provides a low-pass response that is equiripple in the passband with the transmission decreasing monotonically in the stopband. All the transmission zeros are at $s = \infty$. Eq. (17.18) gives $|T|$ in the passband and Eq. (17.19) gives $|T|$ in the stopband, where ϵ is given by Eq. (17.21). The order N can be determined using Eq. (17.22). The poles are given by Eq. (17.23) and the transfer function by Eq. (17.24).

- Figures 17.13 and 17.14 provide a summary of first-order filter functions and their realizations.

- Figure 17.16 provides the characteristics of seven special second-order filtering functions.

- The second-order LCR resonator of Fig. 17.17(a) realizes a pair of complex-conjugate poles with $\omega_0 = 1/\sqrt{LC}$ and $Q = \omega_0 CR$. This resonator can be used to realize the

Rajeev Gandhi Memorial College of Engineering & Technology

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Department of Electronics & Communication Engineering

Academic Year: 2022-23

Subject: Electronic Circuits-Analysis & Design (ECA&D)

Class: II B. Tech, II Sem

Faculty member taught earlier: Dr. Kethepalli Mallikarjuna, Dr.C. Venkataiah

Suggestions:

As per the course structure of the UG (R20), ECA&D subject is completely based on the electronic circuits and its analysis based on the h-parameter model, simplified h-parameter model and also hybrid-pi parameter model. The subject also consists of analysis of feedback amplifier and its analysis based on its discrete components. It also consists of design of oscillator circuits using BJT and JFET. It also consists of different power amplifier and their efficiency calculations. Hence, following suggestions are made by subject experts:

1. As the subject comprises of theory and quantitative analysis and design earlier overall pass percentage was 85%. So, it is required to discuss more about designing problems to improve overall percentage further.
2. To improve the subject knowledge, this subject is to be demonstrated with prototype design models.
3. To improve the results, to take care of slow learners by taking extra classes and make them to practice more from previous year question papers as assignments.
4. Regular counseling and motivation should be given to the students to avoid the lacking in the subject knowledge.
5. The environment of the class should be interactive with respect to the subject discussion so that students can understand elaborately and may ask more questions.

Signature of the subject expert-1
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Professor and HOD
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Signature of the subject expert-2
Dr.C.Venkataiah
Associate Professor
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Assessment

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S.No.	Year (Batch)	Section	Subject	Branch	Registered	Appeared	Failed	Pass(%)	Highest
1	II B.Tech. II Sem. & 2021	B	ECAD Lab	ECE	73	72	8	88.89	10
2	II B.Tech. II Sem. & 2021	B	ECAD	ECE	73	72	14	80.56	9
3	II B.Tech. II Sem. & 2021	A	ECAD	ECE	73	70	18	74.29	9
4	IV B.Tech. II Sem. & 2019	D	SEM	ECE	64	64	0	100.00	9
5	IV B.Tech. II Sem. & 2019	A	SEM	ECE	71	71	0	100.00	10
6	IV B.Tech. I Sem. & 2019	A	DIP Lab	ECE	70	70	0	100.00	10
7	IV B.Tech. I Sem. & 2019	D	DIP	ECE	62	62	13	79.03	10
8	IV B.Tech. I Sem. & 2019	A	DIP	ECE	70	70	0	100.00	10
9	II B.Tech. II Sem. & 2020	A	ECAD Lab	ECE	66	66	3	95.45	10
10	II B.Tech. II Sem. & 2020	B	ECAD	ECE	61	61	3	95.08	10
11	II B.Tech. II Sem. & 2020	A	ECAD	ECE	66	66	4	93.94	10
12	IV B.Tech. I Sem. & 2018	D	DSP&IP Lab	ECE	60	55	3	94.55	9
13	IV B.Tech. I Sem. & 2018	B	DSP&IP Lab	ECE	69	69	0	100.00	10
14	IV B.Tech. I Sem. & 2018	D	DIP	ECE	60	55	13	76.36	7
15	IV B.Tech. I Sem. & 2018	B	DIP	ECE	69	69	2	97.10	9
16	III B.Tech. II Sem. & 2018	C	ECDT Lab	ECE	57	57	0	100.00	10
17	III B.Tech. II Sem. & 2018	C	DSP	ECE	57	57	3	94.74	7
18	III B.Tech. II Sem. & 2018	B	DSP	ECE	69	69	1	98.55	9
19	IV B.Tech. I Sem. & 2017	B	DSP&IP Lab	ECE	57	57	0	100.00	10
20	IV B.Tech. I Sem. & 2017	C	DIP	ECE	52	52	4	92.31	8
21	IV B.Tech. I Sem. & 2017	B	DIP	ECE	57	57	1	98.25	9
22	III B.Tech. II Sem. & 2017	B	S&T Lab	ECE	57	57	0	100.00	10

S.No.	Year (Batch)	Section	Subject	Branch	Registered	Appeared	Failed	Pass(%)	Highest
23	III B.Tech. II Sem. & 2017	B	EM&I	ECE	57	57	3	94.74	8
24	III B.Tech. II Sem. & 2017	A	DSP	ECE	57	57	1	98.25	10
25	II B.Tech. I Sem. & 2018	A	S&SS Lab	ECE	66	66	10	84.85	10
26	IV B.Tech. I Sem. & 2016	B	DSP	EEE	71	71	16	77.46	10
27	IV B.Tech. I Sem. & 2016	A	DSP	EEE	62	61	6	90.16	9
28	III B.Tech. II Sem. & 2016	C	ECDT Lab	ECE	56	51	0	100.00	10
29	II B.Tech. II Sem. & 2017	B	PDC	ECE	62	59	12	79.66	10
30	II B.Tech. II Sem. & 2017	A	PDC	ECE	60	59	11	81.36	10
31	II B.Tech. I Sem. & 2017	D	ECA Lab	ECE	59	51	2	96.08	10
32	II B.Tech. I Sem. & 2017	D	ECA	ECE	59	50	12	76.00	10
33	II B.Tech. I Sem. & 2017	B	ECA	ECE	64	59	18	69.49	9
34	III B.Tech. II Sem. & 2015	D	ECDT Lab	ECE	59	59	0	100.00	10
35	III B.Tech. II Sem. & 2015	D	DSP	ECE	59	59	7	88.14	10
36	II B.Tech. I Sem. & 2016	B	ECA Lab	ECE	61	54	3	94.44	10
37	II B.Tech. I Sem. & 2016	A	ECA Lab	ECE	62	58	3	94.83	10
38	II B.Tech. I Sem. & 2016	B	ECA	ECE	61	54	14	74.07	10
39	II B.Tech. I Sem. & 2016	A	ECA	ECE	62	58	11	81.03	9
40	II B.Tech. II Sem. & 2015	A	ECA Lab	ECE	65	3	0	100.00	8
41	II B.Tech. II Sem. & 2015	A	ECA	ECE	65	3	3	0.00	0
42	II B.Tech. II Sem. & 2015	D	PDC	ECE	62	62	19	69.35	10
43	II B.Tech. II Sem. & 2015	C	PDC	ECE	62	62	17	72.58	9
44	II B.Tech. I Sem. & 2015	D	ECA Lab	ECE	63	62	4	93.55	10
45	II B.Tech. I Sem. & 2015	C	ECA Lab	ECE	64	62	2	96.77	10
46	IV B.Tech. I Sem. & 2013	A	DIP	EIE	1	1	1	0.00	29
47	IV B.Tech. I Sem. & 2013	A	DSP	EEE	63	62	13	79.03	90
48	II B.Tech. I Sem. & 2015	D	ECA	ECE	63	62	15	75.81	10

Developed by Suresh Babu J