SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
		Year: II	Semester: I

Faculty Details

Name of the Faculty : Dr. S. S. SARAVANA KUMAR

Designation : ASSOCIATE PROFESSOR

Department : ECE

Course Details

Name of the Programme: B. Tech

Batch : 2022-26

Branch : ECE

Semester : III

Title of the Course : ELECTRONICS CIRCUITS ANALYSIS

Course Code : **21P04301**

Course Type : Professional Subject

Number of Students : 125

Note to the Faculty Members on how to use this course file format

1. **Time Table and syllabus copy provided to you may also be filed in it.**
2. **Please attach the Marks List of the students in respect of MID/QUIZ-I and MID/QUIZ-II for this course in your Course File**
3. **Photocopy of the best and the worst answer sheets for MID I, & II, be included in the Course File.**
4. **List of Assignments / Seminar Topics you have given to students should also be included in the Course File.**
5. **Model Question Paper, which you have distributed to the students in the beginning of the Semester for the course should be included in the Course File.**
6. **Any additional resources like PPT, OHP, handouts used may also be filed in it.**

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
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STATUS PAPER

1. **TARGET**

   1.1. Percentage of Pass :

   1.2. Percentage of I Class :

2. **COURSE PLAN**

   The coverage of Units by contact classes, lectures, design exercises, solving numerical problems, assignments.

   (Please write how you intend to cover the contents: i.e., coverage of Units by lectures, guest lectures, design exercises, solving numerical problems, demonstration of models, model preparation, or by assignments, etc.)

3. **METHOD OF EVALUATION**

   3.1. Continuous Assessment Examinations (CAE 1, CAE 2)

   3.2. Assignments / Seminars

   3.3. Mini Projects

   3.4. Quiz

   3.5. Term End Examination

4. **List out any new topic(s) or any innovation you would like to introduce in teaching the course in this Semester.**

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

GUIDELINES TO STUDY THE COURSE

Guidelines to Study the Course

- The Course syllabus is written into number of learning objectives and outcomes.
- These learning objectives and outcomes will be achieved through lectures, assessments, assignments, experiments in the laboratory, projects, seminars, presentations, etc.
- Every student will be given an assessment plan, criteria for assessment, scheme of evaluation and grading method.
- The Learning Process will be carried out through assessments of Knowledge, Skills and Attitude by various methods and the students will be given guidance to refer to the text books, reference books, journals, etc.

Pre-requisites: NIL

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

INSTITUTE VISION:

To develop the institution into a world class destination for technological education and research

INSTITUTE MISSION:

M1: To impart high quality, industry relevant, career oriented, engineering education to rural students, to translate our vision into a reality.

M2: To provide the best of instructional and institutional infrastructure facilities.

M3: To have strategic linkages with industry and other institutions.

M4: To mould students to meet the challenges of life with ethics, courage and conviction.

Department of Electronics and Communication Engineering

VISION:

Ignite the young minds to make them intellectuals with ultimate objective of promoting technology across the globe in the area of Electronics and Communication Engineering.

MISSION:

M1: Offer a well-balanced programme of instruction, lab practices, research & development activities.

M2: Emphasis on Competitive learning through professional societies

M3: Providing Industry and department interactions to develop overall skills

Program Educational Objectives (PEOs)

PEO-1: Excel in contemporary problem solving in Electronics and Communication Engineering and the allied fields through the knowledge-base provided by the program.

PEO-2: Demonstrate their technical, communication and leadership skills in professional environment or as entrepreneurs with social responsibility.

PEO-3: Analyze the latest issues and technology growth in the field of Electronics and Communication Engineering and update their knowledge and skills accordingly through continuous learning.

PEO-4: Demonstrate ethical and human values in multicultural and multidisciplinary environment

Programme Specific Outcomes (PSOs)

PSO1: To prepare and motivate graduates with recent technological developments related to core areas like Signal Processing, VLSI, Wireless, Satellite, Radar communications and future technologies so as to contribute effectively for Research & Development by participating in professional activities like publishing and seeking copy rights.

PSO2: To train the graduates for a high degree of employability in both public and private sector industries at national and international level by imparting in them the professional competence, ethical administrative acumen and ability to handle critical situations.

PSO3: To prepare the graduates for life-long learning process with a sense of social responsibility that paves them a way to become good team members and leaders.

II B.Tech I Semester Students Roll List

Branch: ECE **Academic Year : 2023-2024**

Sl. No.	Roll No.	Name of the Student
1	226N1A0401	ACHANTA DHANA SAI VISHNU VARDHAN
2	226N1A0402	ADABALA JYOTSNA RATNA SRI
3	226N1A0403	ADAPA HARI KRISHNA
4	226N1A0404	ADAPUREDDY JANAKI NARASIMHA BABI
5	226N1A0405	ADDAGARLA S S R PRAVEEN
6	226N1A0406	ARUBARUGULA SANJAY
7	226N1A0407	AVISETTI SYAMALA KUMARI
8	226N1A0408	BHARTHU MANOJ
9	226N1A0409	BOKKA TEJASWINI
10	226N1A0410	BOKKA THARUN KUMAR
11	226N1A0411	BOKKA YAMUNA
12	226N1A0412	BONAM JAHNAVI
13	226N1A0413	CHEKKA DEVAHARSHINI
14	226N1A0414	CHEKURI DURGA VEERA NAGENDRA VARMA
15	226N1A0415	CHERUKURI NAGA SATYAVATHI
16	226N1A0416	CHINTHA NANI
17	226N1A0417	CHINTHAPALLI PURNA CHANDRIKA PADMAVATHI
18	226N1A0418	DABBA YUVARAJ SRI SURYA KIRAN
19	226N1A0420	DAMISETTI DHARA SAI LAKSHMI
20	226N1A0421	DATLA PAVAN VARMA
21	226N1A0422	DONIPATI PRASANNA KUMAR
22	226N1A0423	DOPPA KONDALA RAO
23	226N1A0424	DUNABOINA PUJITHA
24	226N1A0425	ELURI SAI SRAVANI
25	226N1A0426	GANASALA BHANU PRAKASH
26	226N1A0427	GANGUMALLA RENUKA SATYA
27	226N1A0428	GUBBALA JAGADEESWARI
28	226N1A0429	GUBBALA VANI ANUSHA

29	226N1A0430	GUDALA CHARAN PAVAN
30	226N1A0432	GUDDANTI GURU SATHWIK
31	226N1A0433	GUMMALLA DEVI NAGASATISH
32	226N1A0434	GUNDUMENU DEVI
33	226N1A0435	GURRALA SIVARAMA CHARAN REDDY
34	226N1A0436	JILLELLA PRANATHI
35	226N1A0437	JOYSIL PEYYALA
36	226N1A0438	KADALI MEGHANA VENKATESWAR RAO
37	226N1A0439	KADALI NAGA SIDDI DEVI SRI
38	226N1A0440	KADIMI PAVANI
39	226N1A0441	KADIYAM HEMANTH MANIKANTA SRI SAI KRISHNA
40	226N1A0442	KALIDINDI HIMA BINDU
41	226N1A0443	KAMANA SAI POOJITHA
42	226N1A0444	KAMUJU DURGA VARSHINI
43	226N1A0445	KANDREGULA LAKSHMI DURGA
44	226N1A0447	KARNIDI JNANA SIVA PRADEEP
45	226N1A0449	KATTA JNANA SUDARSINI
46	226N1A0450	KATTA VENNELA PRASANNA
47	226N1A0451	KESARI KEDHARNADH LAKSHMI NARASIMHA
48	226N1A0452	KODAVATI UMASRI
49	226N1A0453	KOLAPALLI VEERA NAGA SOWJANYA
50	226N1A0454	KOMMIREDDY DURGA SWATHI
51	226N1A0455	KONJETI DURGA MEGHANA
52	236N5A0412	POLABATHULA PRAVALIKA
53	236N5A0413	RAMANATHI PRAVEEN
54	236N5A0414	RAMIREDDY VEERA VAMSI KRISHNA
55	236N5A0415	CHAPPIDI SRINU
56	236N5A0416	CHINTAPALLI SANDHYA SHEM
57	236N5A0417	KANDREGULA BALA GANESH
58	236N5A0418	KARRI TEJESH
59	236N5A0419	KASIBHATLA SHANMUKHACHANDRA SEKHAR

60	236N5A0420	KOPPULA GARGEYA VEERA MANIKANTA
61	236N5A0421	REDDY VENKATESHWAR RAO
62	236N5A0422	SARELLA SILVIYA LAZARUS

II B.Tech I Semester Students Roll List

Branch: ECE-B **Academic Year : 2023-2024**

Sl. No.	Roll No.	Name of the Student
1	226N1A0456	KORLAPATI AMRUTHA
2	226N1A0457	KUDUPUDI MEGHANA SINDHU
3	226N1A0458	KUNCHE DEVA PRASANNA KUMAR
4	226N1A0459	MADE KIRANMAI
5	226N1A0460	MADIKI SUBHASH
6	226N1A0461	MANDAPATI INDRANI
7	226N1A0462	MATTAPARTHI GISHMASANTOSHI
8	226N1A0463	MATTAPARTHI NAVYASRI
9	226N1A0464	MUDUNURI MANI NAVYA SRI
10	226N1A0465	MULAPARTHI BABITA
11	226N1A0466	MUTHYALA SAI VAMSI
12	226N1A0467	NADIMPALLI A N G K MAHESH REVANTH VARMA
13	226N1A0468	NAGISETTY SRI SAI VENKATA KARTHIK
14	226N1A0469	NAIDU SURYA SATYA NAGA KUMARI
15	226N1A0470	NAKKA VENKAT
16	226N1A0471	NALLI PAVAN DURGA RAM
17	226N1A0472	NETHALA PUJITHA
18	226N1A0473	NIPPULETI PURNAVENKATAMUTHYAVENI
19	226N1A0474	NUKALA SIRI SANJANA
20	226N1A0475	NUKALA VENKATA SAI LAKSHMI
21	226N1A0476	PALAGUMMI S N S VISWANADHA KOUSHIK
22	226N1A0477	PALEPU MALLESH
23	226N1A0478	PALEPU SRI DHARMA TEJA
24	226N1A0479	PALIVELA BHARGAVI

25	226N1A0481	PATTA SRINUBABU
26	226N1A0482	PEDAMALLU SATYA NAGA MANOHAR
27	226N1A0483	PERURI RAGA SNEHA VASAVI
28	226N1A0484	PITHANI SAI RAM
29	226N1A0485	POORILLA VENKATA SATYANARAYANA
30	226N1A0486	POTHURI KODANDA RAMA GANAPATHI VARMA
31	226N1A0487	PUVVALA LAKSHMIPATHI
32	226N1A0488	RANKIREDDY YAMINI VEERA NAGALAKSHMI DEVI
33	226N1A0489	RATSA SIVA KRISHNA
34	226N1A0490	SAMSANI LAKSHMI SANTHOSH
35	226N1A0491	SAPE BHAGYA SRI
36	226N1A0492	SEELAM NAVYA SAI SRI
37	226N1A0493	SIDDAMSETTI KEERTHI RANI
38	226N1A0494	TELAGANI VARA LAKSHMI
39	226N1A0495	TOLETI PURNA SAI TEJA
40	226N1A0496	TORAM NAGA DURGA SUBRAHMANESWARA RAO
41	226N1A0498	UNDURTHI LEELA SOWJANYA
42	226N1A04A0	VARRY RISHITHA SRI SAI
43	226N1A04A1	VEGI SATYA SAI MANIKANTA
44	226N1A04A2	VELAVALAPALLI N S N ABHISHEK
45	226N1A04A3	VITHANALA TANUJA
46	226N1A04A4	VYDANI DEVAKI NAGA MALLESWARI
47	226N1A04A5	YALLA VENKATA RAMA MANIKANTA DHATTATREYA
48	226N1A04A6	YENUGULA VENKATA SRI SAI ABHIRAM
49	226N1A04A7	BAIRISETTI DEVI NAGA DHANA PRIYANKA
50	226N1A04A8	GUTTULA MANOJ
51	226N1A04A9	M SATYA SAI LAKSHMI
52	226N1A04B0	VASAMSETTY SWAMY MANIKANTA
53	236N5A0401	AYINAVILLI YAMUNA
54	236N5A0402	GANTI BHUVANENDRA
55	236N5A0403	JALLI VARSHA

56	236N5A0404	KANTAMSETTI VEERA VENKATA SATYANARAYANA
57	236N5A0405	KOPPISETTI DIVYA
58	236N5A0406	KORLA VEERA MANIKANTA
59	236N5A0407	KUDIPUDI SALOMI
60	236N5A0408	MURRE AVINASH
61	236N5A0409	NAIDU RAMASATISH
62	236N5A0410	PARAMATA ABHI RAM
63	236N5A0411	PETA ANAND SUBRAHMANYAM

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Time Table

Day of week	Period 1 09:00AM To 09:50 AM	Period 2 09:50 AM To 10:40 AM	10:40 AM To 10:50 AM	Period 3 10:50 AM To 11:40 PM	Period 4 11:40 AM To 12:30PM	12:30 PM To 01:20 PM	Period 5 01:20 PM To 02:10 PM	Period 6 02:20 PM To 03:20PM	Period 7 03:20 PM To 04:20 PM
Mon		ECA-B	B		ECA-B	L			
Tues		ECA-A	R		ECA-B	U			
Wed		ECA-A	E		ECA-B	N			
Thurs		ECA-B	A		ECA-A	C			
Fri			K	ECA-A		H		ECA-A	
Sat				ECA-B				ECA-A	

Syllabus with Cos

ELECTRONIC CIRCUITS ANALYSIS

Course Outcomes: At the end of the course, the student will be able to:

1. Design and analysis of small signal high frequency transistor amplifier using BJT and FET.
2. Design and analysis of multistage amplifiers using BJT and Differential amplifier using BJT.
3. Design and analysis of Feedback amplifiers using FET.
4. Derive the expressions for frequency of oscillation and condition for oscillation of RC and LC oscillators and their amplitude and frequency stability concept.
5. Know the classification of the power and tuned amplifiers and their analysis with performance comparison.

Unit-I: Small Signal High Frequency Transistor Amplifier Models 10 hours

BJT: Determination of high-frequency parameters in terms of low-frequency parameters, CE short circuit current gain, current gain with resistive load, cut-off frequencies, frequency response and gain bandwidth product.
FET: Analysis of common Source and common drain Amplifier circuits at high frequencies.

Unit-II: Multistage Amplifiers 8 hours

Classification of amplifiers, methods of coupling, cascaded transistor amplifier and its analysis, analysis of two stage RC coupled amplifier, high input resistance transistor amplifier circuits and their analysis-Darlington pair amplifier, Cascode amplifier, Boot-strap emitter follower, Differential amplifier using BJT.

Unit-III: Feedback Amplifiers 10 hours

Feedback principle and concept, types of feedback, classification of amplifiers, feedback topologies, Characteristics of negative feedback amplifiers, Generalized analysis of feedback amplifiers, Performance comparison of feedback amplifiers, Method of analysis of feedback amplifiers

Unit-IV: Oscillators 10 hours

Oscillator principle, condition for oscillations, types of oscillators, RC-phase shift and Wien bridge oscillators with BJT and FET and their analysis, Generalized analysis of LC Oscillators, Hartley and Colpitt's oscillators using BJT, Frequency and amplitude stability of oscillators.

Unit-V: Power Amplifiers 8 hours

Classification of amplifiers(A to H), Class A power Amplifiers, Class B Push-pull amplifiers, Complementary symmetry push pull amplifier, Class AB power amplifier, Class-C power amplifier, Thermal stability and Heat sinks.

Text Books:

1. Integrated Electronics- J.Millman and C.C.Halkias, Tata McGraw-Hill, 1972.
2. Electronic Devices and CircuitsTheory –Robert L.Boylestad and Louis Nashelsky, Pearson/PrenticeHall, TenthEdition, 2009.

Reference Books:

1. Electronic Circuit Analysis and Design –Donald A.Neaman, McGrawHill, 2010.
2. Micro electronic Circuits-Sedra A.S. and K.C. Smith, Oxford University Press, Sixth Edition, 2011.
3. Electronic Circuit Analysis-B.V.Rao, K.R.Rajeswari, P.C.R.Pantulu, K.B.R.Murthy, Pearson Publications.

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COURSE OBJECTIVES

On completion of this Course, the student shall be able to:

CO.No	Course Objective	Outcome
1	To learn hybrid-parameters at high frequency and compare with low frequency parameters.	The student will be able to design and analysis of small signal high frequency transistor amplifier using BJT and FET.
2	Learn and understand the purpose of cascading of single stage amplifiers and derive the overall voltage gain.	The student will be able to design and analysis of multistage amplifiers using BJT and Differential amplifier using BJT.
3	Analyze the effect of negative feedback on amplifier characteristics and derive the characteristics.	The student will be able to design and analysis of Feedback amplifiers using FET.
4	Learn and understand the basic principle of oscillator circuits and perform the analysis of different oscillator circuits.	The student will be able to derive the expressions for frequency of oscillation and condition for oscillation of RC and LC oscillators and their amplitude and frequency stability concept.
5	Compare and analyze different Power amplifiers like Class A, Class B, Class C, Class AB and other types of amplifiers. Analyze different types of tuned amplifier circuits.	The student will be able to know the classification of the power and tuned amplifiers and their analysis with performance comparison

Signature of the Faculty
Date:

Note:

1. For each unit we must create one course objective, hence we may have four to six objectives.
2. During designing the internal / mid question paper, questions must be reflected with respect to the objective, which was designed for that chapter or unit.
3. For each of the OBJECTIVE indicate the appropriate OUTCOMES to be achieved.

PROGRAM OUTCOMES

The expected outcomes of the Course are:

PO.NO	Programme Outcome	PSO.NO	Specific Outcomes of the Course
PO1	Engineering knowledge: Apply the knowledge mathematics, science, engineering fundamentals, and a engineering specialization to the solution of comple engineering problems.	PSO1	To prepare and motivate graduates with recent technological developments related to core areas like Signal Processing, VLSI, Wireless, Satellite, Radar communications and future technologies so as to contribute effectively for Research & Development by participating in professional activities like publishing and seeking copy rights.
PO2	Problem analysis: Identify, formulate, review research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.	PSO2	To train the graduates for a high degree of employability in both public and private sector industries at national and international level by imparting in them the professional competence, ethical administrative acumen and ability to handle critical situations.
PO3	Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.	PSO3	To prepare the graduates for life-long learning process with a sense of social responsibility that paves them a way to become good team members and leaders.
PO4	Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.		
PO5	PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations.		
PO6	The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.		
PO7	Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.		
PO8	Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.		
PO9	Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.		
PO10	Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being		

	able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.		
PO11	Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.		
PO12	Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change		

Course Outcome – program Outcome Relationship Matrix

PO / CO	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO1	3	3										
CO2	3	3	3									
CO3	3	2	3									
CO4	3	3	3									
CO5	3	3										

Course Outcome – program Specific Outcome Relationship Matrix

PO / CO	PSO1	PSO2	PSO3
CO1	3	3	1
CO2	3	3	1
CO3	3	2	1
CO4	3	3	1
CO5	3	3	

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COURSE SCHEDULE – AT A GLANCE

Name of the Faculty : Dr. S. S. Saravana Kumar

Name of the Course : Electronics Circuits Analysis

Course Code : 21P04301

Branch : ECE

The Schedule for the whole Course is:

Unit	Description	Duration (Date)		Total No. of Periods
		From	To	
1	BJT: Determination of high-frequency parameters in terms of low-frequency parameters, CE short circuit current gain, current gain with resistive load, cut-off frequencies, frequency response and gain bandwidth product. FET: Analysis of common Source and common drain Amplifier circuits at high frequencies.	1/08/2023	22/08/2023	17
2	Classification of amplifiers, methods of coupling, cascaded transistor amplifier and its analysis, analysis of two stage RC coupled amplifier, high input resistance transistor amplifier circuits and their analysis-Darlington pair amplifier, Cascode amplifier, Boot-strap emitter follower, Differential amplifier using BJT.	23/08/2023	15/09/2023	16
3	Feedback principle and concept, types of feedback, classification of amplifiers, feedback topologies, Characteristics of negative feedback amplifiers, Generalized analysis of feedback amplifiers, Performance comparison of feedback amplifiers, Method of analysis of feedback amplifiers	16/09/2023	12/10/2023	15
4	Oscillator principle, condition for oscillations, types of oscillators, RC-phase shift and Wien bridge oscillators with BJT and FET and their analysis, Generalized analysis of LC Oscillators, Hartley and Colpitt's oscillators using BJT, Frequency and amplitude stability of oscillators.	13/10/2023	2/11/2023	14
5	Classification of amplifiers(A to H), Class A power Amplifiers, Class B Push-pull amplifiers, Complementary symmetry push pull amplifier, Class AB power amplifier, Class-C power amplifier, Thermal stability and Heat sinks.	3/11/2023	22/11/2023	14

Total No. of Instructional periods available for the course: Hours/Periods

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LESSON PLAN
COURSE: ECA

FACULTY: Dr. S. S. SARAVANA KUMAR

Unit/Expt No.	Topic/Activities Planned	Actual plan		Completed Plan		Remarks
		No of hours	Date	No of hours	Date	
UNIT- I:Small Signal High-Frequency Transistor Amplifier Models						
1.	Introduction	1	24-7-23	1	01-08-23	Chalk Board
2.	Hybrid Pi Parameters	3	25-7-23 & 27-7-23	3	02-08-23 & 04-08-23	Chalk Board
3.	CE Short Circuit Current Gain	2	28-7-23 & 31-7-23	2	04-08-23 & 05-08-23	Chalk Board
4.	Current Gain with Resistive Load & Cut-off Frequencies	2	01-08-23 & 02-08-23	2	08-08-23 & 09-08-23	Chalk Board
5.	Problem Solving	2	03-08-23 & 04-08-23	2	10-08-23 & 11-08-23	Chalk Board
6.	Frequency Response	1	05-08-23	1	11-08-23	Chalk Board
7.	Gain Bandwidth Product	1	07-08-23	1	16-08-23	Chalk Board
8.	Analysis of Common Emitter Amplifiers	1	08-08-23	1	17-08-23	Chalk Board
9.	Analysis of Common Source Amplifiers	1	09-08-23	1	18-08-23	Chalk Board
10.	Analysis of Common Drain Amplifiers	1	10-08-23	1	18-08-23	Chalk Board
11.	Problems	2	11-08-23 & 14-08-23	2	19-08-23 & 22-08-23	Chalk Board
UNIT- II: Multistage Amplifiers						
12.	Classification of amplifiers	2	16-08-23 & 17-8-23	2	23-08-23 & 29-08-23	Chalk Board
13.	Methods of coupling	2	18-8-23 & 19-8-23	2	10-08-23 & 11-08-23	Chalk Board
14.	Cascaded transistor coupling analysis	2	21-8-23 & 22-8-23	2	30-08-23 & 31-08-23	Chalk Board
15.	RC Coupled amplifier	1	23-8-23	1	01-09-23	Chalk Board
16.	Problem Solving	2	24-8-23 & 25-8-23	2	01-09-23 & 05-09-23	Chalk Board
17.	High input resistance transistor amplifier circuit	1	26-8-23	1	07-09-23	Chalk Board
18.	Darlington Pair amplifier	1	28-8-23	1	08-09-23	Chalk Board

19.	Cascode amplifier	1	29-8-23	1	08-09-23	Chalk Board
20.	Boot-strap amplifier	1	30-8-23	1	12-09-23	Chalk Board
21.	Differential amplifier using BJT	1	31-8-23	1	13-09-23	Chalk Board
22.	Problem Solving	2	1-9-23 & 2-9-23	2	14-09-23 & 15-09-23	Chalk Board
UNIT- III: Feedback Amplifiers						
23.	Introduction	1	4-9-23	1	16-09-23	Chalk Board
24.	Types of Feedback	1	5-9-23	1	19-09-23	Chalk Board
25.	Classifications of amplifiers	1	6-9-23	1	20-09-23	Chalk Board
26.	Feedback topologies	2	8-9-23 & 11-9-23	2	21-09-23 & 22-09-23	Chalk Board
27.	Characteristics of negative feedback amplifiers	1	12-9-23	1	22-09-23	Chalk Board
28.	Generalized analysis of feedback amplifiers	2	13-9-23 & 14-9-23	2	23-09-23 & 26-09-23	Chalk Board
29.	Problem Solving	2	15-9-23 & 16-9-23	2	27-09-23 & 29-09-23	Chalk Board
30.	Comparison of feedback amplifiers	1	18-9-23	1	29-09-23	Chalk Board
31.	Methods of Analysis of feedback amplifiers	2	20-9-23 & 22-9-23	2	30-09-23 & 10-10-23	Chalk Board
32.	Problem Solving	2	23-9-23 & 3-10-23	2	11-10-23 & 12-10-23	Chalk Board
UNIT- IV:Oscillators						
33.	Introduction to oscillators	1	4-10-23	1	13-10-23	Chalk Board
34.	Types of Oscillators and its analysis with BJT	3	5-10-23 & 7-10-23	3	13-10-23 & 18-10-23	Chalk Board
35.	Types of Oscillators and its analysis with FET	3	9-10-23 & 11-10-23	3	19-10-23 & 20-10-23	Chalk Board
36.	Analysis of LC Oscillators	1	12-10-23	1	26-10-23	Chalk Board
37.	Hartley and Colpitt's Oscillator	2	13-10-23 & 16-10-23	2	27-10-23	Chalk Board
38.	Frequency and amplitude stability of oscillators	2	17-10-23 & 18-10-23	2	28-10-23 & 31-10-23	Chalk Board
39.	Problem Solving	2	19-10-23 & 20-10-23	2	01-11-23 & 02-11-23	Chalk Board
UNIT – V:Power Amplifiers						
40.	Classification of Power Amplifiers	2	25-10-23 &	2	03-11-23	Chalk Board

			26-10-23			
41.	Class A power Amplifier	1	27-10-23	1	04-11-23	Chalk Board
42.	Class B Push-pull Amplifier	1	28-10-23	1	07-11-23	Chalk Board
43.	Problems	2	30-10-23 & 31-10-23	2	09-11-23 & 10-11-23	Chalk Board
44.	Complementary symmetry Push-pull Amplifier	2	1-11-23 & 2-11-23	2	10-11-23 & 11-11-23	Chalk Board
45.	Class AB Power Amplifier	1	3-11-23	1	14-11-23	Chalk Board
46.	Class C Power Amplifier	1	4-11-23	1	15-11-23	Chalk Board
47.	Thermal Stability & Heat sinks	2	6-11-23 & 7-11-23	2	16-11-23 & 17-11-23	Chalk Board
48.	Problems	2	8-11-23 & 9-11-23	2	18-11-23 & 21-11-23	Chalk Board
49.	Old Papers Discussion	5	10-11-23 to 16-11-23	5	22-11-23 & 25-11-23	Chalk Board
50.	Revision all units	8	17-11-23 to 2-12-23	6	26-11-23 & 02-12-23	Chalk Board

Text Books:

1. Signals, Systems & Communications-B.P. Lathi, BS Publications, 2003.
2. Signals and Systems-A.V. Oppenheim, A.S. Willsky and S.H. Nawab, PHI, 2ndEdn, 1997

Reference Books:

1. Principles of Linear Systems and Signals–BPLathi, Oxford University Press, 2015
2. Signals and Systems–TK Rawat, Oxford University press, 2011

Faculty **HOD** **Dean-Academics** **Principal**

SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
		Year: II	Semester: I

COURSE COMPLETION STATUS

Actual date of completion & Remarks, if any

Unit	Description	Actual Date of Completion	Nos. of Course Objectives Achieved	Signature of HOD with Date
1	BJT: Determination of high-frequency parameters in terms of low-frequency parameters, CE short circuit current gain, current gain with resistive load, cut-off frequencies, frequency response and gain bandwidth product. FET: Analysis of common Source and common drain Amplifier circuits at high frequencies.	22/08/2023	CO1	
2	Classification of amplifiers, methods of coupling, cascaded transistor amplifier and its analysis, analysis of two stage RC coupled amplifier, high input resistance transistor amplifier circuits and their analysis-Darlington pair amplifier, Cascode amplifier, Boot-strap emitter follower, Differential amplifier using BJT.	15/09/2023	CO2	
3	Feedback principle and concept, types of feedback, classification of amplifiers, feedback topologies, Characteristics of negative feedback amplifiers, Generalized analysis of feedback amplifiers, Performance comparison of feedback amplifiers, Method of analysis of feedback amplifiers	12/10/2023	CO3	
4	Oscillator principle, condition for oscillations, types of oscillators, RC-phase shift and Wien bridge oscillators with BJT and FET and their analysis,Generalized analysis of LC Oscillators, Hartley and Colpitt's oscillators using BJT, Frequency and amplitude stability of oscillators.	2/11/2023	CO4	
5	Classification of amplifiers(A to H), Class A power Amplifiers, Class B Push-pull amplifiers, Complementary symmetry push pull amplifier, Class AB power amplifier, Class-C power amplifier, Thermal stability and Heat sinks.	22/11/2023	CO5	

Note: After completion of each unit mention the number of objectives achieved

Course: ELECRONICS CIRCUITS ANALYSIS **Subject code:** 21P04302

LICA Question Bank

Weak Students as per End Examination – Previous Academic Year

Year: **Semester:** **Academic Year: 2022-2023**

S.No.	Roll No.	Name	SGPA
1	226N1A0408	BHARTHU MANOJ	6.28
2	226N1A0421	DATLA PAVAN VARMA	6.55
3	226N1A0432	GUDDANTI GURU SATHWIK	6.54
4	226N1A0433	GUMMALLA DEVI NAGASATISH	6.19
5	226N1A0437	PEYYALA JOYSIL LAZARU	6.12
6	226N1A0460	MADIKI SUBHASH	6.35
7	226N1A0467	NADIMPALLI A N G K MAHESH REVANTH VARMA	6.00
8	226N1A0468	NAGISETTY SRI SAI VENKATA KARTHIK	6.02
9	226N1A0476	PALAGUMMI S N S VISWANADHA KOUSHIK	6.57
10	226N1A0477	PALEPU MALLESH	6.07

Note: Weak Students are the students who secure less than 50% marks in Previous External Examinations

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
		Year: II	Semester: I

List of Weak Students as per the First Mid Result

Mid : I **Date : 10/10/2023**

S.No.	Roll no..	Name	Mid Marks	Quiz Marks	% of Marks
1	226N1A0420	DAMISETTI DHARA SAI LAKSHMI	03	02	20
2	226N1A0421	DATLA PAVAN VARMA	04	05	36
3	226N1A0427	GANGUMALLA RENUKA SATYA	04	03	28
4	226N1A0430	GUDALA CHARAN PAVAN	02	05	28
5	226N1A0433	GUMMALLA DEVI NAGASATISH	04	01	20
6	226N1A0437	OYSIL PEYYALA	03	03	24
7	226N1A0438	KADALI MEGHANA VENKATESWAR RAO	02	03	20
8	226N1A0451	KESARI KEDHARNADH LAKSHMI NARASIMHA	07	03	40
9	236N5A0413	RAMANATHI PRAVEEN	05	04	36
10	236N5A0418	KARRI TEJESH	04	04	32
11	226N1A0459	MADE KIRANMAI	05	03	32
12	226N1A0460	MADIKI SUBHASH	02	02	16
13	226N1A0466	MUTHYALA SAI VAMSI	05	04	36
14	226N1A0471	NALLI PAVAN DURGA RAM	04	03	28
15	226N1A04A6	YENUGULA VENKATA SRI SAI ABHIRAM	06	03	36
16	236N5A0409	NAIDU RAMASATISH	05	04	36
17	236N5A0411	PETA ANAND SUBRAHMANYAM	02	05	28

Note: Weak Students are the students who secure less than 40% marks the first Mid.

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
		Year: II	Semester: I

Mid - Quality & Evaluation

Year: II **Semester: I** **Academic Year: 2023-24**

Mid	Questions	Date Conducted	Date of distribution	Marks entered in register
I	1) Derive the expression for Current gain with Resistive load.	06/10/2023	08/10/2023	10/10/2023
	2a) Discuss the effect of coupling and by-pass capacitors on CE amplifier.			
	2b (Draw the circuit diagram and equivalent circuit of an emitter follower amplifier and derive the expression for Av, Ai and input impedance.			
	3a) Explain the principle of negative feedback in amplifiers			
	3b) State and explain Millers theorem			
II	1a) Develop the circuit of Current Series feedback system and derive the expression for R_{if} and R_{of}.	11/12/2023	15/12/2023	18/12/2023
	1b) Design the circuit of Current Shunt feedback system and derive the expression for R_{if} and R_{of}			
	2a) Determine the condition for frequency of oscillation in an RC phase shift oscillator using BJT Transistor			
	2b) Examine the oscillation condition for LC circuits			
	3a) Explain the operation of transformer coupled Class-A power amplifier.			
	3b) What is cross-over distortion? How to eliminate it?			

SRINIVASA INSTITUTE OF ENGINEERING AND TECHNOLOGY (UGC- AUTONOMOUS)	Course File- Course Plan ELECRONICS CIRCUITS ANALYSIS	A.Y:2023-24	
		Year: II	Semester: I

Course Completion Certificate

I am Dr. S. S. Saravana Kumar faculty in the Department of Electronics and Communication Engineering have taught ELECTRONIC CIRCUIT ANALYSIS course to the students of II B. Tech I Semester and ECE- B. Tech programme during Academic Year2023-24 I certified that, I have completed Five units on 22/11/2023.

Reasons, if any, for not completion of syllabus:

S.No	Unit	Non covered %	Reason(s)

Signature of the Head of the Department
Date:

Signature of the Faculty
Date:

HOD / DEAN-ACADEMICS REVIEW (Fortnightly)

S.No.	Date of Review	Signature of HOD	Signature of Dean-Academics

Quality Audit

S.No.	Date of Audit	Observation if any	Signature of Auditee	Signature of Auditor

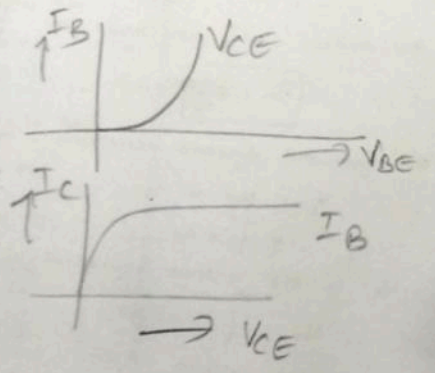
Assig - 1 (Mod-I)

① Derive hybrid π parameters in terms of L.F parameters

② CE short ckt current gain

③ current gain with resistive load

④ High freq c.s amplifier analysis.



$V_{BE} = f(I_B, V_{CE})$

$I_C = f(I_B, V_{CE})$.

$V_{BE} = h_{ie} I_B + h_{re} V_{CE} \longrightarrow (1)$

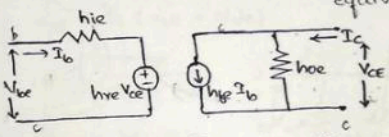
$I_C = h_{fe} I_B + h_{oe} V_{CE} \longrightarrow (2)$

Scholis

Unit - I

HIGH FREQUENCY TRANSISTOR CIRCUITS

* H-parameters model :- [Replace LF transistor with this equivalent circuit]



$X_C = \frac{1}{2\pi fC}$

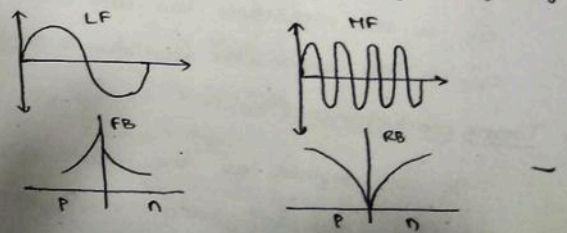
$V_{be} = h_{ie} I_b + h_{re} V_{ce} \longrightarrow (1)$

$I_c = h_{fe} I_b + h_{oe} V_{CE} \longrightarrow (2)$

$h_{ie} = \frac{V_{be}}{I_b}\Big|_{V_{ce}=0}$ $\qquad h_{fe} = \frac{I_c}{I_b}\Big|_{V_{ce}=0}$

$h_{re} = \frac{V_{be}}{V_{ce}}\Big|_{I_b=0}$ $\qquad h_{oe} = \frac{I_c}{V_{ce}}\Big|_{I_b=0}$

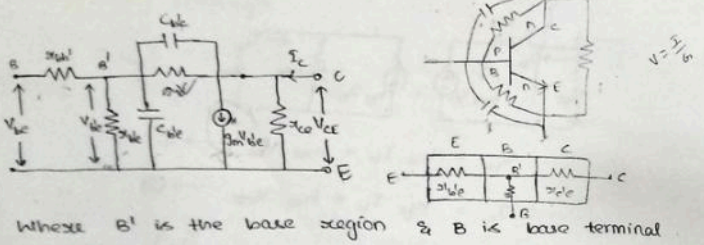
H-parameter model is applicable only for the low frequency signal, not applicable for high frequency signal.



Drawbacks :-

H-parameters model suitable only for low frequency analysis. For high frequency analysis hybrid π-model is used. At high frequencies h-parameter value becomes complex i.e., $h_{ie} = 100\Omega + j$. But a low frequency h-parameter value becomes real i.e., $h_{ie} = 100\Omega$

* Hybrid π - model :- Hybrid π - model is valid for both LF & HF (Giacoletto model) when by removing the capacitance $C_{b'e}$, $C_{b'c}$ it acts for low frequency



Where B' is the base region & B is base terminal

g_m is transconductance

$r_{bb'}$ is the resistance b/w base region & base terminal

$r_{b'e}$ is the resistance b/w base region & emitter terminal

$r_{b'c}$ is the resistance b/w base region & collector terminal

r_{ce} is the resistance b/w collector region & emitter terminal

C_{bc} is the capacitance b/w base & collector junction

C_{be} is the capacitance b/w base & emitter junction

1. Transconductance (g_m) :-

It is defined as the ratio of change in collector current (I_c) due to change in $V_{b'e}$ across emitter junction.

$$g_m = \frac{\partial I_c}{\partial V_{b'e}}\Big|_{V_{CE}\ \text{constant}}$$

I/p conductance = $\frac{I_{i/p}}{V_{i/p}}$

O/p conductance = $\frac{I_{o/p}}{V_{o/p}}$

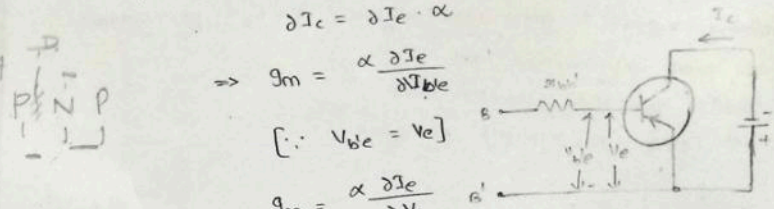
The collector current $I_c = \alpha I_e$

$$\partial I_c = \partial I_e \cdot \alpha$$

$$\Rightarrow g_m = \frac{\alpha\, \partial I_e}{\partial V_{b'e}}$$

$[\because V_{b'e} = V_e]$

$$g_m = \frac{\alpha\, \partial I_e}{\partial V_e}$$



The emitter diode resistance, $r_e = \frac{\partial V_e}{\partial I_e}$

$$\boxed{g_m = \frac{\alpha}{r_e}}$$

The forward dynamic resistance, $r_e = \frac{\eta V_T}{I_e}$

$\eta = 1$ for si ;

2 for Ge

V_T is the voltage equivalent of temperature

$$V_T = \frac{KT}{q} = 26\ mV$$

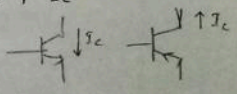
Consider silicon, $\eta = 1$

$$g_m = \frac{\alpha I_e}{V_T}$$

$$g_m = \frac{I_c}{V_T}$$

for npn , I_c is +ve ; pnp , I_c is -ve

$$g_m = \frac{|I_c|}{V_T} = \frac{|I_c|}{26mV}$$



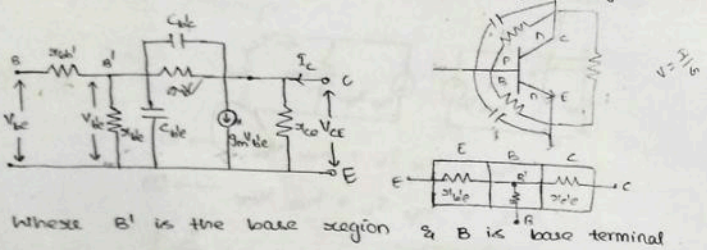
2. Input conductance (g_{be}) :-

for h-parameter model,

i/p impedence , $h_{ie} = \frac{V_{be}}{I_b}\Big|_{V_{CE}=0}$

The low frequency hybrid π model , $V_{CE} = 0$

* Hybrid π - model :- Hybrid π - model is valid for both LF & HF (Giacoletto model) when by removing the capacitance $C_{b'e}$, $C_{b'c}$ it acts for low frequency



Where B' is the base region & B is base terminal

g_m is transconductance

$r_{bb'}$ is the resistance b/w base region & base terminal

$r_{b'e}$ is the resistance b/w base region & emitter terminal

$r_{b'c}$ is the resistance b/w base region & collector terminal

r_{ce} is the resistance b/w collector region & emitter terminal

$C_{b'c}$ is the capacitance b/w base & collector junction

$C_{b'e}$ is the capacitance b/w base & emitter junction

1. Trans conductance (g_m) :-

It is defined as the ratio of change in collector current (I_c) due to change in $V_{b'e}$ across emitter junction

$$g_m = \frac{\partial I_c}{\partial V_{b'e}}\Big|_{V_{CE}\ \text{constant}}$$

I/p conductance = $\frac{I_{i/p}}{V_{i/p}}$

O/p conductance = $\frac{I_{o/p}}{V_{o/p}}$

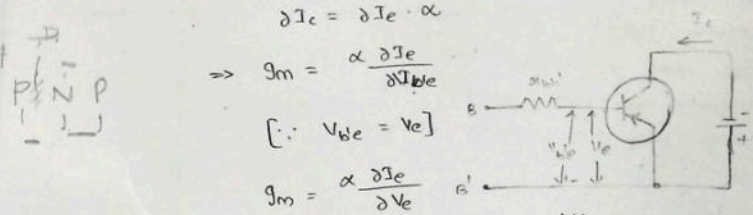
The collector current $I_c = \alpha I_e$

$$\partial I_c = \partial I_e \cdot \alpha$$

$$\Rightarrow g_m = \frac{\alpha\, \partial I_e}{\partial I_{b'e}}$$

$[\because V_{b'e} = V_e]$

$$g_m = \frac{\alpha\, \partial I_e}{\partial V_e}$$



The emitter diode resistance, $r_e = \frac{\partial V_e}{\partial I_e}$

$$\boxed{g_m = \frac{\alpha}{r_e}}$$

The forward dynamic resistance, $r_e = \frac{\eta V_T}{I_e}$

$\eta = 1$ for si ;

2 for Ge

V_T is the voltage equivalent of temperature

$$V_T = \frac{kT}{q} = 26\ mV$$

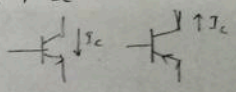
Consider silicon, $\eta = 1$

$$g_m = \frac{\alpha I_e}{V_T}$$

$$g_m = \frac{I_c}{V_T}$$

for npn , I_c is +ve ; PNP , I_c is -ve

$$g_m = \frac{|I_c|}{V_T} = \frac{|I_c|}{26mV}$$

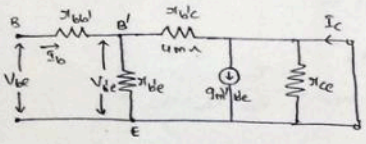


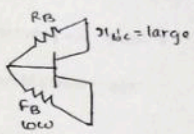
2. Input conductance ($g_{b'e}$) :-

for h-parameter model,

i/p impedence , $h_{ie} = \frac{V_{be}}{I_b}\Big|_{V_{CE}=0}$

The low frequency hybrid π model , $V_{CE} = 0$





generally $r_{b'c} >> r_{b'e}$ $\therefore r_{b'e}$ = small

$V_{b'e} = I_b \cdot r_{b'e}$

$\therefore I_c = g_m V_{b'e}$ [$\because V_{ce}$ is short circuited $\therefore r_{ce}$ becomes zero]

$I_c = g_m (I_b \cdot r_{b'e})$

$\frac{I_c}{I_b} = g_m \cdot r_{b'e}$

$h_{fe} = g_m \cdot r_{b'e}$

$r_{b'e} = \frac{h_{fe}}{g_m}$

$r_{b'e} = \frac{h_{fe}}{|I_c|} \cdot V_T$

$g_{b'e} = \frac{g_m}{h_{fe}}$

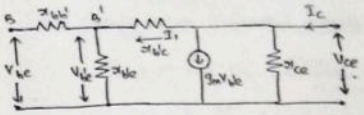
$$\boxed{g_{b'e} = \frac{|I_c|}{h_{fe} \cdot V_T}}$$

3. Feedback ~~capa~~ conductance ($g_{b'c}$) :-

From h-parameter model,

The reverse voltage gain, $h_{re} = \left.\frac{V_{be}}{V_{ce}}\right|_{I_B = 0}$

The low frequency hybrid π model when $I_B = 0$



$V_{ce} = I_1 (r_{b'c} + r_{b'e})$

$I_1 = \frac{V_{ce}}{r_{b'c} + r_{b'e}}$

$V_{b'e} = I_1 \cdot r_{b'e}$

$V_{b'e} = \frac{V_{ce} \cdot r_{b'e}}{r_{b'c} + r_{b'e}}$

$\frac{V_{b'e}}{V_{ce}} = \frac{r_{b'e}}{r_{b'c} + r_{b'e}}$

since $I_B = 0$; $V_{be} = V_{b'e}$

$\frac{V_{be}}{V_{ce}} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$

$h_{re} = \frac{r_{b'e}}{r_{b'e} + r_{b'c}}$

$h_{re} r_{b'e} + h_{re} r_{b'c} = r_{b'e}$

$h_{re} \cdot r_{b'c} = (1 - h_{re}) r_{b'e}$

$r_{b'c} = \frac{(1 - h_{re}) r_{b'e}}{h_{re}}$

$h_{re} << 1$ so $1 - h_{re} \simeq 1$

$\Rightarrow r_{b'c} = \frac{r_{b'e}}{h_{re}}$

$g_{b'c} = \frac{h_{re}}{r_{b'e}}$

$g_{b'c} = \frac{h_{re}}{h_{fe}} \cdot g_m$

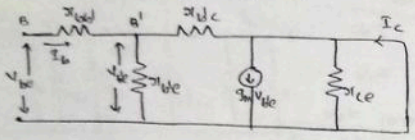
$\Rightarrow$ $$\boxed{g_{b'c} = \frac{h_{re}}{h_{fe}} \cdot \frac{|I_c|}{V_T}}$$

4. Base spreading resistance ($r_{bb'}$) :-

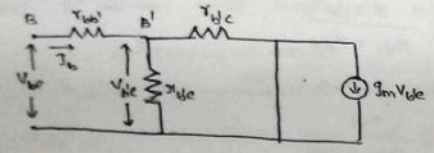
From h-parameter model,

the i/p impedance, $h_{ie} = \left.\frac{V_{be}}{I_b}\right|_{V_{ce}=0}$

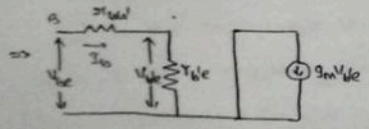
For the low frequency hybrid π model when $V_{ce} = 0$



As $V_{ce} = 0$



As $r_{b'c}$ & $r_{b'e}$ are parallel current flows only through smaller resistance i.e., $r_{b'e}$ in case of parallel connection



$$h_{ie} = r_{bb'} + r_{b'e}$$

$$r_{bb'} = h_{ie} - r_{b'e}$$

$$\boxed{r_{bb'} = h_{ie} - \frac{h_{fe}}{g_m}}$$

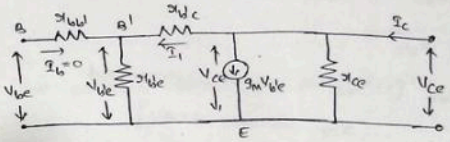
$$r_{bb'} = h_{ie} - \frac{h_{fe} V_T}{|I_{c1}|}$$

5. Output conductance (g_{ce}) :-

From h-parameter,

o/p admittance, $h_{oe} = \left.\frac{I_c}{V_{ce}}\right|_{I_b=0}$

The low frequency hybrid π model when $I_b = 0$



Apply KCL for o/p loop

$$I_c = \frac{V_{ce}}{r_{ce}} + g_m \cdot V_{b'e} + \frac{V_{ce}}{r_{b'e} + r_{b'c}}$$

$\longmapsto$ by current division rule

$$I_c = \frac{V_{ce}}{r_{ce}} + g_m \cdot \frac{V_{ce} \cdot r_{b'e}}{r_{b'e} + r_{b'c}} + \frac{V_{ce}}{r_{b'e} + r_{b'c}}$$

$$\frac{I_c}{V_{ce}} = \frac{1}{r_{ce}} + \frac{g_m \cdot r_{b'e}}{r_{b'e} + r_{b'c}} + \frac{1}{r_{b'e} + r_{b'c}}$$

$$= \frac{1}{r_{ce}} + \frac{h_{fe}}{r_{b'e} + r_{b'c}} + \frac{1}{r_{b'e} + r_{b'c}}$$

$$= \frac{1}{r_{ce}} + \frac{1 + h_{fe}}{r_{b'e} + r_{b'c}}$$

$h_{fe} > 1$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{h_{fe}}{r_{b'e} + r_{b'c}}$$

$$h_{oe} = \frac{1}{r_{ce}} + \frac{h_{fe}}{r_{b'c}} \qquad r_{b'e} \lll r_{b'c}$$

$$h_{oe} = g_{ce} + h_{fe} \cdot g_{b'c}$$

$$\boxed{g_{ce} = h_{oe} - h_{fe} \cdot g_{b'c}}$$

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* Hybrid π Capacitances :-

① Emitter Junction Capacitance : C_E (or) $C_{b'e}$ (or) C_{DE}

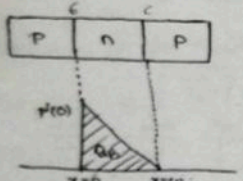


Fig:- Injected minority charge

When emitter base junction is forward biased, diffusion capacitance exist at emitter junction.

The charge stored in base region i.e.,

$$Q_B = \frac{1}{2} \cdot P'(0) \cdot A \cdot w \cdot q \longrightarrow (1)$$

where $\frac{1}{2} P'(0)$ - average concentration

w - width of base region

A - area of cross-section

q - electron charge

The diffusion current, $I = -Aq D_p \cdot \frac{dP}{dx}$

$$I = -Aq D_p \cdot \frac{P'(0) - 0}{0 - w}$$

$$I = Aq D_p \cdot \frac{P'(0)}{w}$$

$$P'(0) = \frac{I w}{Aq D_p} \longrightarrow (2)$$

from (1) & (2)

$$Q_B = \frac{1}{2} \cdot \frac{I \cdot w}{A q D_p} \cdot A \cdot w \cdot q$$

$$Q_B = \frac{I \cdot w^2}{2 D_p}$$

Diffusion capacitance, $C_{DE} = \frac{dQ}{dV}$

$$C_{DE} = \frac{w^2}{2 D_p} \cdot \frac{dI}{dV}$$

the emitter junction capacitance,

$$C_{DE} = \frac{w^2}{2 D_p} \cdot \frac{1}{r_e}$$

The emitter dynamic resistance, $r_e = \frac{\eta V_T}{I_e}$

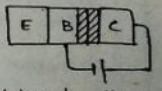
$$r_e = \frac{V_T}{I_e} \quad [\because \text{for Si}, \eta = 1]$$

$$C_{DE} = \frac{w^2}{2 D_p} \cdot \frac{I_e}{V_T}$$

$$g_m = \frac{|I_e|}{V_T} = \frac{I_e}{V_T}$$

$$C_{DE} > g_m \cdot \frac{I_e}{V_T} \qquad \boxed{C_{DE} = g_m \cdot \frac{w^2}{2 D_p}}$$

② Collector Junction Capacitance : C_c or $C_{b'c}$

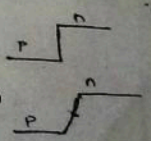


When collector base junction is reverse biased there exists a transition capacitance.

$$\boxed{C_{b'c} = \frac{1}{(V_{CB})^n}}$$

$n = \frac{1}{2}$, for abrupt junction

$n = \frac{1}{3}$, for graded junction



Typical values of Hybrid π parameters :-

S.No :	1	2	3	4	5	6	7
Parameter :	g_m	$r_{b'e}$	$r_{b'c}$	$r_{bb'}$	r_{ce}	$C_{b'e}$	$C_{b'c}$
Value :	50 mA/V	1 kΩ	4 MΩ	100Ω	80 kΩ	100 pf	3 pf

P:- The following low frequency parameters are given $I_c = 10\,mA$, $V_{ce} = 10V$ at room temperature $h_{ie} = 500\Omega$; $h_{oe} = 4\times10^{-5}$ A/V, $h_{fe} = 100$, $h_{re} = 10^{-4}$. Obtain hybrid π capacitance. Conductance.

Sol:- Transconductance, $g_m = \frac{|I_c|}{V_T} = \frac{10\times10^{-3}}{26\times10^{-3}} = 0.38\ \mho$

$$g_{b'e} = \frac{g_m}{h_{fe}} = \frac{0.385}{100} = 3.85\times10^{-3} = 3.85\,m$$

$$g_{b'c} = \frac{h_{re}}{h_{fe}}\cdot\frac{|I_c|}{V_T} = \frac{10^{-4}}{100}\times 0.38 = 0.38\,\mu$$

$$r_{bb'} = h_{ie} - \frac{h_{fe}}{g_m} = 500 - \frac{100}{0.38} = 236.84$$

$$g_{ce} = h_{oe} - h_{fe}\cdot g_{b'c} = 4\times10^{-5} - 100\times0.38\times10^{-6} = 2\,\mu$$

P:- The following low frequency parameters are given as $I_c = 8\,mA$, $V_{ce} = 10V$ at room temperature $h_{ie} = 1\,k\Omega$, $h_{oe} = 2\times10^{-5}$ A/V, $h_{fe} = 50$, $h_{re} = 2.5\times10^{-4}$, $f_T = 60\,MHz$. Obtain hybrid π capacitance. Conductance.

Sol:- $g_m = \frac{|I_c|}{V_T} = \frac{8\times10^{-3}}{26\times10^{-3}} = 0.307$

$$g_{b'e} = \frac{g_m}{h_{fe}} = \frac{0.307}{50} = 6.15\times10^{-3}$$

$$g_{b'c} = \frac{h_{re}}{h_{fe}}\cdot\frac{|I_c|}{V_T} = \frac{2.5\times10^{-4}}{50}\times 0.307 = 1.535\times10^{-6}$$

$$r_{bb'} = h_{ie} - \frac{h_{fe}}{g_m} = 1\times10^{3} - \frac{50}{0.307} = 837.13$$

$$g_{ce} = h_{oe} - h_{fe}\cdot g_{b'c} = 4\times10^{-5} - \frac{50}{100}\times1.535\times10^{-6} =$$

* Variation of Hybrid π parameters with I_c, V_{CE} & temperature

1. Trans conductance (g_m) :-

$$g_m = \frac{|I_c|}{V_T}$$

where $V_T = \frac{kT}{q} = \frac{T}{11,600} = 26\,mV$

$\Rightarrow g_m \propto I_c$, $g_m \propto \frac{1}{T}$

g_m is independent of V_{CE}.

2. Input conductance ($g_{b'e}$) :-

$$g_{b'e} = \frac{g_m}{h_{fe}} = \frac{|I_c|}{V_T\cdot h_{fe}}$$

$g_{b'e} \propto I_c$; $g_{b'e} \propto \frac{1}{T}$

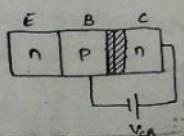
3. Output conductance ($g_{b'c}$) :-

$$g_{b'c} = \frac{h_{re}}{h_{fe}}\cdot g_m = \frac{h_{re}}{h_{fe}}\cdot\frac{|I_c|}{V_T}$$

$g_{b'c} \propto I_c$; $g_{b'c} \propto \frac{1}{T}$

4. Emitter Junction capacitance (C_e or $C_{b'e}$) :-

$$C_{b'e} = g_m\cdot\frac{\omega^2}{2D_p} = \frac{|I_c|}{V_T}\cdot\frac{\omega^2}{2D_p}$$



$C_{b'e} \propto I_c$; $C_{b'e} \propto \frac{1}{T}$

$C_{b'e}$ is independent of V_{CE}.

As collector to base reverse bias voltage increases the base width decreases & hence $C_{b'e}$ decreases.

5. Collector Junction capacitance (C_c (or) $C_{b'c}$) :-

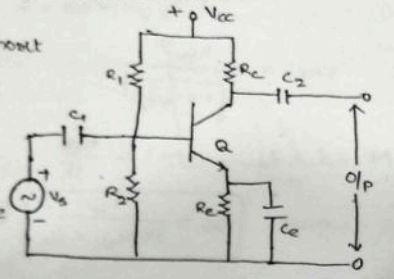
$$C_{b'c} \propto \frac{1}{(V_{cb})^n}$$

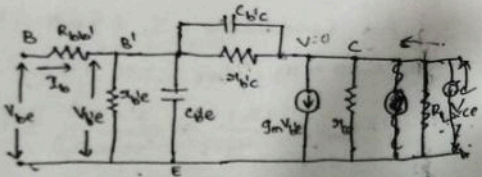
$$C_{b'c} \propto \frac{1}{(V_{ce})^n}$$

$C_{b'c}$ is independent of I_c & T.

* CE Short Circuit Current Gain :-

For fig ① when short circuit current gain analysis, $R_L = 0$ then R_{ce} becomes zero and $r_{b'e}$, $C_{b'c}$, $r_{b'c}$, $C_{b'e}$ appears in parallel hence the resultant equivalent circuit is ②





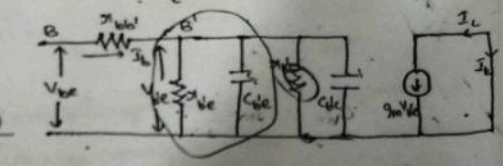
The final circuit is ③

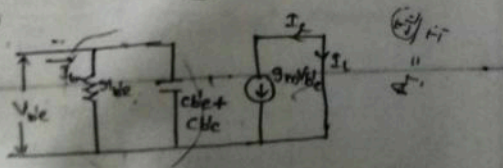
$$Z_{in} = r_{b'e} \,//\, (C_{b'e} + C_{b'c})$$

$$= r_{b'e} \,//\, \left(\frac{1}{j\omega(C_{b'e} + C_{b'c})}\right)$$

$$Z_{in} = \frac{r_{b'e} \times \frac{1}{j\omega(C_{b'e} + C_{b'c})}}{r_{b'e} + \frac{1}{j\omega(C_{b'e} + C_{b'c})}}$$

$$Z_{in} = \frac{r_{b'e}}{1 + j\omega\, r_{b'e}(C_{b'e} + C_{b'c})}$$





From equivalent circuit,

$$V_{b'e} = I_b \cdot Z_{in}$$

the current gain, $AI = \frac{I_L}{I_b}$

$$I_L = -I_c$$

$$I_c = g_m \cdot V_{b'e}$$

$$\Rightarrow AI = \frac{-g_m \cdot V_{b'e}}{I_b} = \frac{-g_m \cdot Y_b \cdot Z_{in}}{Y_b}$$

$$AI = -g_m \cdot \frac{r_{b'e}}{1 + j\omega\, r_{b'e}(C_{b'e} + C_{b'c})}$$

We have $r_{b'e} = \frac{h_{fe}}{g_m}$

$$\Rightarrow A \cdot I = -g_m \cdot \frac{h_{fe}/g_m}{1 + j\omega\, r_{b'e}(C_{b'e} + C_{b'c})}$$

$$A \cdot I = \frac{-h_{fe}}{1 + j\omega\, r_{b'e}(C_{b'e} + C_{b'c})}$$

$$AI = \frac{-h_{fe}}{1 + j 2\pi f\, r_{b'e}(C_{b'e} + C_{b'c})}$$

$$AI = \frac{-h_{fe}}{1 + j\left(f/f_\beta\right)}$$

where $f_\beta = \frac{1}{2\pi\, r_{b'e}(C_{b'e} + C_{b'c})}$

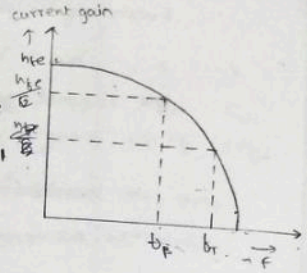
But here f_β is cut off frequency.

magnitude, $|AI| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_\beta}\right)^2}}$

At $f = 0$; $|AI| = h_{fe}$

$f = f_\beta$; $|AI| = \frac{h_{fe}}{\sqrt{2}}$

* β cut-off frequency :-



f_β is the frequency at which current gain is $\frac{1}{\sqrt{2}}$ value of h_{fe}

As frequency ↑, current gain ↓

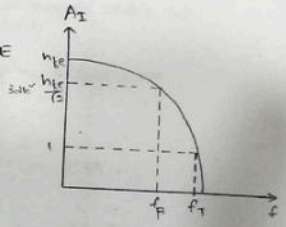
$$f_\beta = \frac{1}{2\pi r_{b'e}(C_{b'e} + C_{b'c})}$$

$$f_\beta = \frac{g_{b'e}}{2\pi (C_{b'c} + C_{b'c})}$$

* 3 dB = half power point

alilins $o/p = i/p$

* Unity Gain Frequency (f_T) :-



f_T is the frequency at which C.E S.C current gain is unity.

$$A_I = \frac{h_{fe}}{\sqrt{1 + (f/f_\beta)^2}}$$

At $f = f_T$; $|A_I| = 1$

$$1 = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f_T}{f_\beta}\right)^2}}$$

$\frac{f_T}{f_\beta} >> 1 \Rightarrow 1 = \frac{h_{fe}}{f_T/f_\beta} \Rightarrow \frac{f_T}{f_\beta} = h_{fe}$

$$\Rightarrow \boxed{f_T = f_\beta \cdot h_{fe}}$$

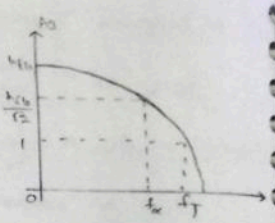
from β-cut off frequency we have,

$$f_\beta = \frac{1}{2\pi r_{b'e}(C_{b'e} + C_{b'c})} = \frac{g_m}{2\pi h_{fe}(C_{b'e} + C_{b'c})}$$

$$f_T = h_{fe} \cdot f_\beta = \frac{g_m}{2\pi (C_{b'e} + C_{b'c})}$$

$$\boxed{f_T = \frac{g_m}{2\pi C_{b'e}}} \quad [\because C_{b'e} >> C_{b'c}]$$

* α-cut-off frequency :- (f_α)



f_α is the frequency at which common base short circuit current gain is $\frac{1}{\sqrt{2}}$ of its h_{fb}

As frequency ↑, current gain ↓

$$A_I = \frac{-h_{fb}}{1 + j\cdot\frac{f}{f_\alpha}}$$

$$|A_I| = \frac{h_{fb}}{\sqrt{1 + \left(\frac{f}{f_\alpha}\right)^2}}$$

At $f = f_\alpha$, $|A_I| = \frac{h_{fb}}{\sqrt{2}}$

where $\boxed{f_\alpha = \frac{h_{fe}}{2\pi r_{b'e} C_{b'e}}}$ $[\because C_{b'e} >> C_{b'c}]$

$\left[\alpha = \frac{I_c}{I_E}\right]$

P:- For transistor $I_c = 2mA$, $V_{CE} = 10V$, $h_{fe} = 50$, $f_T = 50\ mHz$, $C_{b'c} = 3\ pf$. Find g_m, $r_{b'e}$, $C_{b'e}$, f_β & f_α

Soli:-

$$g_m = \frac{|I_c|}{V_T} = \frac{2\times10^{-3}}{26\times10^{-3}} = 0.0769\ A/V = 76.9\ mA/V$$

$$r_{b'e} = \frac{h_{fe}}{g_m} = \frac{50}{76.9\times10^{-3}} = 650\ \Omega$$

$C_{b'e}$ & $f_T = h_{fe}\cdot f_\beta$

$$\Rightarrow f_\beta = \frac{f_T}{h_{fe}} = \frac{50\times10^{-3}}{50} = 1m\ Hz$$

$$f_T = \frac{g_m}{2\pi (C_{b'e} + C_{b'c})} \Rightarrow 50\times10^{-3} = \frac{76.9\times10^{-3}}{2\times\pi(C_{b'e} + 3\times\ldots)}$$

$$0.314 = \frac{76.9\times10^{-3}}{C_{b'e} + 3\times10^{-12}} \Rightarrow C_{b'e} = 0.245 - 3\times\ldots$$

$$= 0.245$$

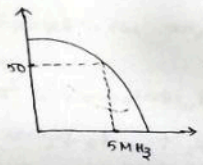
$$f_x = \frac{h_{fe}}{2\pi r_{b'e} C_{b'e}} = \frac{50}{2\times\pi\times 650\times}$$

=

Q:- The s.c current gain of CE amplifier is 50 at a frequency of 5 MHz, $f_\beta = 1$ MHz. Calculate f_T, H_{fe}, s.c current gain at $f = 100$ MHz.

Sol:-

$$|A_I| = \frac{h_{fe}}{\sqrt{1+\left(\frac{f}{f_\beta}\right)^2}}$$



$$50 = \frac{h_{fe}}{\sqrt{1+\left(\frac{5\times10^6}{1\times10^6}\right)^2}}$$

$$h_{fe} = 254.95$$

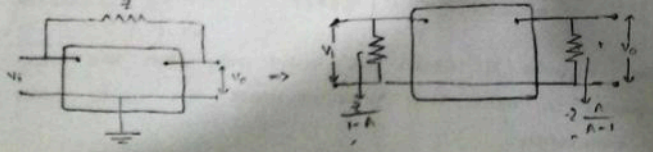
$$\Rightarrow f_T = h_{fe}\cdot f_\beta = 254.95 \times 1\times10^6$$

$$= 254.95\,MHz$$

$$\Rightarrow |A_I| = \frac{h_{fe}}{\sqrt{1+\left(\frac{f}{f_\beta}\right)^2}} = \frac{254.95}{\sqrt{1+\left(\frac{100\times10^6}{1\times10^6}\right)^2}} = 2.55$$

* Miller's Theorem :-

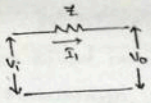
Miller's theorem states that if an impedence is connected b/w i/p & o/p terminals, then this impedance ge can be replaced by two equivalent impedences. One is connected at i/p side & other at o/p side.



where A is voltage gain. $\Rightarrow A = \frac{V_o}{V_i}$

Proof:-

$$I_1 = \frac{V_i - V_o}{Z} = \frac{V_i\left[1-\frac{V_o}{V_i}\right]}{Z}$$

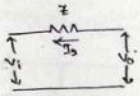


$$I_1 = \frac{V_i[1-A]}{Z}$$

$$\Rightarrow \frac{V_i}{I_1} = \frac{Z}{1-A}$$

$$\boxed{Z_1 = \frac{Z}{1-A}}$$

$$I_2 = \frac{V_o - V_i}{Z} = \frac{V_o\left[1-\frac{V_i}{V_o}\right]}{Z} = \frac{V_o\left[1-\frac{1}{A}\right]}{Z}$$

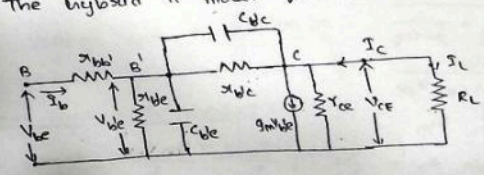


$$I_2 = \frac{V_o\left[\frac{A-1}{A}\right]}{Z} \Rightarrow \frac{V_o}{I_2} = Z\left[\frac{A}{A-1}\right]$$

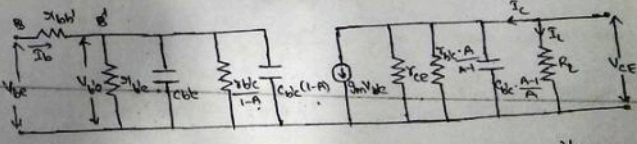
$$\boxed{Z_2 = Z\cdot\frac{A}{A-1}}$$

* Current Gain with Resistive Load :-

The hybrid π model for CE.



In the above circuit $R_{b'c}$ & $C_{b'c}$ are connected b/w i/p & o/p terminals. By using miller's theorem the above circuit is redrawn as shown in fig.



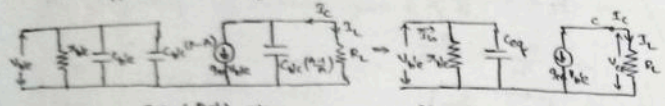
where A is voltage gain i.e., $A = \frac{V_{ce}}{V_{b'e}}$.

$r_{b'c} >> r_{b'e}$ so $\frac{r_{b'c}}{1-A}$ is neglected

$r_{b'c} >> r_{ce}$ so $r_{b'c} \cdot \frac{A}{1-A}$ is neglected

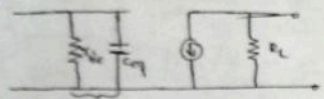
From typical values neglect r_{ce}.

The approximate equivalent circuit is



neglect $C_{b'c}\left(\frac{A-1}{A}\right)$ also

$C_{eq} = C_{b'e} + C_{b'c}(1-A)$



$C_{eq} = C_{b'e} + C_{b'c}(1+g_m R_L)$

Voltage gain, $A = \frac{V_{ce}}{V_{b'e}} = \frac{g_L \cdot R_L}{V_{b'e}}$

$A = \frac{-g_m V_{b'e} \cdot R_L}{V_{b'e}}$

$A = -g_m \cdot R_L$

$Z_{in} = r_{b'e} // C_{eq} = r_{b'e} // \frac{1}{j\omega C_{eq}}$

$Z_{in} = \frac{r_{b'e} \cdot \frac{1}{j\omega C_{eq}}}{r_{b'e} + \frac{1}{j\omega C_{eq}}}$

$Z_{in} = \frac{r_{b'e}}{1 + j\omega C_{eq} r_{b'e}}$

$V_{b'e} = I_b \cdot Z_{in}$

current gain, $A_I = \frac{I_L}{I_b} = \frac{-I_C}{I_b} = \frac{-g_m V_{b'e}}{I_b}$

$A_I = \frac{-g_m \cdot r_L \, Z_{in}}{r_L}$

$A_I = -g_m \cdot \frac{r_{b'e}}{1 + j\omega r_{b'e} C_{eq}}$

we know that $r_{b'e} = \frac{h_{fe}}{g_m}$

$A_I = \frac{-h_{fe}}{1 + j\frac{\omega}{g_m} r_{b'e} C_{eq}} = \frac{-h_{fe}}{1 + j f \cdot 2\pi r_{b'e} C_{eq}}$

$A_I = \frac{-h_{fe}}{1 + j\left(\frac{f}{f_H}\right)}$ where $f_H = \frac{1}{2\pi r_{b'e} C_{eq}}$

$= \frac{1}{2\pi r_{b'e}\left[C_{b'e} + C_{b'c}(1+g_m R_L)\right]}$

magnitude, $|A_I| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_H}\right)^2}}$

At $f = 0$; $|A_I| = h_{fe}$

At $f = f_H$; $|A_I| = \frac{h_{fe}}{\sqrt{2}}$

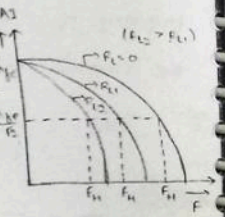
Variation of AI with R_L

$f_H = \frac{1}{2\pi r_{b'e}\left[C_{b'e} + C_{b'c}(1+g_m R_L)\right]}$

$R_L = 0 \Rightarrow f_H = \frac{1}{2\pi r_{b'e}\left[C_{b'e} + C_{b'c}\right]}$

$f_H = f_\beta$ $\quad f_\beta = \frac{1}{2\pi r_{b'e}(C_{b'e} + C_{b'c})}$

$R_L \uparrow$, $f_\beta \downarrow$



* Validity of hybrid π model :-

Hybrid π model is valid only when

$\left[2\pi f\left(\frac{\omega^2}{6 D_p}\right) << 1\right] \rightarrow ①$

$f_T = \frac{g_m}{2\pi C_{b'e}} \Rightarrow C_{b'e} = \frac{g_m}{2\pi f_T}$

$\therefore C_{b'e} = g_m \cdot \frac{\omega^2}{2 D_p}$

$\frac{C_{b'e}}{g_m} = \frac{\omega^2}{2 D_p} \Rightarrow \frac{C_{b'e}}{3 g_m} = \frac{\omega^2}{6 D_p}$

$\frac{g_m}{2\pi f_T} \times \frac{1}{3 g_m} = \frac{\omega^2}{6 D_p}$

$\frac{1}{6\pi f_T} = \frac{\omega^2}{6 D_p}$

① $\Rightarrow 2\pi f\left(\frac{1}{6\pi f_T}\right) << 1 \Rightarrow \frac{f}{3 f_T} << 1$

$\Rightarrow \boxed{f << 3 f_T}$

$C_{b'e} = \left[C_{b'e} = g_m \cdot \frac{\omega^2}{2 D_p}\right]$

$\Rightarrow \frac{C_{b'e}}{g_m} = \frac{\omega^2}{2 D_p}$

$\left[\frac{C_{b'e}}{3 g_m} = \frac{\omega^2}{6 D_p}\right]$

The hybrid π model is valid only when the input frequency is much less than 3 times the unity gain frequency.

* Frequency response of CE amplifier :-

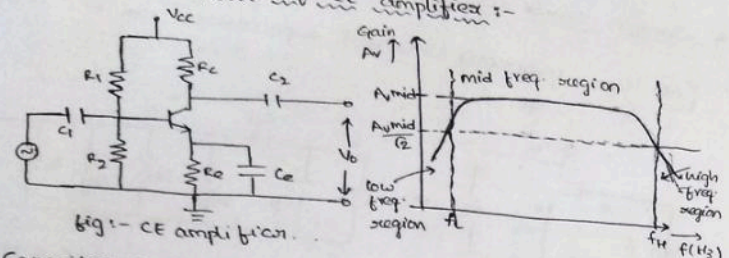


fig :- CE amplifier.

→ Capacitor C_1 blocks DC component present in the input signal & allows only AC component. If capacitor C_1 is not connected the Q point position will change.

→ capacitor C_2 blocks DC component & passes only AC component to the load or to the next stage.

→ Capacitor C_e : the by-pass capacitor provides low reactance path for amplified AC signal.

Here $R_1 > R_2$ → then only stability factor is less.

⇒ The frequency response is divided into three regions:

i) low frequency region
ii) mid frequency region
iii) high frequency region

1. low frequency region :- At low frequency region the gain decreases due to external capacitors (C_1, C_2, C_e).

2. High frequency region :- In high frequency region the gain decreases due to internal capacitors or parasitic capacitors (C_{be}, C_{bc}).

3. mid frequency region :- In mid frequency region, the gain constant, the effect of internal & external capacitors will be cancelled & the gain remains constant.

4/2/18

* Cut-off frequency :- The frequency at which amplifier gain is $\frac{1}{\sqrt{2}}$ of the maximum value.

* Bandwidth :- The range of frequencies over which the gain is constant.

$$B.W = f_H - f_L$$

$P = \frac{P_o}{P_i}$ — initially (V.V. small values)

$P = \log \frac{P_o}{P_i}$ Bel

$P = 10 \times \log \frac{P_o}{P_i}$ dB

⇒ Initially $P = \frac{P_o}{P_i}$

$P = \log \frac{P_o}{P_i}$ Bel

$P = 10 \times \log \frac{P_o}{P_i}$ dB

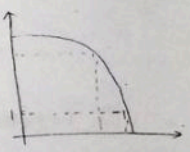
$P = \frac{V^2}{R} \Rightarrow P \propto V^2$; $P = I^2 R \Rightarrow P \propto I^2$

Voltage gain, $A_V = 20 \log \frac{V_o}{V_i}$

Current gain, $A_I = 20 \log \frac{I_o}{I_i}$

$$A_I = \frac{-h_{fe}}{1 + j\left(\frac{f}{f_\beta}\right)}$$

Gain Band width product :-



CE short circuit current gain,

$$|A_I| = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f}{f_\beta}\right)^2}}$$

At $f = f_T$; $|A| = 1$

$$\Rightarrow 1 = \frac{h_{fe}}{\sqrt{1 + \left(\frac{f_T}{f_\beta}\right)^2}}$$

As $\frac{f}{f_\beta} >> 1 \Rightarrow 1 = \frac{h_{fe}}{f_T / f_\beta} \Rightarrow \frac{f_T}{f_\beta} = h_{fe}$

$$\boxed{f_T = h_{fe} \cdot f_\beta}$$ where $f_\beta = \frac{1}{2\pi r_{b'e}(C_{b'e} + C_{b'c})}$

The above eqn indicates the gain band width product.

Note:- For an amplifier, the gain BW product should be as high as possible.

Ex:- A Ge pnp transistor operating in active region has base width of 2.5×10^{-4} cm at 300 k the emitter current $I_E = 4mA$. Find (a) Emitter junc. diffusion capacitance, C_{DE} (b) Frequency, f_T. Given that the diffusion constant D_p in n-type base is 50 cm^2/sec.

Sol:- (a) $C_{DE} = g_m \cdot \frac{W^2}{2D_p}$

$g_m = \frac{|I_{C1}|}{V_T} = \frac{I_E}{V_T} = \frac{4 \times 10^{-3}}{26 \times 10^{-3}} = 0.154$ A/V

$C_{DE} = 0.154 \times \frac{(2.5 \times 10^{-4})^2}{2 \times 50}$

$= 9.625 \times 10^{-11}$

(b) $f_T = \frac{g_m}{2\pi C_{DE}}$

$C_{DE} = \frac{g_m W^2}{2D_p} = 9.625 \times 10^{-11}$

$f_T = \frac{0.154}{2\pi \times 9.625 \times 10^{-11}} = 254.65$ MHz

* High Frequency FET model :-

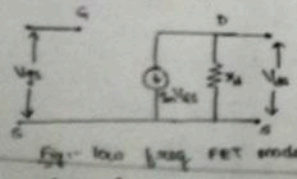
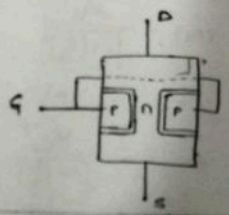


Fig:- low freq FET model



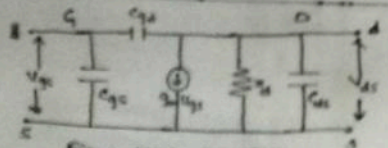
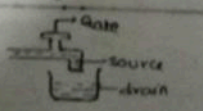
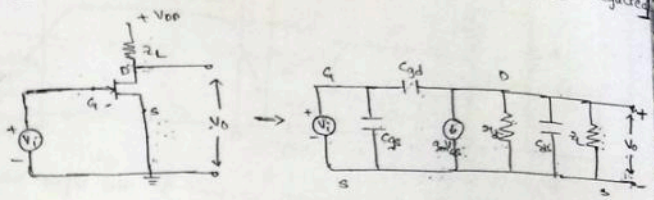


Fig :- High freq FET model



* Common Source (CS) FET Amplifier at high frequency :-

[At low frequency internal capacitances can be neglected]



By Norton's theorem, the equivalent circuit at D, G, S terminals are

→ To obtain norton's equivalent impedance at D & S all independent voltage sources are shorted & all independent current sources are opened.

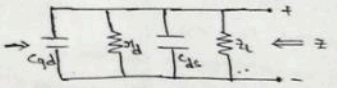


Fig:- Equivalent circuit to find 'z'.

The admittance, $Y = \frac{1}{Z} = \frac{1}{Z_L} + \frac{1}{r_d} + \frac{1}{1/j\omega C_{ds}} + \frac{1}{1/j\omega C_{gd}}$

$\Rightarrow Y = Y_L + g_d + Y_{ds} + Y_{gd}$

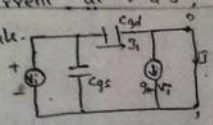
where $Y_L = \frac{1}{Z_L}$ is the admittance corresponds to Z_L.

$Y_{ds} = \frac{j\omega C_{ds}}{1}$ is the admittance corresponds to C_{ds}.

$g_d = \frac{1}{r_d}$ is the conductance corresponds to r_d

$Y_{gd} = j\omega C_{gd}$ is the admittance corresponds to C_{gd}

→ To obtain norton's equivalent current at D & S, short circuit the D & S terminals.



$I_1 = g_m V_i + I$

$V_i Y_{gd} = g_m V_i + I$

$I = -g_m V_i + V_i Y_{gd}$

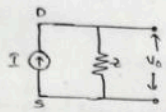
$I = V_i [-g_m + Y_{gd}]$

Voltage gain, $A_V = \frac{V_o}{V_i} = \frac{I \cdot Z}{V_i}$

$= \frac{I}{Y \cdot V_i}$

$= \frac{V_i [-g_m + Y_{gd}]}{Y \cdot V_i}$

$A_V = \frac{-g_m + Y_{gd}}{Y_L + g_d + Y_{ds} + Y_{gd}}$



For low frequencies,

$A_V = \frac{-g_m}{Y_L + g_d} = \frac{-g_m}{\frac{1}{Z_L} + \frac{1}{r_d}}$

$A_V = \frac{-g_m}{1/Z_L'}$

$\boxed{A_V = -g_m \cdot Z_L'}$

Common Drain FET Amplifier at high frequencies:-

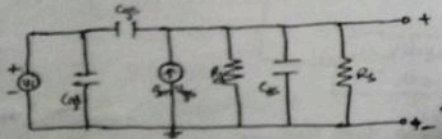
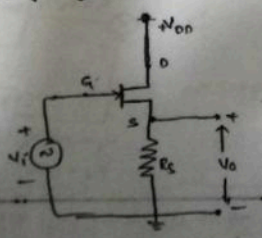
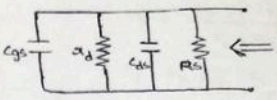


Fig:- high frequency CD equivalent ckt



→ To obtain norton's equivalent circuit at source & drain:

Equivalent circuit to find impedance is



admittance, $Y = \frac{1}{Z}$

$Y = \frac{1}{R_s} + \frac{1}{r_d} + \frac{1}{1/j\omega C_{ds}} + \frac{1}{1/j\omega C_{gs}}$

where $g_s = \frac{1}{R_s}$ is conductance corresponds to R_s

$g_d = \frac{1}{r_d}$ is conductance corresponds to r_d

$Y_{ds} = j\omega C_{ds}$ is admittance corresponds to C_{ds}

$Y_{gs} = j\omega C_{gs}$ is admittance corresponds to C_{gs}

To find norton's equivalent circuit at D & S terminals short circuit D & S terminal.

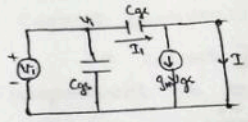


Fig:- to find I

Apply KCL,

$I_1 + g_m V_{GS} = I$

$V_i Y_{gs} + g_m V_{gs} = I$

From ckt, $V_{gs} = V_i - V_o$

$\Rightarrow I = g_m (V_i - V_o) + V_i Y_{gs}$

$I = g_m V_i - g_m V_o + V_i Y_{gs}$

From CS amplifier, $V_o = I \cdot Z = \frac{I}{Y}$

$V_o = \frac{g_m V_i - g_m V_o + V_i Y_{gs}}{Y}$

$V_o = \left[\frac{g_m + Y_{gs}}{Y}\right] V_i - \frac{g_m V_o}{Y}$

$V_o \left[1 + \frac{g_m}{Y}\right] = \left[\frac{g_m + Y_{gs}}{Y}\right] V_i$

Voltage gain, $\boxed{A_V = \frac{V_o}{V_i} = \frac{g_m + Y_{gs}}{g_m + Y}}$

$$A_V = \frac{g_m + j\omega C_{gs}}{g_m + g_s + g_d + y_{ds} + y_{gs}}$$

$$= \frac{g_m + j\omega C_{gs}}{g_m + g_d + j\omega C_{ds} + j\omega C_{gs} + \frac{1}{R_S}}$$

$$= \frac{g_m + j\omega C_{gs}}{g_m + g_d + (C_{ds} + C_{gs})j\omega + \frac{1}{R_S}}$$

$$= \frac{[g_m + j\omega C_{gs}]R_S}{1 + (g_m + g_d + j\omega C_T)R_S} \quad \text{where } C_T = C_{ds} + C_{gs}$$

At low frequencies,

$$A_V = \frac{g_m R_S}{1 + g_m R_S + g_d R_S} \quad [\because g_m R_S >> 1]$$

$$= \frac{g_m R_S}{g_m R_S + g_d R_S} = \frac{g_m}{g_m + g_d}$$

$$A_V = \frac{g_m}{g_d} \Big/ \frac{g_m}{g_d} + 1 = \frac{g_m r_d}{g_m r_d + 1}$$

$$\boxed{A_V = \frac{\mu}{\mu + 1}} \quad [\because \mu = g_m r_d]$$

7/12/2015

7/12/2015

FEEDBA

* Feedback :- T
output signal
→ Voltage gain
of an ampl
feedback.

i/p signa

→ Feed back

1. Negative
If
opposite
"Negative

x_s +

24/02/15

UNIT - 2

* MULTI STAGE AMPLIFIER *

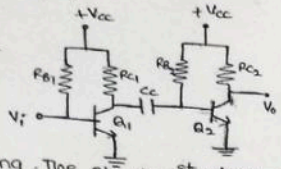
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1. To transfer AC o/p from one stage to i/p of 2nd stage.
2. To block DC from o/p of one stage to i/p of 2nd stage.

* Methods of coupling / Types of coupling :-

There are 4 coupling techniques.

1. Resistor - capacitor (RC) coupling :-

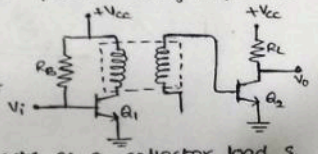


→ In RC coupling resistor, capacitor are used as coupling device. It is also known as capacitive coupling. The o/p of 1st stage is coupled to the i/p of 2nd stage using a capacitor Cc.

→ The coupling capacitor provides DC isolation from one stage to next stage.

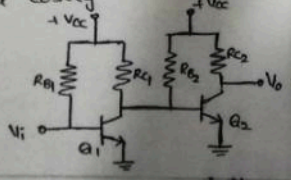
→ The capacitive coupling does not provide any impedance matching.

2. Transformer Coupling :-



→ In transformer coupling, transformer is used as coupling device. The primary winding of transformer acts as a collector load & the secondary winding transfers AC o/p signal directly to the base of 2nd stage. Transformer coupling provides impedance matching. It is bulky & costly.

3. Direct Coupling :-



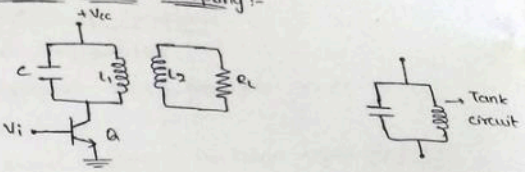
→ It is also called as DC coupling.

→ The o/p of 1st stage is directly coupled to the i/p of 2nd stage.

→ Due to direct coupling B.W increases but it doesn't provide dc isolation.

→ The Q-point will be shift & amplifier property will be changed.

4. Inductive coxl) Tuned coupling :-



→ Here the coupling device is tank circuit.

→ It is widely used in tuned amplifiers.

Formulas

* Gain in multi stage amplifiers :-

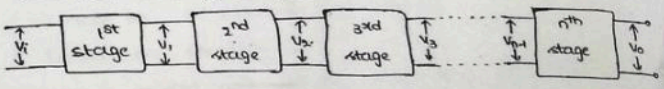


Fig :- n stage cascade amplifier

Voltage gain of 1st stage, $AV_1 = \frac{V_1}{V_i}$

2nd stage, $AV_2 = \frac{V_2}{V_1}$

3rd stage, $AV_3 = \frac{V_3}{V_2}$

⋮

nth stage, $AV_n = \frac{V_o}{V_{n-1}}$

Overall voltage gain, $A_{ov} = \frac{V_o}{V_i}$

$$A_{ov} = \frac{V_o}{V_i} = \frac{V_1}{V_i} \times \frac{V_2}{V_1} \times \frac{V_3}{V_2} \times \frac{V_4}{V_3} \times \cdots \times \frac{V_o}{V_{n-1}}$$

$$A_{ov} = AV_1 \cdot AV_2 \cdot AV_3 \cdots AV_n$$

The total voltage gain is the product of the overall voltage gain in individual stage.

→ If all stages are identical

$$A_{ov} = (A_V)^n$$

take log on both sides for eqn ③

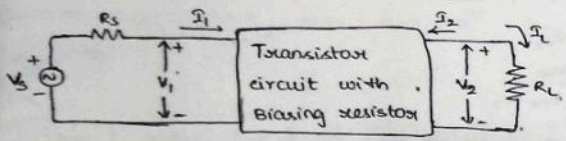
$$20\log_{10} A_{ov} = 20\log_{10}[A_{V_1} \cdot A_{V_2} \cdot A_{V_3} \cdots A_{V_n}]$$

$$= 20\log_{10} A_{V_1} + 20\log_{10} A_{V_2} + 20\log_{10} A_{V_3} + \cdots + 20\log_{10} A_{V_n}$$

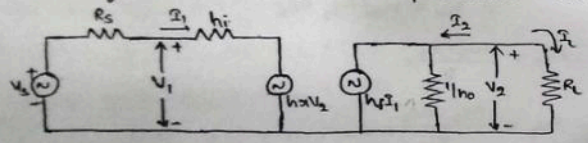
$$A_{ov}(dB) = A_{V_1}(dB) + A_{V_2}(dB) + A_{V_3}(dB) + \cdots + A_{V_n}(dB)$$

The overall voltage gain in dB is the voltage sum of individual voltage gains in dB.

* Analysis of Single Stage Amplifier :-



The equivalent circuit in h-parameter model is



Now current gain from equivalent circuit

Current gain :-

$$\text{current gain } (A_I) = \frac{I_L}{I_1}$$

$$A_I = \frac{-I_2}{I_1} \quad [\because I_L = -I_2]$$

From o/p circuit,

$$I_2 = h_f I_1 + h_o V_2$$

$$V_2 = -I_L R_L = -I_2 R_L$$

$$I_2(1 + h_o R_L) = h_f I_1$$

$$\frac{I_2}{I_1} = \frac{h_f}{1 + h_o R_L}$$

$$\therefore \boxed{A_I = \frac{-I_2}{I_1} = \frac{-h_f}{1 + h_o R_L}}$$

Input impedance :-

$$Z_i = \frac{V_1}{I_1}$$

From i/p circuit,

$$V_1 = h_i I_1 + h_r V_2$$

$$Z_i = \frac{h_i I_1 + h_r V_2}{I_1}$$

$$Z_i = h_i + h_r \cdot \frac{V_2}{I_1} \quad [\because V_2 = -I_2 R]$$

$$\Rightarrow Z_i = h_i + h_r \cdot \frac{-I_2 R_L}{I_1}$$

$$\therefore \boxed{Z_i = h_i + h_r A_I R_L}$$

Voltage Gain :-

$$A_V = \frac{V_2}{V_1} = \frac{-I_2 R_L}{V_1} = \frac{-I_2}{I_1} \cdot \frac{R_L}{\frac{V_1}{I_1}}$$

$$\boxed{A_V = \frac{A_I R_L}{Z_i}}$$

Output Admittance :-

$$Y_o = \frac{I_2}{V_2}\Big|_{V_s=0} = \frac{h_f I_1 + h_o V_2}{V_2}$$

$$Y_o = h_o + h_f \frac{I_1}{V_2}$$

from i/p circuit, $I_1 R_S + I_1 h_i + h_r V_2 = 0$

$$I_1(R_S + h_i) + h_r V_2 = 0$$

$$\frac{I_1}{V_2} = \frac{-h_r}{R_S + h_i}$$

$$\therefore \boxed{Y_o = h_o - \frac{h_f h_r}{R_S + h_i}}$$

2131

Note:-

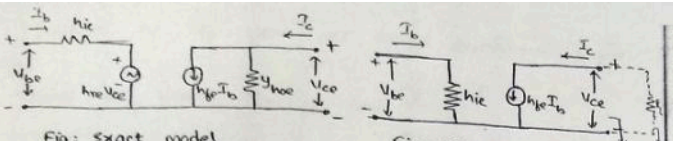


Fig: exact model

Fig:- approximate model

when $h_{oe} \cdot R_L < 0.1$, we use approximate model.

Approximate model :-

current gain, $A_I = -h_{fe}$ i/p resistance, $R_i = h_{ie}$

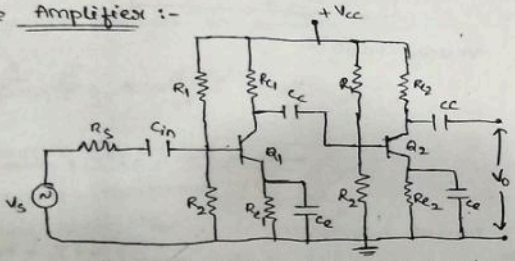
voltage gain, $A_V = \frac{A_I \cdot R_L}{R_i}$ o/p admittence, $Y_o = h_{oe} - \frac{h_{fe} h_{re}}{h_{ie} + R_g}$ (exact)

$Y_o = 0$, $R_o = \frac{1}{Y_o} = \infty$

→ when load, R_L is connected,

$R_o' = R_o \parallel R_L = \infty \parallel R_L = R_L$

* CE - CE Cascade Amplifiers :-



operation :-

→ Resistors R_1, R_2 provide required biasing for amplifier.

→ Emitter resistor is used as thermal stabilising resistance & emitter bipass capacitor, ce is used to provide low reactance path for amplified AC signal.

→ Coupling capacitor, C_c is used to block DC & allows AC signal to the next stage.

→ The i/p signal & o/p signal are in phase.

[even - in ϕ, odd - out ϕ]

Analysis :-

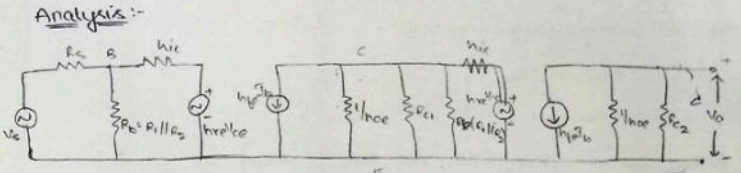


Fig :- h-parameter model

→ For h-parameter model, short circuit all the capacitors when supply given is AC.

Second stage analysis :-

Current gain, $A_{I_2} = \frac{-h_{fe}}{1 + h_{oe} R_L}$

$R_L = R_{C_2}$

$A_{I_2} = \frac{-h_{fe}}{1 + h_{oe} R_{C_2}}$

I/p resistance, $R_{i_2} = h_{ie} + h_{re} A_{I_2} \cdot R_L$

$= h_{ie} + h_{re} A_{I_2} R_{C_2}$

Voltage gain, $A_{V_2} = \frac{A_{I_2} \cdot R_L}{R_{i_2}}$

$A_{V_2} = \frac{A_{I_2} \cdot R_{C_2}}{R_{i_2}}$

O/p admittence, $Y_{o_2} = h_{oe} - \frac{h_{re} \cdot h_{fe}}{R_E + h_{ie}}$

$R_{O_2} = \frac{1}{Y_{o_2}}$

$R_{O_2}' = R_{O_2} \parallel R_{C_2}$

First stage analysis :-

current gain, $A_{I_1} = \frac{-h_{fe}}{1 + h_{oe} R_{L_1}}$

$R_{L_1} = R_{C_1} \parallel R_B \parallel R_{i_2}$

i/p resistance, $R_{i_1} = h_{ie} + h_{re} A_{I_1} R_{L_1}$

Voltage gain $A_{V_1} = \frac{A_{I_1} \cdot R_{L_1}}{R_{i_1}}$

O/p admittance $Y_{O1} = h_{oe} - \frac{h_{fe}\, h_{re}}{R_s + h_{ie}}$.

$R_{O1} = \frac{1}{Y_{O1}}$

$R_{O1}' = R_{O1} \| R_{C1}$.

Yoz/is

P:- A two stage CE-CE cascade amplifier has the following

first stage : $R_{C_1} = 10k\Omega$, $R_1 = 20k\Omega$, $R_2 = 200k\Omega$, $R_{E_1} = 10k\Omega$, $R_s = 1k\Omega$

second stage : $R_{C_2} = 2k\Omega$, $R_1 = 150k\Omega$, $R_2 = 300k\Omega$, $R_{E_2} = 100k\Omega$. Find voltage gain, current gain, i/p impedence, o/p admittance

Assume $h_{ie} = 1.2k\Omega$, $h_{re} = 2.5 \times 10^{-4}$, $h_{oe} = 25\mu A/V$, $h_{fe} = 50$

Sol:-

$h_{oe} \cdot R_L = h_{oe} \cdot R_{C_2} = 25 \times 10^{-6} \times 2 \times 10^3 = 0.05$

As $h_{oe} \cdot R_L < 0.1$, we use approximate model

Analysis of 2nd stage (CE) :-

current gain, $A_{I_2} = -h_{fe} = -50$

i/p resistance, $R_{i_2} = h_{ie} = 1.2k\Omega$

voltage gain, $A_{V_2} = \frac{A_{I_2} \cdot R_L}{R_{i_2}} = \frac{A_{I_2} \cdot R_{C_2}}{R_{i_2}} = \frac{-50 \times 2 \times 10^3}{1.2 \times 10^3}$

$= -83.3$

O/p admittance, $Y_{O_2} = 0$

$R_{O_2} = \frac{1}{Y_{O_2}} = \infty$

$R_{O_2}' = R_{O_2} \| R_{C_2} = R_{C_2} = 2k\Omega$

Analysis of 1st stage (CE) :-

current gain, $A_{I_1} = -h_{fe} = -50$

i/p resistance, $R_{i_1} = h_{ie} = 1.2k\Omega$

first stage load, $R_{L_1} = R_{C_1} \| R_1 \| R_2 \| R_{i_2}$

$R_{L_1} = 10k \| 50k \| 30k \| 1.2k$

$= \frac{10k \times 50k}{10k + 50k} \| 30k \| 1.2k$

$= \frac{500k \times 30k}{60k + 30k} \| 1.2k$

$= 1045.296\ \Omega$

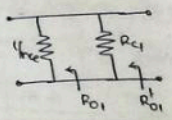
Voltage gain, $A_{V_1} = \frac{A_{I_1} \cdot R_{L_1}}{R_{i_1}} = \frac{-50 \times 1045.296}{1.2 \times 10^3}$

$= -43.554$

$Y_{O1} = 0$

$R_{O1} = \frac{1}{Y_{O1}} = \frac{1}{0} = \infty$

$R_{O1}' = R_O \| R_{C_1} = R_{C_1} = 10k\Omega$



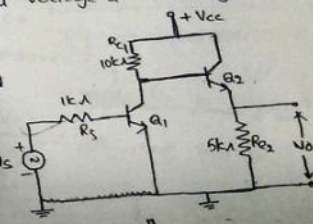
* CE-CC cascade Amplifiers :-

P:- A 2-stage CE-CC cascade amplifier is as shown in fig. has the following h-parameter values

CE : $h_{ie} = 2k$, $h_{fe} = 50$, $h_{re} = 6 \times 10^{-4}$, $h_{oe} = 25\mu A/V$

CC : $h_{ie} = 2k$, $h_{fe} = -51$, $h_{re} = 1$, $h_{oe} = 25\ \mu A/V$

calculate i i/p impedance ii o/p resistance iii individual voltage & current gain iv overall voltage & current gain.



Sol:- AC equivalent circuit :-

1. All capacitors are short circuited
2. DC voltage sources are grounded

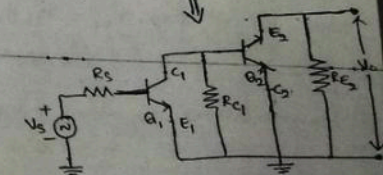


Fig:- AC equivalent circuit

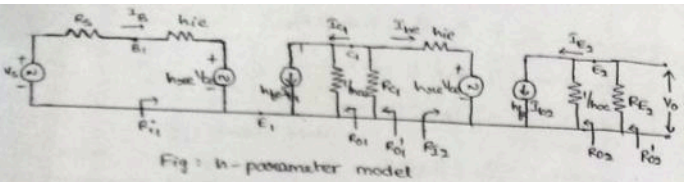


Fig: h-parameter model

$h_{oe} \cdot R_L = h_{oe} \cdot R_{E_2} = 25\times10^{-6} \times 5\times10^{3} = 0.125$

As $h_{oe} R_L > 0.1$, we use exact analysis

2nd stage analysis (C-C):-

Current gain, $AI_2 = \dfrac{-h_{fe}}{1+h_{oe}R_L} = \dfrac{-h_{fe}}{1+h_{oe}R_{E_2}}$ $[\because R_L = R_{E_2}]$

$AI_2 = \dfrac{+51}{1+25\times10^{-6}\times5\times10^{3}} = +45.33$

i/p resistance, $R_{i_2} = h_{ic} + h_{rc} \cdot AI_2 \cdot R_L = h_{ic} + h_{rc} \cdot AI_2 \cdot R_{E_2}$

$= 2\times10^{3} + 1\times(+45.33)\times5\times10^{3}$

$= +228.65\ k\Omega$

voltage gain, $A_{V_2} = \dfrac{AI_2 \cdot R_L}{R_{i_2}} = \dfrac{AI_2 \cdot R_{E_2}}{R_{i_2}}$

$= \dfrac{+45.33\times5\times10^{3}}{+228.65\times10^{3}} = \dfrac{-226.65}{228.65}$

$= -0.009 + 0.991$

Analysis of 1st stage:-

Current gain, $AI_1 = \dfrac{-h_{fe}}{1+h_{oe}R_{L_1}} = \dfrac{-50}{1+8.125} = \dfrac{-40.34}{9.13}$

$25\times10^{-6}\times10.46\times10^{3} = 9.58$

Load for 1st stage, $R_{L_1} = R_{C_1} \parallel R_{i_2} = 10k \parallel +228.65k$

$= 10.46k \quad 9.58\ k\Omega$

i/p resistance, $R_{i_1} = h_{ie} + h_{re} \cdot AS_1 \cdot R_{L_1}$

$= 2\times10^{3} + 6\times10^{-4}\times(-40.34)\times9.58\times10^{3}$

$= 1.768\ k\Omega$

voltage gain, $A_{V_1} = \dfrac{AI_1 \cdot R_{L_1}}{R_{i_1}} = \dfrac{(-40.34)\cdot(9.58)}{1.768\times10^{3}}$

$= -218.53$

o/p admittence, $Y_{01} = h_{oe} - \dfrac{h_{fe}\,h_{re}}{R_s + h_{ie}}$

$= 25\times10^{-6} - \dfrac{50\times6\times10^{-4}}{2\times10^{3}\times1\times10^{3}}$

$= 1.7\times10^{-5}\ \mho$

o/p resistance of transistor, $R_{01} = \dfrac{1}{Y_{01}} = 66666.667\ \Omega$

o/p resistance of amplifier, $R'_{01} = R_{01} \parallel R_{C_1} = 66666.667 \parallel 10k$

$R'_{01} = 8695.65\ \Omega$

o/p resistance of 2nd stage :- o/p resistance of 1st stage acts as source resistance for 2nd stage.

$R_{S_2} = R'_{01} = 8695.65$

$Y_{02} = h_{oc} - \dfrac{h_{fc}\cdot h_{rc}}{h_{ic} + R_{S_2}}$

$= 25\times10^{-6} - \dfrac{(-51)(1)}{2\times10^{3} + 8695.65}$

$= 4.793\ m\mho$

iv) overall voltage gain, $A_V = A_{V_1} \cdot A_{V_2}$

$= (-218.53)\cdot(0.991)$

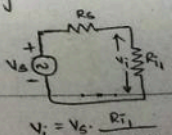
$= -216.56$

overall voltage gain (AVs) i.e., including source at Vs.

$A_{V_S} = \dfrac{V_o}{V_s} = \dfrac{V_o}{V_i} \times \dfrac{V_i}{V_s} = A_V \times \dfrac{V_i}{V_s}$

$A_{V_S} = -216.56 \times \dfrac{1.768\times10^{3}}{1.768\times10^{3} + 1\times10^{3}}$

$= -138.32$



$V_i = V_s \cdot \dfrac{R_{i_1}}{R_{i_1} + R_s}$

$\dfrac{V_i}{V_s} = \dfrac{R_{i_1}}{R_{i_1} + R_s}$

Overall current gain (A_I) :-

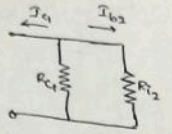
$$A_I = \frac{-I_{E_2}}{I_{B_1}} = \frac{-I_{E_2}}{I_{B_2}} \times \frac{I_{B_2}}{I_{B_1}} = \frac{-I_{E_2}}{I_{B_2}} \times \frac{I_{b_2}}{I_{C_1}} \times \frac{I_{C_1}}{I_{b_1}}$$

$$A_I = -A_{I_2} \cdot \frac{I_{b_2}}{I_{C_1}} \times A_{I_1}$$

$$A_I = A_{I_2} \cdot A_{I_1} \cdot \frac{R_{C_1}}{R_{C_1} + R_{i_2}}$$

$$= (45.33) \times (-40.34) \times \frac{10 \times 10^3}{10 \times 10^3 + 228.69 \times 10^3}$$

$$= -76.62$$



$$I_{b_2} = -I_{C_1} \cdot \frac{R_{C_1}}{R_{C_1} + R_{i_2}}$$

$$\frac{-I_{b_2}}{I_{C_1}} = \frac{R_{C_1}}{R_{C_1} + R_{i_2}}$$

Stability

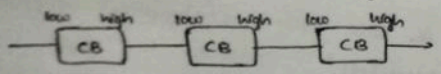
* Choice of transistor configuration in multi stage :-

The multi stage amplifier is divided into 3 stages.

1. i/p stage 2. o/p stage 3. Intermediate stage

Intermediate Stage :- The common collector (CC) configuration is not suitable for intermediate stage because the voltage gain, $A_V = 1$

→ The common base configuration is also not preferred for intermediate stage because the total voltage gain is equal to the gain of last stage alone.



Input & Output Stage :-

→ The main objective of i/p & o/p stages is "impedence matching" not the voltage gain.

→ For i/p stage either CB or CC configuration is preferred the similar choice is also made for o/p stage

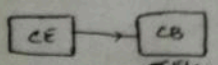


Fig:- cascade

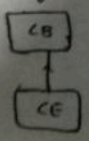


Fig : Cascode

* CE - CB Cascode Amplifier :-

One transistor amplifier is connected in series with on top of another is called as cascoding arrangement.

→ Cascoding Amplifier consists CE amplifier in series with CB amplifier.

→ The drawback of CB configuration is low impedance it is overcome by cascode arrangement.

→ The cascode arrangement provides better frequency response

→ To obtain AC equivalent circuit

↓ all capacitors are short circuited

↓↓ DC power supply, V_{cc} is grounded

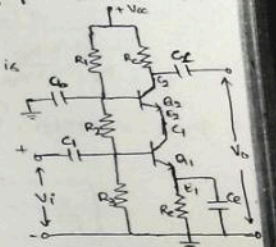


Fig:- CE-CB cascode Amplifier

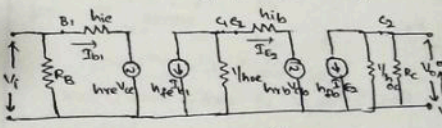


Fig:- h-parameter model

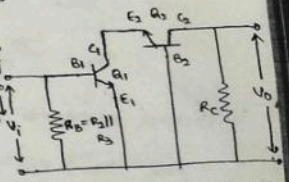


Fig:- AC equivalent circuit

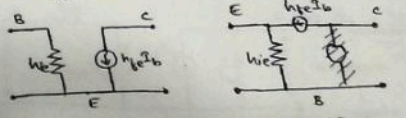


Fig:- CE

Fig:- CB

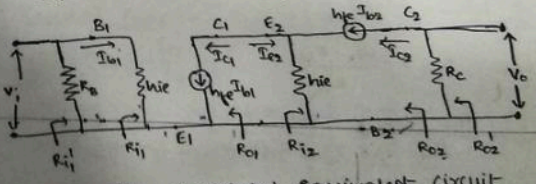


Fig:- simplified equivalent circuit

Analysis of 2nd stage (CB) :-

1. Current gain, $A_{I_2} = \frac{I_{c_2}}{I_{E_2}}$

$$= \frac{h_{fb} \cdot I_{b_2}}{(1+h_{fb}) I_{b_2}}$$

$$A_I = \frac{h_{fb}}{1+h_{fb}}$$

$I_E = I_c + I_b$

$\frac{I_E}{I_b} = \frac{I_c}{I_b} + 1$

$\frac{I_E}{I_b} = h_{fe} + 1$

$I_E = (1+h_{fe}) I_b$

2. Input resistance, $R_{i_2} = \frac{V_{be_2}}{I_{e_2}}$

$$= \frac{V_{be_2}}{(1+h_{fe}) I_{b_2}}$$

$$= \frac{h_{ie}}{1+h_{fe}}$$

$V_{be} = h_{ie} I_b$

$h_{ie} = \frac{V_{be}}{I_b}$

3. Voltage Gain, $A_{V_2} = \frac{A_{I_2} \cdot R_{L_2}}{R_{i_2}}$

$$A_{V_2} = \frac{A_{I_2} \cdot R_c}{R_{i_2}}$$

	CE	CB	CC
R_i	med	low	high
R_o	med	high	low
A_V	-	high	$\simeq 1$
A_I	-	$\simeq 1$	high

4. Output resistance, $R_{O_2} = \infty$

$R'_{O_2} = R_{O_2} \,||\, R_c = R_c$

Analysis of first stage (CE) :-

By using approximate model,

1. Current gain, $A_{I_1} = -h_{fe}$
2. i/p resistance, $R_{i_1} = h_{ie}$
3. Voltage gain, $A_{V_1} = \frac{A_{I_1} \cdot R_{L_1}}{R_{i_1}}$

$$A_{V_1} = \frac{A_{I_1} \cdot R_{i_2}}{R_{i_1}} = \frac{-h_{fe} R_{i_2}}{R_{i_1}}$$

4. o/p impedance, $R_{O_1} = \infty$

$R'_{O_1} = R_{O_1} \,||\, R_{i_2} = R_{i_2}$

5. Overall voltage gain :- $A_V = A_{V_1} \cdot A_{V_2}$

$$A_V = \frac{A_{I_2} \cdot R_c}{R_{i_2}} \times \frac{A_{I_1} R_{i_2}}{R_{i_1}}$$

$$A_V = \frac{A_{I_1} A_{I_2} R_c}{R_{i_1}}$$

* High input resistance circuits :-

For some applications it is necessary to have an amplifier with high input impedance. Emitter follower has high input impedance typically 500 kΩ.

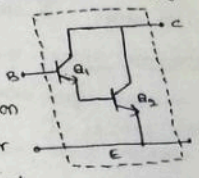
→ For achieving more input impedance the "Darlington Pair" is used.

→ Darlington pair consists of two cascaded cc configuration.

→ The voltage gain of the darlington pair is less than unity. since each transistor is in cc configuration

→ The current gain of Darlington pair is equal to the product of individual current gains.

→ Darlington pair is also called as "Compound Amplifier" (or) "Composite Amplifier."



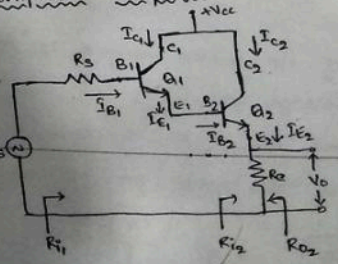


Fig:- Darlington Emitter Follower

Analysis of 2nd stage :-

$h_{oe} \cdot R_L < 0.1$

$h_{oe} \cdot R_E < 0.1$

The value of R_E is selected in such a way that $h_{oe} \cdot R_E < 1$. Hence we use approximate analysis.

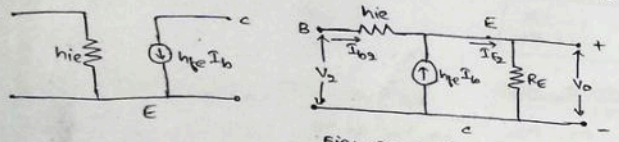


Fig:- Equivalent circuit for 2nd stage

1. Current gain :- $A_{I_2} = \frac{I_{e_2}}{I_{b_2}}$

Apply KCL,

$I_{b_2} + h_{fe} I_{b_2} = I_{e_2}$

$I_{E_2} = (1 + h_{fe}) I_{b_2}$

$A_{I_2} = \frac{(1 + h_{fe}) I_{b_2}}{I_{b_2}}$

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

2. Input resistance :- $R_{i_2} = \frac{V_2}{I_{b_2}}$

Apply KVL relation,

$V_2 = h_{ie} I_{b_2} + V_o$

$V_2 = h_{ie} I_{b_2} + I_{E_2} R_E$

$V_2 = h_{ie} I_{b_2} + (1 + h_{fe}) I_{b_2} \cdot R_E$

$V_2 = I_{b_2} [h_{ie} + (1 + h_{fe}) R_E]$

$\frac{V_2}{I_{b_2}} = h_{ie} + (1 + h_{fe}) R_E$

$R_{i_2} = h_{ie} + (1 + h_{fe}) R_E$

$\therefore \boxed{R_{i_2} \simeq (1 + h_{fe}) R_E}$

$\because h_{ie} <<< (1 + h_{fe}) R_E$

3. Voltage Gain :-

$A_{V_2} = \frac{A_{I_2} \cdot R_L}{R_{i_2}} = \frac{(1 + h_{fe}) R_E}{h_{ie} + (1 + h_{fe}) R_E}$

$1 - A_{V_2} = 1 - \frac{(1 + h_{fe}) R_E}{h_{ie} + (1 + h_{fe}) R_E}$

$1 - A_{V_2} = \frac{h_{ie}}{h_{ie} + (1 + h_{fe}) R_E}$

$1 - A_{V_2} = \frac{h_{ie}}{R_{i_2}} \Rightarrow \boxed{A_{V_2} = 1 - \frac{h_{ie}}{R_{i_2}}}$

Analysis of 1st stage :-

The i/p impedance of 2nd stage acts as load for 1st stage.

so, $h_{oe} \cdot R_L < 0.1$

but here $h_{oe} \cdot R_L > 0.1$

Hence use the exact analysis for 1st stage.

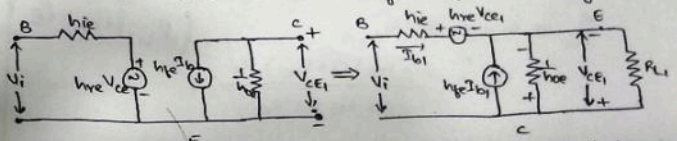


Fig:- Equivalent circuit for 1st stage

1. Current Gain :-

$A_{I_1} = \frac{I_{e_1}}{I_{b_1}}$

Apply KCL relations,

$-I_{b_1} + h_{fe} I_{b_1} + V_{CE_1} \cdot h_{oe} = I_{e_1}$

$I_{b_1} + h_{fe} I_{b_1} - I_{e_1} R_{L_1} \cdot h_{oe} = I_{e_1}$ $[\because V_{CE_1} = -I_{e_1} R_{L_1}]$

$I_{b_1} (1 + h_{fe}) = I_{e_1} (1 + h_{oe} R_{L_1})$

$$\frac{I_{e_1}}{I_{b_1}} = \frac{1+h_{fe}}{1+h_{oe}R_{L_1}}$$

$$A_{I_1} = \frac{1+h_{fe}}{1+h_{oe}\cdot R_{i_2}} = \frac{1+h_{fe}}{1+h_{oe}\cdot(1+h_{fe})R_E}$$

$$\boxed{A_{I_1} = \frac{1+h_{fe}}{1+h_{oe}\cdot h_{fe}\cdot R_E}} \quad [\because h_{fe} >>> 1]$$

2. Input Resistance :-

$$R_{i_1} = \frac{V_i}{I_{b_1}}$$

Apply KVL relations,

$$V_i = h_{ie} I_{b_1} + h_{re} V_{CE_1} - V_{CE_1}$$

$h_{re} << 1 \Rightarrow$ so neglect $h_{re} V_{ce_1}$

$$\Rightarrow V_i = h_{ie} I_{b_1} - V_{ce_1}$$

$$V_i = h_{ie} I_{b_1} + I_{e_1} R_{L_1} \quad [\because V_{ce_1} = -I_{e_1} R_{L_1}]$$

$$V_i = I_{b_1}\left[h_{ie} + \frac{I_{e_1}}{I_{b_1}} R_{L_1}\right]$$

$$\frac{V_i}{I_{b_1}} = h_{ie} + A_{I_1} R_{L_1} \qquad (R_{L_1} = (1+h_{fe})R_E)$$

$$= h_{ie} + \frac{(1+h_{fe})(1+h_{fe})\cdot R_E}{1+h_{oe}h_{fe}R_E}$$

$$R_{i_1} = h_{ie} + \frac{(1+h_{fe})^2 R_E}{1+h_{oe}h_{fe}R_E}$$

$$\boxed{R_{i_1} \simeq \frac{(1+h_{fe})^2 R_E}{1+h_{oe}h_{fe}R_E}}$$

3. Voltage Gain (A_{V_1}) :-

Similar as 1st stage,

$$A_{V_1} = 1 - \frac{h_{ie}}{R_{i_1}}$$

4. Overall Voltage Gain :-

$$A_V = A_{V_1}\cdot A_{V_2}$$

$$= \left(1 - \frac{h_{ie}}{R_{i_1}}\right)\left(1 - \frac{h_{ie}}{R_{i_2}}\right)$$

$$R_{i_1} >>> R_{i_2}$$

$$\rightarrow \boxed{A_V = 1 - \frac{h_{ie}}{R_{i_2}}}$$

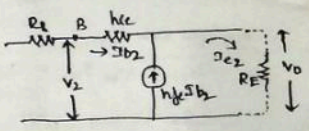
5. Overall Current Gain :-

$$A_I = A_{I_1}\cdot A_{I_2} = \frac{1+h_{fe}}{1+h_{oe}h_{fe}R_E}\cdot(1+h_{fe})$$

$$\boxed{A_I = \frac{(1+h_{fe})^2}{1+h_{oe}h_{fe}R_E}}$$

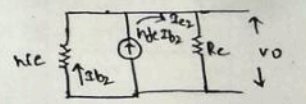
6. Output resistance (R_{O_2}) :-

$$R_{O_2} = \frac{V_o}{I_{E_2}}\Big|_{V_2=0}$$



$$R_{O_2} = \frac{V_o}{(1+h_{fe})I_{b_2}}$$

$$R_{O_2} = \frac{h_{ie}I_{b_2}}{(1+h_{fe})I_{b_2}}$$



$$R_{O_2} = \frac{h_{ie}}{1+h_{fe}}$$

By considering source resistance,

$$R_{O_2} = \frac{R_{S_2} + h_{ie}}{1+h_{fe}}$$

$$\text{I}^{\text{ly}} \quad \boxed{R_{O_1} = \frac{R_{S_1} + h_{ie}}{1+h_{fe}}}$$

$$\boxed{R_{O_2} = \frac{R_{S_2} + h_{ie}}{1+h_{fe}}}$$

Advantages :-

1. High input impedance
2. High current gain

Disadvantages :-

1. The leakage current of one transistor is amplified by the other amplifier thereby overall leakage current increases.
2. The biasing ntw consists of R_1 & R_2 appear in ||el with i/p impedance R_i i.e., effective resistance R_i is

$$R_i' = R_1 \,||\, R_1 \,||\, R_2 = R_i \,||\, R_B$$

$R_i >> R_B \Rightarrow R_i' \simeq R_B$ finally

The input impedance decreases.

We cannot avoid biasing resistors. By modifying the circuit the effect can be reduced.

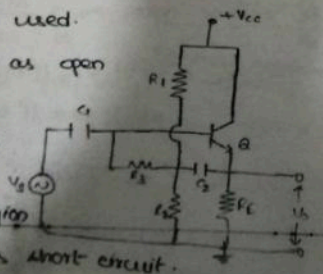
Applications

* Bootstrapped Emitter Follower :-

→ The input resistance of an emitter follower reduced due to biasing network, to overcome this problem Bootstrapping technique is used.

→ For DC signal, capacitor acts as open circuit.

→ so the resistances R_1, R_2, R_3 provides required biasing to keep the transistor in active region



→ For AC signal, capacitor acts as short circuit.

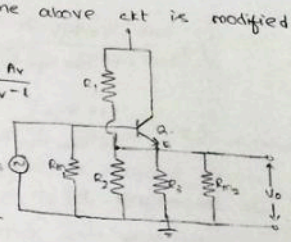
→ Hence one end of R_3 is connected to i/p & other end is connected to o/p

By using Miller's theorem, the above ckt is modified as

where $R_{m_1} = \frac{R_3}{1 - A_V}$, $R_{m_2} = \frac{R_3 A_V}{A_V - 1}$

for CC configuration $A_V \simeq 1$

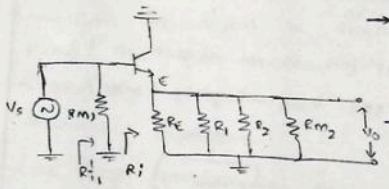
then $A_V \to 1$; $R_{m_1} = \infty$, $R_{m_2} = \infty$



→ AC equivalent for the circuit :-

→ V_{cc} is grounded

→ All capacitors are short circuited.



→ Effective i/p resistance,

$R_i' = R_i \,||\, R_{m_1} = R_1 \,||\, \infty$

$\Rightarrow R_i' = R_i$

→ Effective load resistance,

$R_L = R_E \,||\, R_1 \,||\, R_2 \,||\, R_{m_2}$

$R_L = R_E \,||\, R_1 \,||\, R_2$

Problems

P :- A Darlington pair has total input impedance 1.2 MΩ & total current gain 1130. Find emitter resistor R_E

Sol :- Given $R_i = 1.2\,M\Omega$, $A_I = 1130$, $R_E = ?$

method ① :- $A_V = \frac{A_I \cdot R_L}{R_I} = \frac{A_I R_E}{R_I}$

For CC configuration, $A_V \simeq 1$,

$$1 = \frac{A_I R_E}{R_I}$$

$$\Rightarrow R_E = \frac{R_I}{A_I} = \frac{1.2 \times 10^6}{1130} = 1061.946\ \Omega$$

$$R_E = 1.062\ k\Omega$$

method ② :-

Overall current gain, $A_I = A_{I_2} \cdot A_{I_1}$

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

$$A_{I_1} = \frac{1+h_{fe}}{1+h_{oe}h_{fe}R_E}$$

$$A_I = \frac{(1+h_{fe})^2}{1+h_{oe}h_{fe}R_E}$$

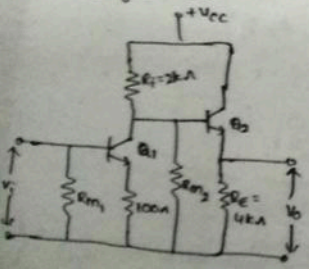
i/p impedance, $R_i' = \frac{(1+h_{fe})^2 R_E}{1+h_{oe}h_{fe}R_E}$

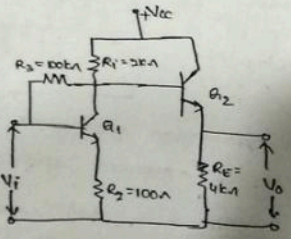
$$R_i = A_I R_E$$

$$R_E = \frac{R_i}{A_I} = \frac{1.2 \times M}{1130} = 1.062\,k\Omega$$

2. A two stage cascade amplifier is as shown in fig. Given $h_{ie} = 1.1k\Omega$, $h_{fe} = 150$ $h_{re} = h_{oe} = 0$. Find A_V, A_I, R_3, R_O

Sol:- By using miller's theorem, the above circuit is modified as





where $R_{m_1} = \frac{R_3}{1 - A_{V_1}}$

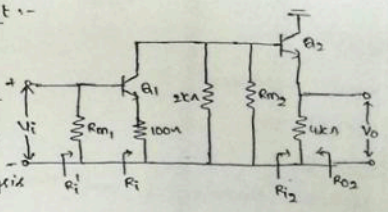
$$R_{m_2} = \frac{R_3 A_{V_1}}{A_{V_1} - 1}$$

where 1st stage is CE,

$A_V >> 1$

$R_{m_2} \simeq R_3$, $R_{m_2} \simeq 100k\Omega$

AC Equivalent Circuit :-



Analysis of 2nd stage (cc) :-

since $h_{oe} = 0$, $h_{oe} R_L < 0.1$

so we use approx. analysis

i. current gain, $A_{I_2} = 1 + h_{fe} = 1 + 50 = 51$

ii. i/p resistance, $R_{i_2} = h_{ie} + (1+h_{fe}) R_E$

$= 1.1k + (1+50) \times 4k$

$= 0.2051\,M\Omega$

iii. Voltage gain, $A_{V_2} = \frac{A_{I_2} \cdot R_L}{R_{i_2}} = \frac{A_{I_2} \cdot R_E}{R_{i_2}}$

$= \frac{51 \times 4k}{205100}$

$= 0.9946$

(b) Analysis of 1st stage :- (CE)

since $h_{oe} = 0$; we use approx. analysis $h_{oe} R_L < 0.1$

i. current gain, $A_{I_1} = -h_{fe} = -50$

ii. i/p resistance, $R_{I_1} = h_{ie} = 1.1k\Omega$

iii. Voltage gain, $A_{V_1} = \frac{A_{I_1} R_{L_1}}{R_{I_1}}$

$\Rightarrow R_{L_1} = 2k \,||\, R_{m_2} \,||\, R_{i_2}$

$= 2k \,||\, 100k \,||\, 0.2051M$

$\frac{1}{R_{L_1}} = \frac{1}{2k} + \frac{1}{100k} + \frac{1}{0.2051M} = 0.5148\,mmho$

$R_{L_1} = 1.942k\Omega$

$\Rightarrow A_{V_1} = \frac{-50 \times 1.942K}{1.1\,K} = -88.273$

Overall voltage gain, $A_{V_o} = A_{V_1} \cdot A_{V_2}$

$= -88.273 \times 0.9946$

$= -87.796$

Overall current gain, $A_I = A_{I_1} \cdot A_{I_2}$

$= -50 \times 51$

$= -2550$

Effective i/p impedance, $R_i' = R_{i_1} // R_{m_1}$

$R_{m_1} = \frac{R_3}{1 - A_{V_1}} = \frac{100k}{1 + 88.273} = 1.120\ k\Omega$

$R_i' = 1.1k // 1.120k$

$R_i' = 0.555k\Omega$

o/p resistance, $R_o = \frac{R_{s_2} + h_{ie}}{1 + h_{fe}}$

$R_o = \frac{1.94k + 1.1k}{1 + 50}$

$= 0.059k\Omega = 59\Omega$

* Frequency response of RC coupled amplifier :-

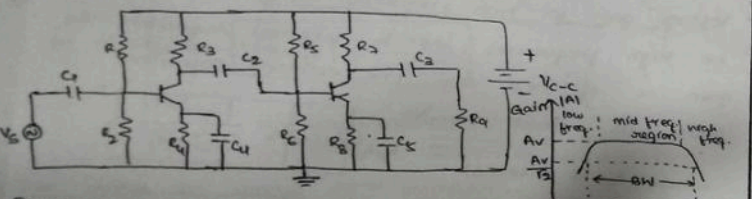


Fig:- Freq. response

→ Frequency response is a plot of amplifier gain against i/p signal frequency.

* Cut-off frequencies :- The frequency at which the gain is $\frac{1}{\sqrt{2}}$ of its maximum value.

f_1 → lower cut off freq.

f_2 → upper cut off freq.

These are also called as half power frequencies.

Bandwidth :- The range of frequency for which the gain is constant.

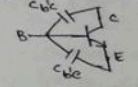
$BW = f_2 - f_1$

→ At low frequencies, the gain decreases due to external capacitors i.e., coupling capacitors & bypass capacitors.

→ At low frequencies, the capacitive reactance is extremely high. Hence most of the i/p signal is dropped across capacitor. Only a small portion of i/p signal is applied to the transistor. Hence gain decreases.

→ For low frequencies the bypass capacitor offers high reactance (CE doesn't act as short circuit). The amplified AC signal is dropped across C_e & R_e. Hence the gain decreases.

→ At high frequencies, the gain decreases due to internal capacitors.



→ At high frequencies, the capacitive reactance of junction capacitor is small and provides shunting effects at junctions. Hence gain decreases.

→ At high frequencies the coupling & bypass capacitors acts as short ckt & do not effect freq. response.

→ At mid frequency region, the gain is constant because external capacitors acts as SC & internal capacitors acts as O.C.

* Effect of coupling capacitors :-

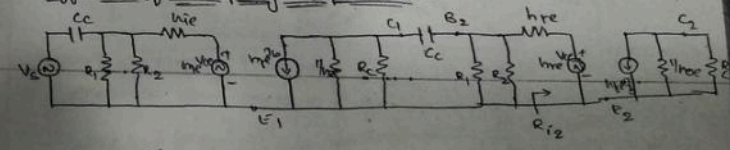


Fig:- Equivalent h-parameter model

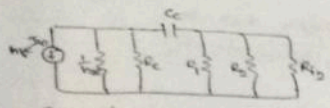


Fig:- 1st stage of op section & 2nd stage ip section

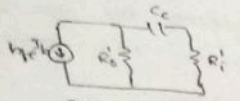


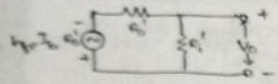
Fig:- simplified ckt

$R_o' = \frac{1}{h_{oe}} \| R_c$; $R_i' = R_1 \| R_2 \| R_{i2}$

* Voltage gain for mid frequency range :-

In mid frequency region, external capacitors acts as s.c & internal capacitors acts as o.c

Using source transformation,





Using voltage division,

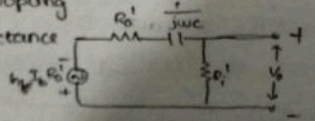
$$V_o = \frac{-h_{fe} I_b R_o' R_i'}{R_i' + R_o'}$$

$$\frac{V_o}{V_i} = \frac{-h_{fe} I_b R_o' \cdot R_i'}{(R_i' + R_o') V_i}$$

$$\boxed{A_{V_{mid}} = \frac{-h_{fe} I_b R_o' R_i'}{(R_i' + R_o') V_i}} \longrightarrow (1)$$

* Voltage gain for low frequency range :-

At low frequencies, the coupling capacitors offers high reactance



o/p voltage, $V_o = \frac{-h_{fe} I_b R_o' R_i'}{R_o' + R_i' + \frac{1}{j\omega c}}$ ... we can't neglect C_c because C_c offers high reactance $\uparrow X_c = \frac{1}{2\pi f c} \downarrow$

$$V_o = \frac{-h_{fe} I_b R_o' R_i'}{R_o' + R_i' \left[1 + \frac{1}{j\omega C_c (R_o' + R_i')}\right]}$$

$$\frac{V_o}{V_i} = \frac{\frac{-h_{fe} I_b R_o' R_i'}{(R_o' + R_i') V_i}}{1 - j \frac{1}{\omega C_c (R_o' + R_i')}}$$

$$A_{V_{low}} = \frac{A_{vmid}}{1 - j \frac{1}{2\pi f_c C_c (R_o' + R_i')}}$$

$$A_{V_{low}} = \frac{A_{vmid}}{1 - j \left(\frac{f_L}{f}\right)}$$

where $f_L = \frac{1}{2\pi C_c (R_o' + R_i')}$

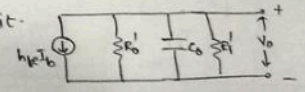
$$|A_{V_{low}}| = \frac{|A_{vmid}|}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}}$$

At $f = f_L$; $\boxed{|A_{V_{low}}| = \frac{|A_{vmid}|}{\sqrt{2}}}$

$$\frac{|A_{V_{low}}|}{|A_{vmid}|} = \frac{1}{\sqrt{2}} = 0.707$$

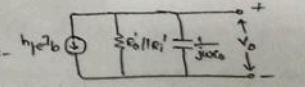
* Voltage gain for high frequency range :-

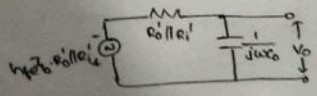
At high frequencies, due to internal capacitors the gain is effected and the external capacitors acts as short circuit.



where C_o is internal capacitor.

Using source transformation :-





By voltage division,

$$V_o = \frac{-h_{fe} I_b R_o' \| R_i' \cdot \frac{1}{j\omega C_o}}{R_o' \| R_i' + \frac{1}{j\omega C_o}}$$

$$V_o = \frac{-h_{fe} I_b \frac{R_o' \cdot R_i'}{R_o' + R_i'} \cdot \frac{1}{j\omega C_o}}{\frac{R_o' R_i'}{R_o' + R_i'} + \frac{1}{j\omega C_o}} = \frac{-h_{fe} I_b \cdot \frac{R_o' R_i'}{R_o' + R_i'} \cdot \frac{1}{j\omega C_o}}{\frac{1}{j\omega C_o}\left[1 + \frac{R_o' R_i'}{R_o' + R_i'} j\omega C_o\right]}$$

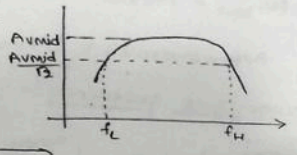
$$\frac{V_o}{V_i} = \frac{\frac{-h_{fe} I_b R_o' R_i'}{(R_o' + R_i') \cdot V_i}}{1 + j\omega C_o \frac{R_o' R_i'}{R_o' + R_i'}}$$

$$A_{v\,high} = \frac{A_{vmid}}{1 + j2\pi f C_o \frac{R_o' R_i'}{R_o' + R_i'}}$$

$$A_{v\,high} = \frac{A_{vmid}}{1 + j\left(\frac{f}{f_H}\right)}$$

where $f_H = \frac{1}{2\pi C_o \cdot \frac{R_o' R_i'}{R_o' + R_i'}}$

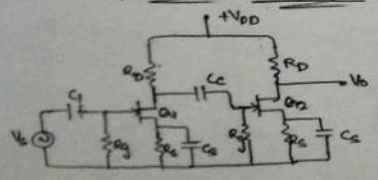
$$|A_{v\,high}| = \frac{|A_{vmid}|}{\sqrt{1 + \left(\frac{f}{f_H}\right)^2}}$$



At $f = f_H$; $\boxed{|A_{v\,high}| = \frac{|A_{vmid}|}{\sqrt{2}}}$

$$\frac{|A_{v\,high}|}{|A_{vmid}|} = \frac{1}{\sqrt{2}} = 0.707$$

* Two stage RC coupled FET amplifier :-



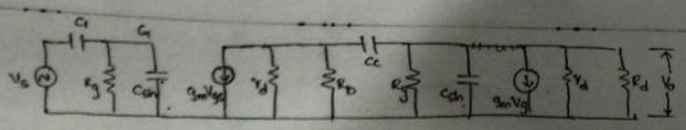


Fig:- small signal equivalent circuit

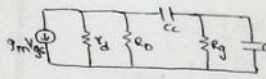
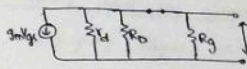


Fig:- o/p section of 1st stage
& i/p section of 2nd stage

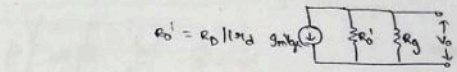
Cc - coupling capacitor
Csh - total shunt capacitor

* Voltage gain for mid frequency range :-

For mid frequency region, Cc acts as S.C & Csh acts as O.C

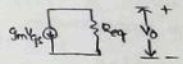


$R_o' = R_D \| r_d$



$V_o = -g_m V_{gs} R_{eq}$ $\quad R_{eq} = R_o' \| R_g$

$= r_d \| R_D \| R_g$

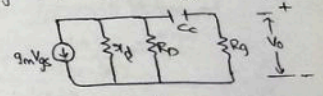


$\frac{V_o}{V_{gs}} = -g_m R_{eq}$ $\quad (V_i = V_{gs})$

$\boxed{A_{vmid} = -g_m R_{eq}}$

* Voltage gain for low frequency range :-

At low frequencies, coupling capacitors offers high reactance & Csh as O.C

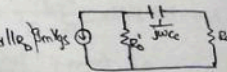


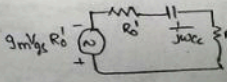
$$V_o = \frac{-g_m V_{gs} R_o' R_g}{R_o' + R_g + \frac{1}{j\omega C_c}}$$

$$= \frac{-g_m R_o' R_g'}{(R_o' + R_g')\left[1 + \frac{1}{j\omega C_c (R_o' + R_g')}\right]}$$

$$= \frac{-g_m \frac{R_o' R_g'}{R_o' + R_g'}}{1 - j\frac{1}{2\pi f C_c (R_o' + R_g')}}$$

$R_o' = r_d \| R_D$





$$A_{v\,low} = \frac{A_{vmid}}{1 - j\left(\frac{f_L}{f}\right)} \quad \text{where } f_L = \frac{1}{2\pi C_c (R_o' + R_g')}$$

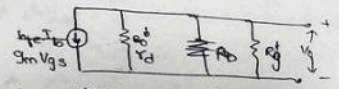
$$|A_{V_{low}}| = \frac{|A_{vmid}|}{\sqrt{1+\left(\frac{f_L}{f}\right)^2}}$$

At $f = f_L$, $\boxed{|A_{V_{low}}| = \frac{|A_{vmid}|}{\sqrt{2}}}$

$$\frac{|A_{V_{low}}|}{|A_{vmid}|} = \frac{1}{\sqrt{2}} = 0.707$$

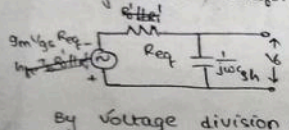
* Voltage gain for high frequency range :-

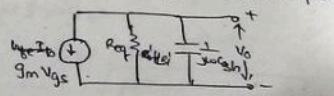
At high frequencies, due to internal capacitors the gain is effected & the external capacitors act as s.c



where c_o is internal capacitor

Using source transformation,





By voltage division,

$$V_o = \frac{-g_m V_{gs} \cdot R_{eq} \cdot \frac{1}{j\omega C_{sh}}}{R_{eq} + \frac{1}{j\omega C_{sh}}} = \frac{-h_{fe} I_b \frac{R_o' R_i'}{R_o' + R_i'} \cdot \frac{1}{j\omega C_o}}{\frac{R_o' R_i'}{R_o' + R_i'} + \frac{1}{j\omega C_o}}$$

$$\frac{V_o}{V_i} = \frac{-h_{fe} I_b \frac{R_o' R_i'}{(R_o' + R_i') V_i} R_{eq} \cdot \frac{1}{j\omega C_{sh}}}{1 + j\omega C_o \cdot \frac{R_o' R_i'}{R_o' + R_i'} \frac{1}{j\omega C_{sh}} \left[1 + j\omega C_{sh} R_{eq}\right]}$$

$$A_{V_{high}} = \frac{A_{vmid} - g_m R_{eq}}{1 + j 2\pi f C_o \frac{R_o' R_i'}{R_o' + R_i'} \, j\omega C_{sh} R_{eq}} = \frac{A_{vmid}}{1 + j\left(\frac{f}{f_H}\right)}$$

where $f_H = \frac{1}{2\pi C_o \frac{R_o' R_i'}{R_o' + R_i'}}$ $\quad f_H = \frac{1}{2\pi C_{sh} R_{eq}}$

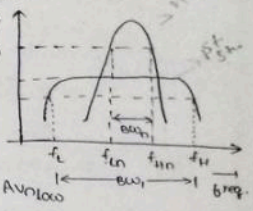
$$|A_{V_{high}}| = \frac{|A_{vmid}|}{\sqrt{1+\left(\frac{f}{f_H}\right)^2}}$$

At $f = f_H$, $\boxed{|A_{V_{high}}| = \frac{|A_{vmid}|}{\sqrt{2}}}$

$$\frac{|A_{V_{high}}|}{|A_{vmid}|} = \frac{1}{\sqrt{2}} = 0.707$$

* Effect of Cascading on Bandwidth :-

The overall gain of cascading Gain amplifier is equal to the product of individual gains.



$A_{V_{low}(overall)} = A_{V_1 low} \times A_{V_2 low} \times \cdots \times A_{V_n low}$

For identical stages,

$A_{V_1 low} = A_{V_2 low} = \cdots = A_{V_n low}$

$A_{V_{low}(overall)} = (A_{V_{low}})^n$

lower 3dB frequency :-

$$\frac{(A_{V_{low}})_{overall}}{A_{V\,mid}} = \left(\frac{A_{V_{low}}}{A_{vmid}}\right)^n = \frac{1}{\left[1 - j\left(\frac{f_L}{f}\right)\right]^n}$$

$$\frac{|A_{V_{low}}|_{overall}}{|A_{vmid}|} = \frac{1}{\left(\sqrt{1+\left(\frac{f_L}{f}\right)^2}\right)^n}$$

at $f = f_{Ln}$, $\frac{|A_{V_{low}}|_{overall}}{|A_{vmid}|} = \frac{1}{\sqrt{2}}$

$$\frac{1}{\sqrt{2}} = \frac{1}{\left(\sqrt{1+\left(\frac{f_L}{f_{Ln}}\right)^2}\right)^n}$$

squaring 0.S.B

$$\frac{1}{2} = \frac{1}{\left[1+\left(\frac{f_L}{f_{Ln}}\right)^2\right]^n}$$

$$2 = \left[1+\left(\frac{f_L}{f_{Ln}}\right)^2\right]^n$$

$$2^{1/n} = 1 + \left(\frac{f_L}{f_{Ln}}\right)^2$$

$$2^{1/n} - 1 = \left(\frac{f_L}{f_{Ln}}\right)^2$$

$$\frac{f_L}{f_{Ln}} = \sqrt{2^{1/n} - 1}$$

$$\boxed{f_{Ln} = \frac{f_L}{\sqrt{2^{1/n} - 1}}}$$

where f_L is lower 3 dB freq. of single stage
f_{Ln} is lower 3 dB freq. of multistage
n is no. of stages.

Upper 3 dB frequency :-

$$\frac{(A_{v\,high})_{overall}}{(A_{vmid})} = \left(\frac{A_{v\,high}}{A_{vmid}}\right)^n$$

$$= \frac{1}{\left(1 + j\frac{f}{f_H}\right)^n}$$

$$\frac{|A_{v\,high}|_{overall}}{|A_{vmid}|} = \frac{1}{\left(\sqrt{1 + \left(\frac{f}{f_H}\right)^2}\right)^n}$$

at $f = f_{Hn}$; $\frac{|A_{v\,high}|_{overall}}{|A_{vmid}|} = \frac{1}{\sqrt{2}}$

$$\therefore \frac{1}{\sqrt{2}} = \frac{1}{\left(\sqrt{1 + \left(\frac{f_{Hn}}{f_H}\right)^2}\right)^n}$$

S.O.B.S

$$\frac{1}{2} = \frac{1}{\left[1 + \left(\frac{f_{Hn}}{f_H}\right)^2\right]^n}$$

$$2 = \left[1 + \left(\frac{f_{Hn}}{f_H}\right)^2\right]^n$$

$$2^{1/n} = 1 + \left(\frac{f_{Hn}}{f_H}\right)^2$$

$$2^{1/n} - 1 = \left(\frac{f_{Hn}}{f_H}\right)^2$$

$$\frac{f_{Hn}}{f_H} = \sqrt{2^{1/n} - 1}$$

$$f_H = \frac{f_{Hn}}{\sqrt{2^{1/n} - 1}}$$

$$\boxed{f_{Hn} = \sqrt{2^{1/n} - 1} \cdot f_H}$$

where f_H is upper 3 dB freq. of single stage.
f_{Hn} is upper 3 dB freq. of multi stage
n is no. of stages.

Note:-

1. Voltage gain for non-identical stages

$$A_{overall} = A_1 \cdot A_2 \cdot A_3 \cdots A_n$$

2. lower 3 dB freq. for non-identical stages

$$f_{Ln} = \sqrt{f_{L1}^2 + f_{L2}^2 + \cdots + f_{Ln}^2}$$

3. Upper 3 dB freq. for non-identical stages

$$f_{Hn} = \sqrt{\left(\frac{1}{f_{H1}}\right)^2 + \left(\frac{1}{f_{H2}}\right)^2 + \cdots + \left(\frac{1}{f_{Hn}}\right)^2}$$

P:- A single stage CE amplifier has voltage gain 12 and lower cut off frequency 200 Hz & upper cut off frequency 5 kHz. If five such stages are connected in cascade connection. Calculate total gain, bandwidth.

Sol:- Given $A_V = 12$

$f_L = 200$ Hz

$f_H = 5$k Hz

$(A_{V(Low)})_{overall} = (A_{V(Low)})^n$

$= (12)^5$

$= 248832$

$f_{Ln} = \frac{f_L}{\sqrt{2^{1/n}-1}}$

$f_{Ln} = \frac{200}{\sqrt{2^{1/5}-1}} = 512.69$ Hz

$f_{Hn} = f_H \sqrt{2^{1/n}-1}$

$= 5 \cdot k \sqrt{2^{1/5}-1}$

$f_{Hn} = 1.928$ k Hz

$\therefore$ Bandwidth $= f_{Hn} - f_{Ln}$

$= 1.928\,k - 518.65$

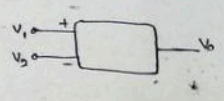
$= 1409.35$ Hz

$= 1.409$ k Hz

Soln:-

* Differential Amplifier :-

An amplifier which amplifies the difference b/w two input signals is called as differential amplifier.



→ For an ideal differential amplifier the output voltage is directly proportional to the difference between the two signals.

$$V_0 \propto (V_1 - V_2)$$

* Differential mode gain (A_d) :-

$V_0 = A_d \cdot (V_1 - V_2)$

$$A_d = \frac{V_0}{V_1 - V_2}$$

let differential voltage, $V_d = V_1 - V_2$

$$\Rightarrow A_d = \frac{V_0}{V_d}$$

where A_d is called differential mode gain

In general A_d is expressed in dB's

$\Rightarrow A_d$ in dB $= 20 \log (A_d)$ dB.

* Common mode gain (A_c) :-

When same input signals are applied to the differential amplifier i.e., $V_1 = V_2$.

Ideally, the o/p voltage, $V_0 = A_d(V_1 - V_2)$

i.e., $V_0 = 0$ $[\because V_1 = V_2]$

But for practical differential amplifier the o/p not only depends on differential i/p's but also depends on average common level of 2 signals i.e., common mode signal, $V_c = \frac{V_1 + V_2}{2}$ $\Rightarrow V_0 = A_c \cdot V_c$

where A_c is common mode gain

The total output of differential amplifier is

$$V_o = A_d V_d + A_c V_c$$

* Common Mode Rejection Ratio (CMRR) :-

The ability of an amplifier to reject common mode signal is ~~called~~ expressed by a ratio called Common Mode Rejection Ratio (CMRR).

→ It is defined as the ratio of differential mode gain to the common mode gain.

$$CMRR = \rho = \left| \frac{A_d}{A_c} \right|$$

Ideally, common mode gain, $A_c = 0$

$\Rightarrow$ "CMRR $= \infty$"

Practically, differential gain is high & common mode gain is low.

$\therefore$ "CMRR is high."

→ CMRR in dB $= 20 \log \left(\frac{A_d}{A_c} \right)$

* Configurations of differential amplifier :-

1. Dual i/p, balanced o/p
2. Dual i/p, unbalanced o/p
3. Single i/p, balanced o/p
4. Single i/p, unbalanced o/p

1. Dual i/p, balanced o/p :-

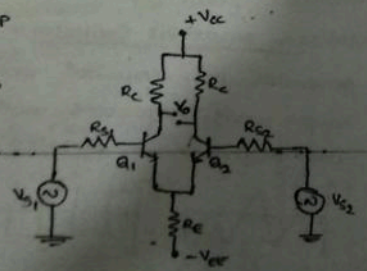


Fig :- dual i/p, balanced o/p

2. Dual i/p unbalanced o/p :-

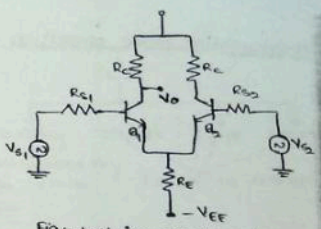
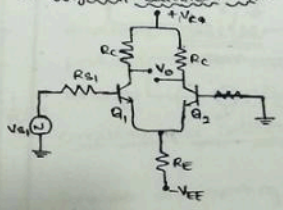
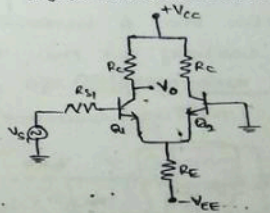


Fig :- dual i/p unbalanced o/p

3. Single i/p balanced o/p :-



4. Single i/p unbalanced o/p :-



Q :- The bandwidth of an amplifier is from 15 Hz to 30k Hz. Find the range of frequencies for which gain drops by 0.5 dB from its mid band value.

Sol :- Given $f_L = 15$ Hz, $f_H = 30$ kHz

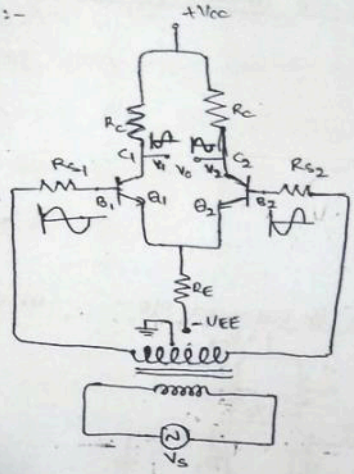
$$\Rightarrow 20 \log_{10} \left| \frac{A_{V_{low}}}{A_{V_{mid}}} \right| = -0.5$$

$$\log_{10} \left| \frac{A_{V_{low}}}{A_{V_{mid}}} \right| = \frac{-0.5}{20} = -0.025$$

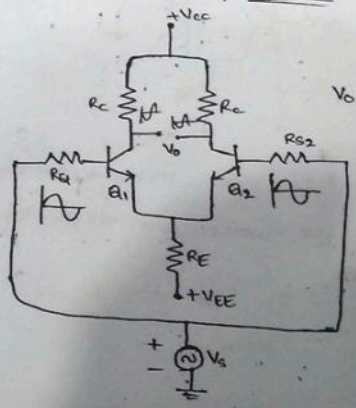
$$\left| \frac{A_{V_{low}}}{A_{V_{mid}}} \right| = 10^{-0.025} = 0.944$$

$$\frac{1}{\sqrt{1 + \left(\frac{f_L}{f}\right)^2}} = 0.944 \Rightarrow 1 + \frac{(15)^2}{f^2} =$$

* Differential mode operation :-



* Common mode operation :-



$V_o = 0$

Definition :- Oscilla
generates an AC

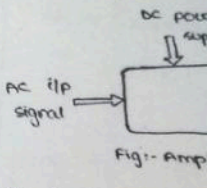


Fig :- Amp

→ An Oscillator is

→ A Rectifier is

* Requirements of

1. An electronic
is required

2. +Ve feed back

3. Barkhausen
produce sustai

* Classification

1. Based on

(a) sinusoido
generates
sinusoidal

(b) Non- sin
generates
square wave
-dal oscilla

Code No: RT22041 R13 SET - 3

ELECTRONICS CIRCUIT ANALYSIS

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answer **ALL** the question in **Part-A**
3. Answer any **THREE** Questions from **Part-B**

PART-A

1. a) Write about Gain-Bandwidth product.
   b) Explain the need of cascading amplifiers.
   c) Explain how the noise is reduced due to the negative feedback.
   d) Write advantages and disadvantages of wien bridge oscillator.
   e) What you meant by cross over distortion.
   f) Classify tuned amplifier.

PART-B

2. a) Draw the circuit diagram of cascade- transistor amplifier circuit and analyze its performance.
   b) Explain the differential mode and Common Mode operation of emitter coupled differential amplifier.

3. a) Draw the circuit diagram of Darlington pair circuit and derive its important characteristics.
   b) Compute the value of overall current gain and input impedance of a Darlington pair with 1K emitter resistance connected to the emitter of a second transistor if h_{fe} , h_{ie},h_{oe} and h_{re} of both the transistor are given as - 51,1.1k ,0 and 1 respectively.

4. a) What are the different types of feedback amplifiers? Give their equivalent circuits.
   b) An amplifiers with negative feedback gives an output of 12.5 with an output of 1.5V. When feedback is removed, it requires 0.25V input for the same output. Find i) values of voltage gain without feedback. ii) value of β, if the input and output are in phase and β is real.

5. a) Calculate the value of 'C' in the frequency –determining network of a FET RC phase shift oscillator circuit having R=2.5K , assuming frequency of oscillation f=1.625KHz. Repeat same if it is BJT RC phase shift oscillation with R_C=4K .
   b) Draw the circuit of Hartley oscillator and explain its working .Derive the expressions for frequency of oscillation and condition for starting of oscillation.

6. a) Derive the expression for maximum value of conversion efficiency of class A power amplifier.
   b) Write a note on Heat sinks.

7. a) derive the equation for voltage gain of capacitive coupled tuned amplifier.
   b) What is the effect of cascading single tuned amplifier on bandwidth? Derive the expression for it.

*****

Code No: RT22041 R13 SET - 4

ELECTRONICS CIRCUIT ANALYSIS

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answer **ALL** the question in **Part-A**
3. Answer any **THREE** Questions from **Part-B**

PART-A

1. a) Why h-parameter model is not suitable for high frequency analysis?
   b) Write about CMRR.
   c) Give characteristics of negative feedback amplifier.
   d) Explain the principle of operation of oscillator.
   e) Explain the term impedance matching.
   f) Write about stability of tuned amplifies.

PART-B

2. a) Draw the circuit for Darlington pair amplifier and derive the expressions for A_I, A_v, R_i And Ro.
   b) Draw the circuit diagram of emitter coupled differential amplifier and obtain its d.c analysis.

3. a) Compare the three types of coupling methods used in multistage amplifiers.
   b) Perform the analysis of boot – strapped emitter follower circuit.

4. a) Draw the circuit diagram of current shunt feedback and derive expressions for input and output resistance.
   b) Explain the concept of feedback with block diagram.

5. a) Discuss and explain the basic circuit of an LC oscillator and derive the conditions for the oscillations.
   b) A Hartley oscillator is to span a frequency range from 50KHz to 150KHz. The variable capacitance has the values in the range 50pF to 450pF.The transistor to be used as hfe=50 and he = 0.5. Determine the values of the inductances. Neglect mutual inductance betwee the coils and use CE circuit configuration.

6. a) A single transistor is operating as an ideal class B amplifier with a 500 load. A d.c me in the collector circuit reads 10mA. How much signal power is derived to the load?
   b) Draw a neat circuit diagram of push pull class B amplifier. Explain its working.

7. a) Explain the operation of a single tuned amplifier circuit and its frequency response.
   b) Draw the circuit diagram of double tuned amplifier and simplify the same with equivalent circuit.

*****

Code No: RT22041 **R13** **SET - 1**

ELECTRONICS CIRCUIT ANALYSIS

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answer **ALL** the question in **Part-A**
3. Answer any **THREE** Questions from **Part-B**

PART-A

1. a) Name various components in Hybrid II model of transistor and its values
b) List the features of Darlington pair amplifier.
c) Write advantages of negative feedback in amplifier?
d) Classify different types of oscillator.
e) What are the types of distortions possible in an amplifier
f) What is the importance of stagger tuning.

PART-B

2. a) Derive the relation between Ft and Fβ
b) Draw the equivalent circuit of hybrid-model and derive the expression for hybrid -π impedance in terms of low frequency h-parameters.

3. a) Draw the circuit diagram of cascade amplifier circuit and analyze its performance.
b) Draw and explain darlington pair and its

4. a) Give comparison of positive and negative feedback.
b) Discuss the effect of negative feedback with respect to closed loop gain, bandwidth and distortion.

5. a) what is barkhausen criteria and derive the equation for frequency of wein bridge oscillator
b) Perform the generalized analysis of LC oscillators with suitable block diagram and obtain the condition for Hartley and colpitt's oscillators.

6. a) Differentiate between push-pull and complementary symmetry configuration of a class B power amplifier.
b) For a class B amplifier driven from a 24V power supply and driving a 8 load, compute i) Input d.c power, ii) output power, iii) conversion efficiency if the peak to peak output voltage across the load resistance is 22 Volts maximum.

7. a) Explain how the stagger –tuned design is superior to synchronously tuned design in the design of a multistage amplifier?
b) What is the effect of cascading on tuned amplifier in terms of bandwidth and gain

*****

Code No: RT22041 **R13** **SET - 2**

ELECTRONICS CIRCUIT ANALYSIS

Time: 3 hours Max. Marks: 70

Note: 1. Question Paper consists of two parts (**Part-A** and **Part-B**)
2. Answer **ALL** the question in **Part-A**
3. Answer any **THREE** Questions from **Part-B**

PART-A

1. a) How Hybrid-π parameters vary with temperature?
b) Write a note on difference amplifier.
c) Classify the amplifiers.
d) Explain the Barkhausen criterion in detail.
e) Write features of Power amplifiers.
f) Write advantage and disadvantage of tuned amplifier.

PART-B

2. a) Derive the expressions for the CE current gain and voltage gain including source resistance Rs.
b) Derive the expression for f_H and input admittance for emitter follower amplifier at high frequencies.

3. a) Draw the circuit diagram of a cascade amplifier and derive its overall voltage gain and impedance from its equivalent circuit.
b) Derive the expression for voltage gain and input impedance of bootstrap emitter follower amplifier.

4. a) Explain the method of analysis of feedback amplifier.
b) Calculate the voltage gain, input impedance and output impedance of a voltage series feedback amplifier having an open loop gain A=300, R_i=1.5K , R_0=50K and β=1/20.

5. a) Draw the diagram of Colpitt's oscillator and explain its working.
b) What are the factors that affects the frequency stability of an oscillator? How frequency stability can be improved in oscillators?

6. a) Derive the expression for efficiency of a direct coupled Class A power amplifier.
b) A single transistor operates as an ideal class B amplifier. If d.c current drawn from the supply is 25mA, calculate the a.c power delivered to load for load of 2K.

7. a) Derive the expression for the gain of a single-tuned capacitance coupled amplifier, Discuss about its Selectivity .
b) Explain the neutralization technique in tuned amplifiers.

*****

$$A_V = \frac{g_m + j\omega C_{gs}}{g_m + g_s + g_d + y_{ds} + y_{gs}}$$

$$= \frac{g_m + j\omega C_{gs}}{g_m + g_d + j\omega C_{ds} + j\omega C_{gs} + \frac{1}{R_L}}$$

$$= \frac{g_m + j\omega C_{gs}}{g_m + g_d + (C_{ds} + C_{gs})j\omega + \frac{1}{R_L}}$$

$$= \frac{[g_m + j\omega C_{gs}]R_s}{1 + (g_m + g_d + j\omega C_T)R_s} \quad \text{where } C_T = C_{ds} + C_{gs}$$

At low frequencies,

$$A_V = \frac{g_m R_s}{1 + g_m R_s + g_d R_s} \quad [\because g_m R_s >> 1]$$

$$= \frac{g_m R_s}{g_m R_s + g_d R_s} = \frac{g_m}{g_m + g_d}$$

$$A_V = \frac{g_m}{g_d} \Big/ \frac{g_m}{g_d} + 1 = \frac{g_m r_d}{g_m r_d + 1}$$

$$\boxed{A_V = \frac{\mu}{\mu + 1}} \quad [\because \mu = g_m r_d]$$

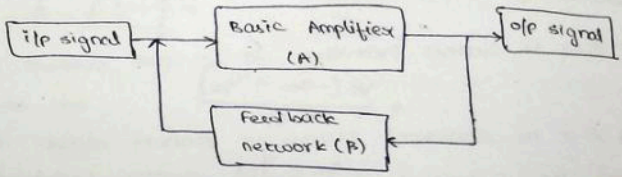
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UNIT - III

FEEDBACK AMPLIFIERS

* Feedback :- The term feed back means some portion of output signal is feed back to the input

→ Voltage gain (A_V), B.W, I/P impedence (R_i), O/P impedence (R_o) of an amplifier can be altered by using the concept of feedback.



→ Feed back can be of two types.

1. Negative feed back
2. Positive feed back

1. Negative Feed back :-

If the input signal & feed back signal are opposite in phase then the feed back is known as "Negative Feed back".

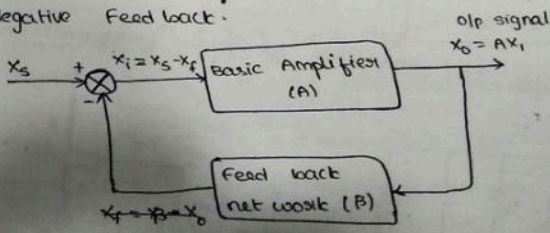


fig:- -ve feed back

→ It is used in amplifiers.

Advantages :- 1. It provides stability for voltage gain.
2. It increases input impedance, & reduces o/p impedance
3. Band width increases (Gain ↓)
4. Reduces distortion & noise

Disadvantages:-

1. Reduces gain of the amplifier.
2. Positive Feedback :-

If the i/p signal & feedback signal are in phase then the signal feedback is called "+ve feedback."

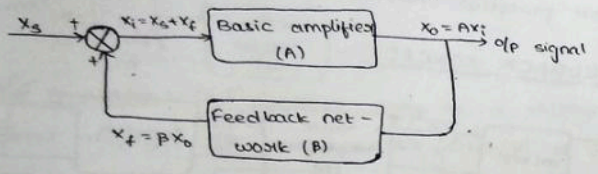


fig:- +ve feedback

→ It is used in oscillators.

Advantages :-

1. Increases the gain of amplifier.

Disadvantages:-

1. Reduces band width.
2. Increase the noise, instability.

* Classification of Amplifiers :-

1. Voltage amplifier
2. Current amplifier
3. Trans-conductance amplifier
4. Trans-resistance amplifier

→ Voltage Amplifier :- A voltage amplifier produces an output voltage proportional to input voltage.

Using voltage division rule,

$$V_i = V_s \cdot \frac{R_i}{R_i + R_s}$$

if $R_i >> R_s$

$$V_i = V_s$$

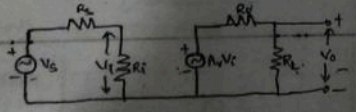


Fig:-equivalent circuit of voltage amp.

Using voltage division rule,

$$V_o = \frac{A_v \cdot V_i \cdot R_L}{R_L + R_o}$$

If $R_o << R_L$

$$V_o = A_v \cdot V_i \Rightarrow \boxed{A_v = \frac{V_o}{V_i}}$$

- For a good voltage amplifier i/p impedence must be very large and o/p resistance should be small value w.r.t source & load resistance.

Note:-

1. For ideal voltage amplifier, $R_i = \infty$, $R_o = 0$
2. For practical voltage amp. $R_i >> R_s$, $R_o << R_L$

→ Current Amplifier :-

A current amplifier produces an output current proportional to the input current.

Using current division rule,

$$I_i = I_s \cdot \frac{R_s}{R_i + R_s}$$

If $R_i << R_s$

$$\Rightarrow I_i = I_s$$

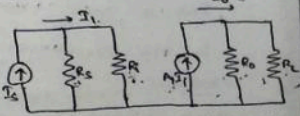


Fig:- equiv. ckt of current amp.

Using current division rule, $I_o = \frac{A_i I_i \cdot R_o}{R_o + R_L}$

If $R_o >> R_L$

$$\Rightarrow I_o = A_i I_i \Rightarrow \boxed{A_i = \frac{I_o}{I_i}}$$

For a good current amplifier i/p resistance must be low and o/p resistance should be high.

Note:-

1. For ideal current amp ; $R_i = 0$, $R_o = \infty$
2. For practical current amp ; $R_i << R_s$, $R_o >> R_L$

→ Transconductance Amplifier :-

A transconductance amplifier produces the output current which is proportional to i/p voltage.

Using voltage division rule,

$$V_i = V_s \cdot \frac{R_i}{R_i + R_s}$$

If $R_i >> R_s$

$\Rightarrow V_i = V_s$

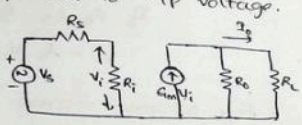


Fig:- equiv ckt of transconductance

Using current division rule,

$$I_o = G_m \cdot V_i \cdot \frac{R_o}{R_o + R_L}$$

If $R_o >> R_L$

$\Rightarrow I_o = G_m V_i \Rightarrow \boxed{G_m = \frac{I_o}{V_i}}$

For a good transconductance amplifier both the i/p & o/p resistance must be high.

Note:-

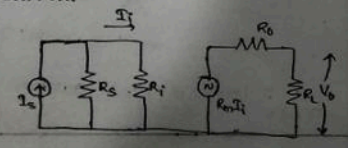
1. For ideal transconductance amp ; $R_i = \infty$, $R_o = \infty$
2. For practical transconductance amp ; $R_i >> R_s$, $R_o >> R_L$

→ Transresistance Amplifier :-

A transresistance amplifier produces an o/p voltage proportional to i/p current.

Using current division rule,

$$I_i = I_s \times \frac{R_s}{R_s + R_i}$$



If $R_s >> R_i$

$\Rightarrow I_i = I_s$

Using voltage division rule, $V_o = R_m \cdot I_i \cdot \frac{R_L}{R_L + R_o}$

If $R_L >> R_o \Rightarrow V_o = R_m I_i$

$\Rightarrow \boxed{R_m = \frac{V_o}{I_i}}$

For a good transresistance amplifier both the i/p & o/p resistance must be low.

Note:-

1. For ideal transresistance ; $R_i = 0$, $R_o = 0$
2. For practical transresistance ; $R_i << R_s$ & $R_o << R_L$

* FEEDBACK CONCEPT :-

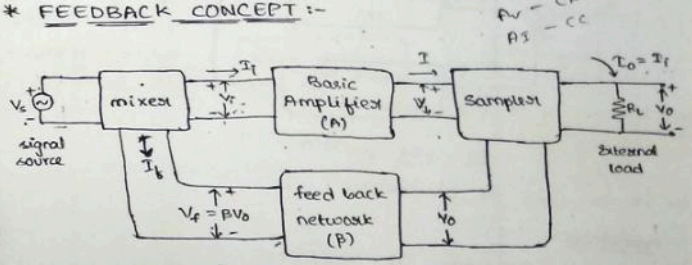


Fig:- Basic Feed back Amplifier

(1) Signal Source :- A signal source is either voltage source or current source.

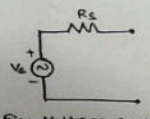


Fig:- Voltage source

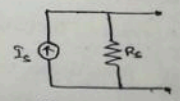


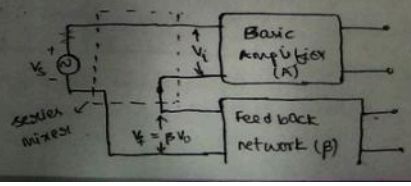
Fig:- Current source

(2) Mixer :- Mixer block is used to combine source signal and feedback signal.

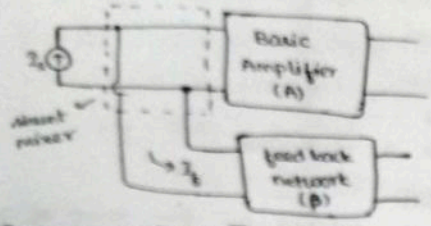
→ There are two types of mixing techniques.

1. Series mixing
2. Parallel / shunt mixing

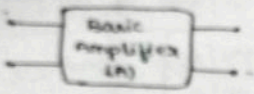
Series mixing :- When the source signal & feed back signal are both voltages then series mixing technique is used.



Shunt mixing :- When the source signal S_i feedback signal are both currents then the shunt mixing is used.



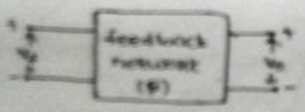
(b) Basic Amplifier :- The amplifier may be a voltage or current amplifier. It increases the strength of a signal.



Voltage gain, $A_v = \frac{V_o}{V_i}$

Current gain, $A_i = \frac{I_o}{I_i}$

(c) Feedback Network :- It is a passive two port N/w consisting of capacitors, resistors & inductors.



$V_f = \beta V_o$

→ For -ve feedback system, the feedback network is designed with only resistors.

→ For +ve feedback system the feedback n/w is designed with R (or) RC (or) LC (or) RLC

(d) Sampler :-

Sampling block is used to sample the o/p of basic amplifier. There are 2 types of sampling techniques

i. Voltage sampling ii. Current sampling

Voltage Sampling :- If the o/p of basic amplifier is voltage then sampling is done in shunt with the load

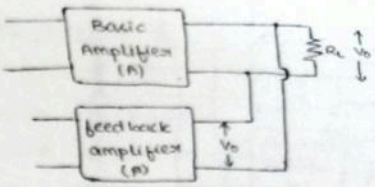


Fig :- Voltage sampling or node sample

Current Sampling :- If the o/p of the basic amplifier current then sampling is done in series with the l

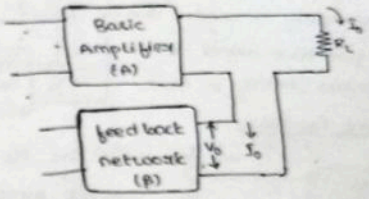


Fig :- Current sampling or series sample

(e) Transfer ratio (or) Gain :- (A_v, A_i, G_m, R_m) → A_f

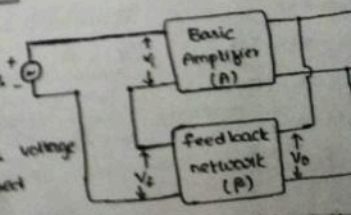
* FEEDBACK TOPOLOGIES :-

These are four basic topologies

1. Voltage series feedback
2. Voltage shunt feedback
3. Current series feedback
4. Current shunt feedback

1. Voltage series Feedback :-

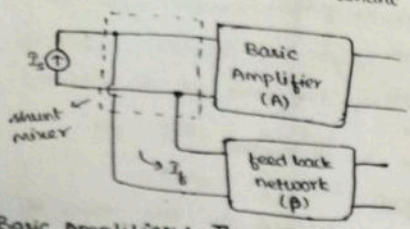
Here, the o/p is voltage so voltage sampling is used. The feedback signal is voltage so series mixing is used



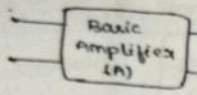
2. Voltage shunt Feedback :-

Here the o/p is voltage so voltage sampling is
The o/p of feedback signal is current so shu

Shunt mixing :- When the source signal & feedback signal are both currents then the shunt mixing is used.



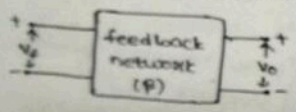
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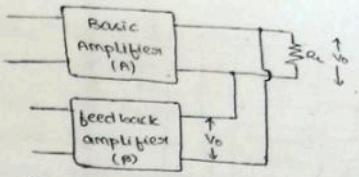


Fig :- Voltage sampling or node sample

Current Sampling :- If the o/p of the basic amplifier is current then sampling is done in series with the load.

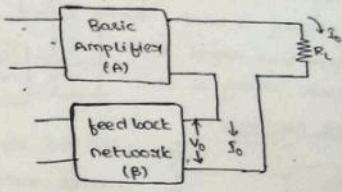


Fig :- Current sampling or series sample

(d) Transfer ratio or Gain (Av, Ai, Gm, Rm) → Af

FEEDBACK TOPOLOGIES :-

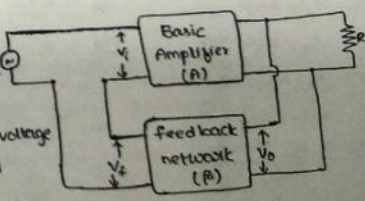
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3. Current series feedback
4. Current shunt feedback

1. Voltage series Feedback :-

Here, the o/p is voltage so voltage sampling is used.

The feedback signal is voltage so series mixing is used

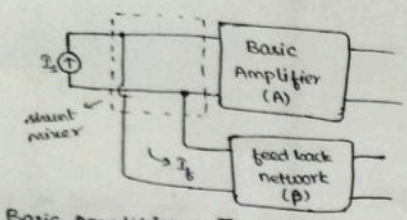


2. Voltage Shunt Feedback :-

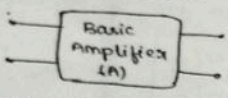
Here the o/p is voltage so voltage sampling is used.

The o/p of feed back signal is current so shunt mixing is used

Shunt mixing :- When the source signal & feedback signal are both currents then the shunt mixing is used.



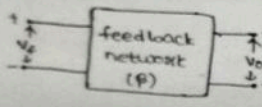
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Sampling block is used to sample the o/p of basic amplifier. There are 2 types of sampling techniques.

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Voltage Sampling :- If the o/p of basic amplifier is voltage then sampling is done in shunt with the load.

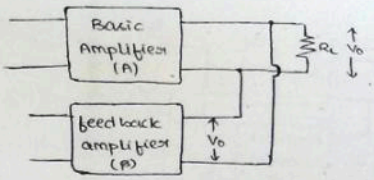
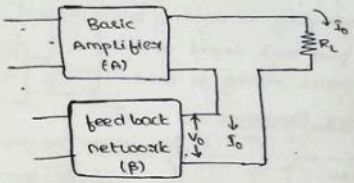


Fig :- Voltage sampling or node sample

Current Sampling :- If the o/p of the basic amplifier is current then sampling is done in series with the load.



(5) Transfer ratio by gain :- Fig :- Current sampling or series sample

(Av, Ai, Gm, Rm) → Af

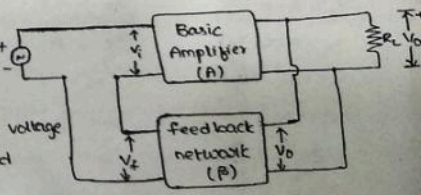
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These are four basic topologies.

1. Voltage series feedback
2. Voltage shunt feedback
3. Current series feedback
4. Current shunt feedback

1. Voltage series Feedback :-

Here, the o/p is voltage so voltage sampling is used. The feedback signal is voltage so series mixing is used



2. Voltage Shunt Feedback :-

Here the o/p is voltage so voltage sampling is used. The o/p of feed back signal is current so shunt mixing is used

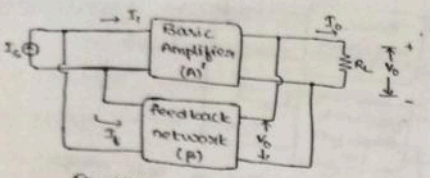
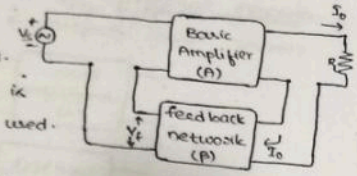


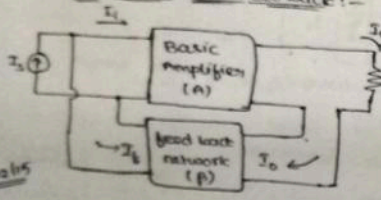
Fig:- Voltage Shunt Feedback

3. Current Series Feedback :-

Here the o/p is current so, current sampling is used. The o/p of feed back signal is voltage so series mixing is used.

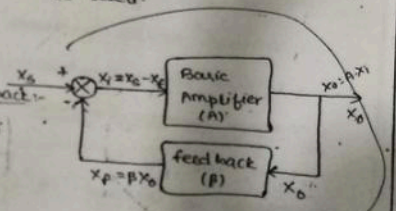


4. Current Shunt Feedback :-



Here the o/p is current so, current sampling is used. The o/p of feedback signal is current so shunt mixing is used.

* Gain with feedback :-



with feedback :-

$X_o = A X_i$

$X_o = A(X_s - X_f)$

$X_o = AX_s - A\beta X_o$

$X_o(1+A\beta) = AX_s$

$\frac{X_o}{X_s} = \frac{A}{1+A\beta}$

without feedback :-

$X_o = A X_i$

$\frac{X_o}{X_i} = A$

$\Rightarrow X_s = X_i$

$A = \frac{X_o}{X_s} \Rightarrow X_o = AX_s$

For -ve feedback, the gain $A_f = \frac{A}{1+A\beta}$

For +ve feedback, gain $A_f = \frac{A}{1-A\beta}$

* Characteristics of -ve feedback :-[-ve F/B reduces the transfer gain]

1. Better stabilization in gain
2. Increase in bandwidth
3. High i/p impedance
4. Low o/p impedance
5. Reduction in noise & distortion.

1. Stabilized voltage gain :-

"Sensitivity of Gain" is defined as the ratio of fractional change in gain of an amplifier with feedback to the fractional change in gain of an amplifier without feedback.

$$S = \frac{dA_f/A_f}{dA/A}$$

The gain of an amplifier, $A_f = \frac{A}{1+A\beta}$

diff w.r.t 'A' O.B.S

$$\frac{dA_f}{dA} = \frac{1}{(1+A\beta)^2}$$

[β is transfer function of feedback n/w]

$$\frac{dA_f}{dA} = \frac{A}{1+A\beta} \times \frac{1}{1+A\beta} \times \frac{1}{A}$$

$$\frac{dA_f}{dA} = \frac{A_f}{A} \times \frac{1}{1+A\beta}$$

$$S = \frac{dA_f/A_f}{dA/A} = \frac{1}{1+A\beta}$$

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

Gain, $A_f = \frac{A}{1+A\beta} = \frac{A}{D}$

Due to -ve feedback the gain decreases by a factor $1+A\beta$

2. Increase in Band Width :-

The Gain band width product of an amplifier with feedback should be equal to the gain band width product of an amplifier without feed back.

$$A_f \cdot BW_f = A \cdot BW$$

$$BW_f = \frac{A}{A_f} BW$$

$$= \frac{A}{A/1+A\beta} \cdot BW$$

$$\boxed{BW_f = (1+A\beta)\, BW}$$

Due to -ve feed back, the band width of an amplifier increases by a factor $1+A\beta$

3. High i/p impedance :-

For a voltage amplifier, the i/p impedance must be as high as possible

Without feedback :-

$V_s = I_i R_i + V_f$

$V_s = I_i R_i + \beta V_o$

$V_s = I_i R_i + \beta \cdot AV_i$

$V_s = I_i R_i + \beta \cdot A \cdot I_i R_i$

$V_s = I_i R_i (1+A\beta)$

$\frac{V_s}{I_i} = R_i (1+A\beta)$

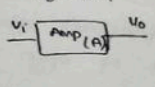
$\Rightarrow$ i/p imp with f/b

$R_{if} = R_i (1+A\beta)$

without f/b :-

$V_i = I_i R_i$

$V_o = AV_i$



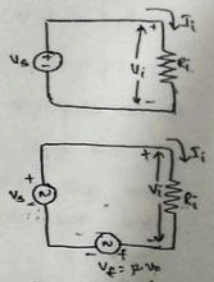


fig:- with feedback

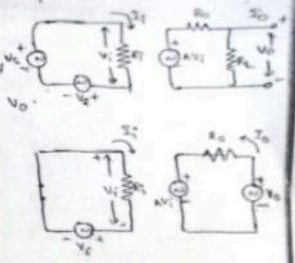
4. Low o/p impedance :-

For a voltage amplifier the o/p impedance must be small.

To measure o/p impedance

i) the source, V_s must be short circuited

ii) Load, R_L is open circuited & connect V_o.



Apply KVL for o/p circuit,

$AV_i + I_o R_o - V_o = 0$

$I_o = \frac{V_o - AV_i}{R_o} \longrightarrow (1)$

From i/p circuit,

$V_i = -V_f = -\beta V_o$

$I_o = \frac{V_o + A\beta V_o}{R_o} = \frac{(1+A\beta) V_o}{R_o}$

$\frac{R_o}{1+A\beta} = \frac{V_o}{I_o}$

$\Rightarrow \boxed{R_{of} = \frac{R_o}{1+A\beta}}$

5. Reduction of Noise :-

$$N_f = \frac{N}{1+A\beta}$$

There are several sources of noise in an amplifier

Let 'N' be the noise without feedback

'N_f' be the noise with feedback

Due to -ve feedback the noise reduced by a factor $1+A\beta$ i.e., $N_f = \frac{N}{1+A\beta}$

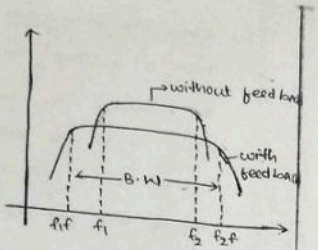
6. Reduction in distortion :- Let 'D' be the distortion without feedback & D_f be the distortion with feedback. Due to -ve feedback the noise reduces by a factor $1+A\beta$.

Note :-

1. Due to -ve feedback gain decreases. bandwidth increases.

2. The lower cut of frequency decreases by a factor $1+A\beta$

i.e., $f_1 f = \frac{f_1}{1+A\beta}$



3. The upper cut of frequency increases by a factor $1+A\beta$ i.e., $f_2 f = f_2(1+A\beta)$

1. An amplifier has an open loop gain of 1000 & a feedback ratio of 0.04. If the open loop gain changes by 10%. Find % change in gain of amplifier with feedback

Sol:- [Open loop gain = Amp without feedback]

$A = 1000$, $\beta = 0.04$, $\frac{dA}{A} = 10\%$

we have $\delta = \frac{dA_f/A_f}{dA/A} = \frac{1}{1+A\beta}$

$$\frac{dA_f}{A_f} = \frac{dA}{A} \cdot \frac{1}{1+A\beta} = 10\% \cdot \frac{1}{1+(1000)(0.04)}$$

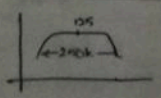
$$= (10\%)(0.02439)$$

$$= 0.2439\%$$

2. An amplifier has a mid band gain of 125 & B.W of 250 kHz (a) If 4% -ve feedback is introduced find new B.W & gain (b) If the B.W is to be restricted to 1M Hz, find the feedback ratio.

Sol:- Given $A = 125$, $BW = 250\ kHz$, $\beta = 4\% = 0.04$

(a) $A_f = \frac{A}{1+A\beta} = \frac{125}{1+(125)(0.04)} = 20.833$



$BW_f = (1+A\beta)\,BW = [1+(125)(0.04)] \times 250 \times 10^3$

$= 1500\ kHz$

$A < A_f$, new BW ↑

(b) $BW_f = (1+A\beta)\cdot BW$

$1M = (1+0.5\beta)\cdot(250\ k)$

$\beta = \frac{1M - 250k}{312.50k} = 0.024$

3. An amplifier has a voltage gain of 400, $f_1 = 50\ Hz$, $f_2 = 200\ kHz$ and a distortion of 10%. without feedback. Determine the amplifier voltage gain, $f_1 f$, $f_2 f$ and D_f when $\beta = 0.01$

Sol:- $A = 400$, $f_1 = 50\ Hz$, $f_2 = 200\ kHz$, $D = 10\%$, $\beta = 0.01$

$$A_f = \frac{A}{1+A\beta} = \frac{400}{1+(400)(0.01)} = \frac{400}{5} = 80$$

$$f_1 f = \frac{f_1}{5} = \frac{50}{5} = 10\ Hz$$

$$f_2 f = f_2(5) = 200 \times 10^3 \times 5 = 1000\ kHz$$

$$D_f = \frac{D}{5} = \frac{10\%}{5} = 2\% = 0.02$$

4. An amplifier has voltage gain with feedback is 100 if the gain without feedback changes by 20% and the gain with feedback should not exceed 2%. Determine the values of open loop gain A & feedback ratio, β.

Sol:- $A_f = 100$, $\frac{dA}{A} = 20\%$, $\frac{dA_f}{A_f} = 2\%$

$$\delta = \frac{d[dA_f/A_f]}{dA/A} = \frac{1}{1+A\beta} \Rightarrow \frac{1}{1+A\beta} = \frac{0.02}{0.2}$$

$$\Rightarrow 1+A\beta = 10$$

$$\Rightarrow A_f = \frac{A}{1+A\beta} \Rightarrow 100 = \frac{A}{10} \Rightarrow A = 1000$$

$$\Rightarrow \beta = \frac{9}{1000} = 0.009$$

Voltage Series Feedback Amplifier :-

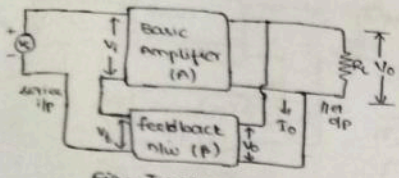


Fig :- Topology

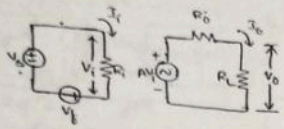


Fig :- Equivalent ckt

Voltage gain :-

$V_o = A V_i$

$V_o = A[V_s - V_f]$

$V_o = AV_s - A\beta V_o$

$V_o(1 + A\beta) = AV_s$

$\frac{V_o}{V_s} = \frac{A}{1+A\beta}$

$\therefore \boxed{A_f = \frac{A}{1+A\beta}}$

Due to -ve feedback ∴ voltage gain decreases by $(1+A\beta)$.

Band width :-

$BW_f \times A_f = BW \times A$

$BW_f = \frac{A}{A_f} \times BW$

$BW_f = \frac{A}{A/1+A\beta} BW$

$BW_f = (1+A\beta) BW$

Input resistance :-

$V_s = I_i R_i + V_f$

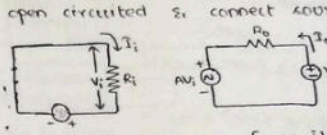
$V_s = I_i R_i + \beta V_o = I_i R_i + \beta A V_i$

$V_s = I_i R_i + A\beta I_i R_i = I_i R_i (1+A\beta)$

$\frac{V_s}{I_i} = R_i (1+A\beta)$

$\boxed{R_{if} = R_i (1+A\beta)}$

Output Resistance :- To measure output resistance i. V_s must be short circuited ii. R_L is open circuited & connect source V_o



Apply KVL to o/p circuit

$AV_i + I_o R_o - V_o = 0$

$I_o = \frac{V_o - AV_i}{R_o}$

From i/p circuit,

$V_i = -V_f = -\beta V_o$

$I_o = \frac{V_o + A\beta V_o}{R_o}$

$I_o = \frac{V_o(1+A\beta)}{R_o}$

$R_{of} = \frac{V_o}{I_o} = \frac{R_o}{1+A\beta}$

P :- A voltage series -ve feedback amplifier has a voltage gain without feedback $A = 500$, $R_i = 3k\Omega$, $R_o = 20k\Omega$ & feedback ratio, $\beta = 0.01$. Calculate the voltage gain A_f, R_{if}, R_{of}.

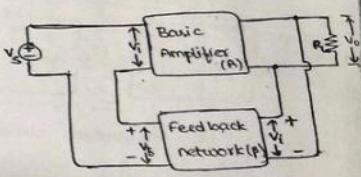


Fig :- Topology

Sol :-

$A = 500$, $R_i = 3k\Omega$,

$R_o = 20k\Omega$, $\beta = 0.01$

$A_f = \frac{A}{1+A\beta} = \frac{500}{1+(500)(0.01)}$

$= 83.33$

$R_{if} = R_i(1+A\beta) = 3 \times 6 \times 10^3 = 18\,k\Omega$

$R_{of} = \frac{20 \times 10^3}{6} = 3.33k\Omega$

P :- An amplifier has a voltage gain of 4000 its $R_i = 2k\Omega$ & o/p impedance is $60k\Omega$. Calculate the voltage gain, i/p & o/p impedance of the circuit when

s.t. of the feedback is fed in the form of series -ve voltage feedback

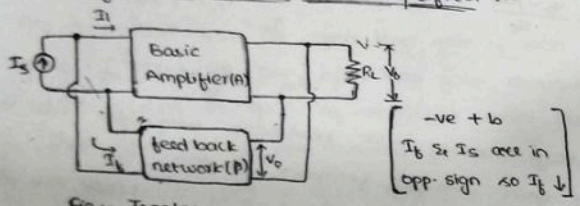
Sol:-

$$A_f = \frac{A}{1+A\beta} = \frac{4000}{1+(4000)(0.05)} = 19.9$$

$$R_{if} = R_i(1+A\beta) = 2\times10^3 \times 201 = 402\ k\Omega$$

$$R_{of} = \frac{R_o}{1+A\beta} = \frac{60\times10^3}{201} = 0.298\ k\Omega$$

* Voltage Shunt Feedback Amplifier :-



-ve + to I_f & I_s are in opp. sign so $I_f \downarrow$

Fig :- Topology

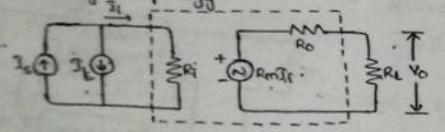


Fig:- Equivalent circuit

$A = \frac{V_o}{V_i}$

$R = \frac{V_o}{I_s}$ ↓ transresistance (R_m) without load

$R_i \rightarrow$ Amplifier i/p impedance

$R_m = \frac{+0}{-1}$

Transresistance:-

Using voltage division,

$$V_o = \frac{R_m \cdot I_i \cdot R_L}{R_L + R_o}$$

$$\frac{V_o}{I_i} = \frac{R_m \cdot R_L}{R_L + R_o} \Rightarrow R_M = \frac{R_m \cdot R_L}{R_L + R_o}$$

$$V_o = R_m \cdot I_i \longrightarrow (1)$$

I/p resistance :-

Apply KCL to input circuit,

$$I_s = I_i + I_f$$

$$I_s = I_i + \beta V_o$$

$$I_s = I_i + \beta R_M I_i$$

i/p resistance, $R_{if} = \frac{V_i}{I_s}$

$$R_{if} = \frac{V_i}{I_i + \beta R_M I_i} = \frac{V_i}{I_i(1+\beta R_M)}$$

$$\boxed{R_{if} = \frac{R_i}{1+\beta R_M}}$$

O/p resistance :- To measure o/p impedance

i) Open circuit current source i.e., $I_s = 0$

ii) remove R_L

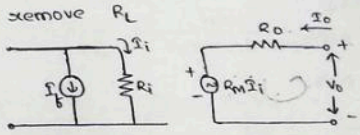


Fig :- simplified equivalent ckt

KCL :-

$I_f + I_i = 0$

$I_i = -I_f = -\beta V_o$

Apply KVL,

$$R_M I_i + I_o R_o - V_o = 0$$

$$I_o = \frac{V_o - R_M I_i}{R_o}$$

From i/p circuit, $I_i = -I_f = -\beta V_o$

$$I_o = \frac{V_o + R_M \beta V_o}{R_o} = \frac{V_o(1+R_M\beta)}{R_o}$$

$$\Rightarrow \frac{V_o}{I_o} = \frac{R_o}{1+R_M\beta}$$

$$\boxed{R_{of} = \frac{R_o}{1+R_M\beta}}$$

* Current Series Feedback Amplifier :-

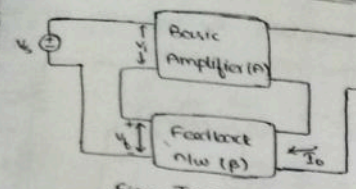


Fig :- Topology

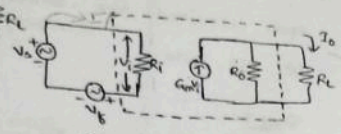


Fig :- Equivalent circuit

Transconductance :-

Using current division,

$$I_o = \frac{G_m V_i R_o}{R_o + R_L}$$

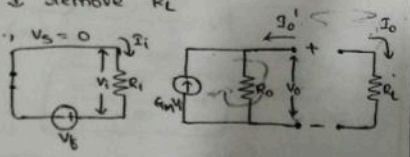
$$\frac{I_o}{V_i} = \frac{G_m R_o}{R_o + R_L}$$

$$G_M = \frac{G_m R_o}{R_o + R_L}$$

$$I_o = G_M \cdot V_i \longrightarrow (1)$$

O/p resistance :-

To measure o/p impedance ∴ remove R_L & s.c voltage source i.e., $V_s = 0$



Apply KCL to o/p circuit,

$$I_o' = \frac{V_o}{R_o} - G_m V_i$$

$$V_i = -V_f = -\beta I_o = +\beta I_o'$$

$$I_o' = \frac{V_o}{R_o} - G_m \beta I_o'$$

$$I_o'(1 + G_m \beta) = \frac{V_o}{R_o}$$

$$\frac{V_o}{I_o'} = R_o(1 + G_m \beta)$$

$$\boxed{R_{of} = R_o (1 + G_m \beta)}$$

I/p resistance :-

Apply KVL to i/p circuit,

$$V_s = I_i R_i + V_f$$

$$V_s = I_i R_i + \beta I_o$$

$$V_s = I_i R_i + \beta \cdot G_m V_i$$

$$V_s = I_i R_i + \beta G_m I_i R_i$$

$$V_s = I_i R_i (1 + \beta G_m)$$

$$\frac{V_s}{I_i} = R_i (1 + \beta G_M)$$

$$R_{if} = R_i (1 + \beta G_M)$$

* Current Shunt Feedback Amplifier :-

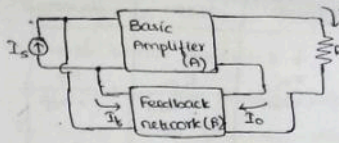


Fig :- Topology

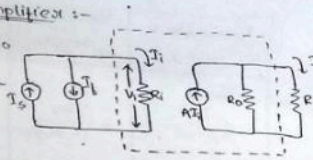


Fig :- Equivalent circuit

Gain :-

Using current division

$$I_o = \frac{A_i I_i \cdot R_o}{R_o + R_L}$$

$$\frac{I_o}{I_i} = \frac{A_i R_o}{R_o + R_L} = A_I$$

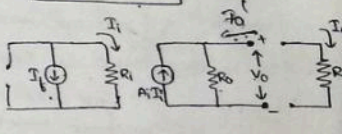
$$A_I = \frac{A_i R_o}{R_o + R_L}$$

$$I_o = A_I \cdot I_i \longrightarrow (1)$$

O/p resistance :-

∴ o.c current source i.e., $I_s = 0$

∴ remove R_L



Apply KCL to o/p circuit

$$I_o' = \frac{V_o}{R_o} - A_i I_i$$

from i/p circuit,

$$I_i = -I_f = -\beta I_o = \beta I_o' \quad [\because I_o = I_o']$$

$$I_o' = \frac{V_o}{R_o} - A_i \beta I_o'$$

$$\frac{V_o}{I_o'} = R_o (1 + A_i \beta)$$

$$\boxed{R_{of} = R_o (1 + A_i \beta)}$$

I/p resistance :- $I_s = I_f + I_i$

$$I_s = I_f + \beta I_o$$

$$I_s = I_f + \beta \cdot A_i I_i$$

$$I_s = I_i (1 + \beta A_i)$$

i/p resistance, $R_{if} = \frac{V_i}{I_s}$

$$R_{if} = \frac{V_i}{I_i (1 + \beta A_i)}$$

$$\boxed{R_{if} = \frac{R_i}{1 + \beta A_i}}$$

Parameter	Voltage series	Voltage shunt	Current series	Current shunt
Gain	↓ $= \frac{A_V}{1+A_V\beta}$	↓ $= \frac{R_m}{1+R_m\beta}$	↓ $= \frac{G_m}{1+G_m\beta}$	↓ $= \frac{A_I}{1+A_I\beta}$
Bandwidth	↑	↑	↑	↑
Noise	↓	↓	↓	↓
Distortion	↓	↓	↓	↓
i/p resistance (R_{if})	↑ series	↓ shunt	↑ shunt series	↓ shunt
o/p resistance (R_{of})	↓ (v)	↓ (v)	↑ (c)	↑ (c)

* Analysis of Feedback Amplifiers :-

Voltage Series Feedback :-

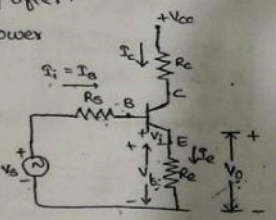
The common collector (or) emitter follower is an example of voltage series amplifier.

→ It is also called as Emitter follower

Step 1 :-

Find the feedback topology

If $V_o = 0$ then feedback signal $V_f = 0$ hence it is voltage sampling



$V_s = I_i R_s + V_i + V_f$

$V_i = V_s - I_i R_s - V_f$

here the feedback signal is subtracted from the source signal, V_s. Hence it is series mixing.

∴ The above circuit is voltage series feedback.

Step 2 :- Basic amplifier without feedback

1. To obtain i/p circuit set $V_o = 0$. The source signal in series with R_s appears at base & emitter terminal

2. To obtain o/p circuit set $I_i = 0$, when i/p loop is open circuited the emitter resistor R_E appears only at o/p side.

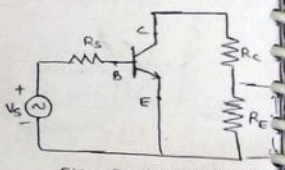


Fig :- Equivalent circuit

Step 3 :-

Replace transistor by h-parameter model.

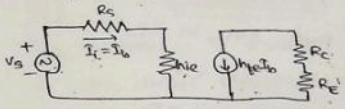


Fig :- Equivalent circuit

Step 4 :- Open loop voltage gain

$$A_V = \frac{V_o}{V_s} = \frac{h_{fe} \cdot I_b \cdot R_E}{V_s}$$

$$\Rightarrow V_s = I_b R_s + I_b h_{ie}$$

$$V_s = I_b (R_s + h_{ie})$$

$$A_V = \frac{h_{fe} I_b R_E}{I_b (R_s + h_{ie})}$$

$$\boxed{A_V = \frac{h_{fe} R_E}{R_s + h_{ie}}}$$

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

$A_f = \frac{A}{D}$

Step 5 :- Feedback ratio (β)

$$\beta = \frac{V_f}{V_o} \quad [\because V_f = V_o]$$

$$\beta = 1$$

Step 6 :- Desensitivity

$$D = 1 + A_V\beta$$

$$D = 1 + A_V$$

$$D = 1 + \frac{h_{fe} \cdot R_E}{R_s + h_{ie}}$$

$$D = \frac{R_s + h_{ie} + h_{fe} R_E}{R_s + h_{ie}}$$

Voltage gain with feedback

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

$$= \frac{h_{fe} R_E}{R_s + h_{ie}} \times \frac{R_s + h_{ie}}{R_s + h_{ie} + h_{fe} R_E}$$

$$A_{vf} = \frac{h_{fe} R_E}{R_s + h_{ie} + h_{fe} R_E}$$

$R_{if} = R_i (1 + A_v \beta)$

$R_{of} = \frac{R_o}{1 + A\beta}$

i/p impedance :-

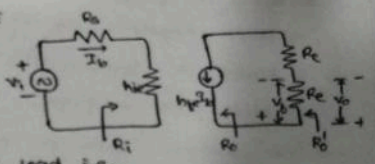
$$R_{if} = R_i (1 + A_v \beta)$$

$$R_{if} = R_i \cdot D$$

But $R_i = R_s + h_{ie}$

$$\Rightarrow R_{if} = R_s + h_{ie} \times \frac{R_s + h_{ie} + h_{fe} R_E}{R_s + h_{ie}}$$

$$R_{if} = R_s + h_{ie} + h_{fe} R_E$$



o/p resistance :-

$R_o = \infty$,

$R_{of} = \frac{R_o}{D} = \infty$ [∵ without load i.e., DC external resistance, $R_o \sim \infty$]

$R_o' = R_E$

$$R_{of}' = \frac{R_o'}{D} = R_E \times \frac{R_s + h_{ie}}{R_s + h_{ie} + h_{fe} R_E}$$

* Current Series Feedback :-

The common emitter amplifier is an example of current series feedback

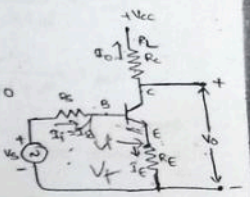


Fig :- CE Amplifier

Step 1 :- Find the feedback topology

If $I_o = 0$ then feedback signal $V_f = 0$

Hence it is current sampling

$$V_s = I_i R_s + V_i + V_f$$

$$V_i = V_s - I_i R_s - V_f$$

The feedback signal V_f is subtracted from the source signal V_s . Hence it is series mixing.

∴ The above circuit is current series mixing feedback

Step 2 :- Basic amplifier without feedback

1. To obtain i/p circuit set $I_o = 0$ so o/p loop is open circuited.

∴ The resistor, R_E appears in i/p loop.

2. To obtain o/p circuit set $I_i = 0$, so i/p loop is open cktd.

∴ resistor, R_E appears in o/p loop

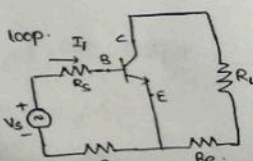
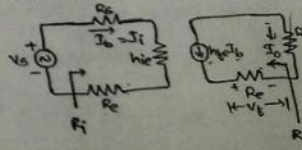


Fig :- Equivalent ckt

Step 3 :-

Replace transistor by h-parameter model



Step 4 :-

Open loop transconductance

$$G_m = \frac{I_o}{V_s}$$

$I_o = -h_{fe} I_b$

Apply KVL to i/p ,

$V_s = I_b R_s + h_{ie} I_b + R_E I_b$

$$V_s = I_b (R_s + h_{ie} + R_e)$$

$$G_m = \frac{-I_b \cdot h_{fe}}{I_b (R_s + h_{ie} + R_e)}$$

$$G_m = \frac{-h_{fe}}{R_s + h_{ie} + R_e}$$

Step 5:-

feed back ratio, $\beta = \frac{V_f}{I_o} = \frac{-I_o R_e}{I_o}$

$$\beta = -R_e$$

Step 6:-

Density factor, $D = 1 + G_m \beta$

$$= 1 + \frac{h_{fe} R_e}{R_s + h_{ie} + R_e}$$

$$= \frac{R_s + h_{ie} + R_e (1 + h_{fe})}{R_s + h_{ie} + R_e}$$

Voltage gain, $A_{v_f} = \frac{V_o}{V_s} = \frac{-I_o R_L}{V_s}$

$$A_{v_f} = -G_m R_L$$

$$A_{v_f} = \frac{h_{fe} R_L}{R_s + h_{ie} + R_e}$$

i/p resistance, $R_{if} = R_i (1 + G_m \beta) = R_i D$

i/p loop, $R_i = R_s + h_{ie} + R_e$

$\Rightarrow R_{if} = (R_s + h_{ie} + R_e) \times \frac{R_s + h_{ie} + R_e (1 + h_{fe})}{R_s + h_{ie} + R_e}$

$$R_{if} = R_s + h_{ie} + R_e (1 + h_{fe})$$

o/p resistance:- $R_o = \infty$, $R_{of} = R_o D = \infty$

with connecting external components, $R_o' = R_L$

$$R_{of}' = R_o' D = \frac{R_L [R_s + h_{ie} + R_e (1 + h_{fe})]}{R_s + h_{ie} + R_e}$$

sulalm

UNIT - 2

MULTISTAGE AMPLIF

* Classification of Amplifiers :-

1. Based on configuration

(a) CE Amplifier (b) CB Amplifier

2. Based on input

(a) small signal amplifier (b) large

3. Based on no. of stages

(a) Single stage amplifier (b) multi

4. Based on Biasing conditions (B

(a) class A (b) class B (c) class

(d) class AB (e) class D (f) class

5. Based on coupling

(a) Direct coupled amp (b) RC coupled

6. Based on frequency

(a) Audio frequency amp (b) Radio fre

7. Based on Band width

(a) Wide band amplifier (b) Narro

→ The voltage gain (or) current

stage amplifier is not sufficie

Hence two or more stages are

produce high gain such an

"Multi-stage Amplifier"

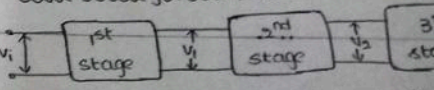
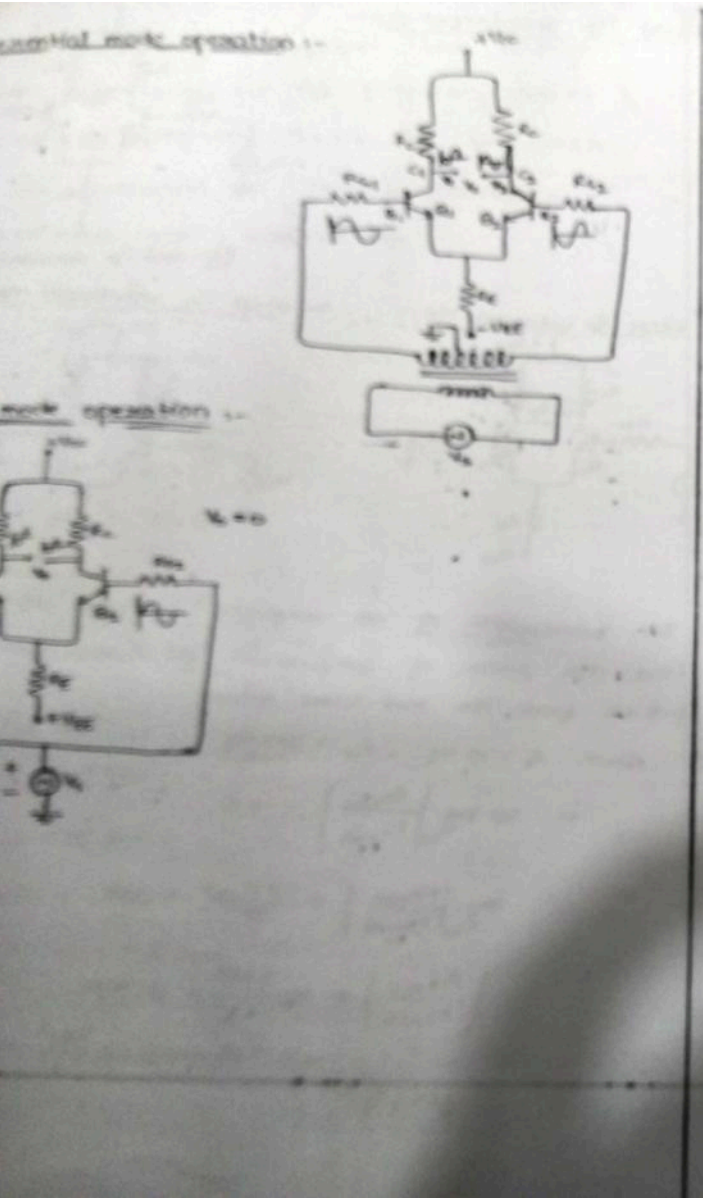


Fig:- multi stage amplif

When amplifiers are cascaded



UNIT- 4

OSCILLATORS

Definition :- Oscillator is an electronic circuit which generates an AC output signal without any AC i/p signal

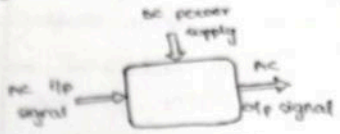


Fig:- Amplifier

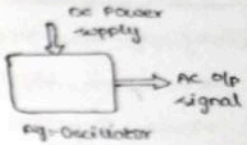


Fig:- Oscillator

→ An Oscillator is also called as DC to AC convertor.

→ A Rectifier is one which converts AC to DC.

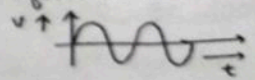
* **Requirements of an Oscillator** :-

1. An electronic device which can act as an amplifier is required
2. +ve feed back is implemented to produce oscillations.
3. Barkhausen criterion is to be implemented to produce sustained oscillations.

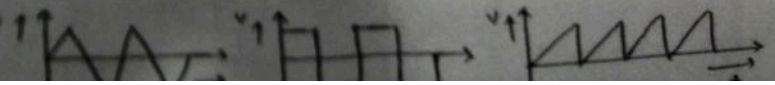
* **Classification of Oscillators** :-

1. Based on output wave form

(a) **Sinusoidal Oscillator** :- An electronic circuit which generates sinusoidal wave form is known as sinusoidal Oscillator



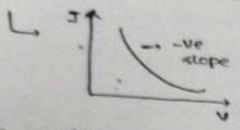
(b) **Non-Sinusoidal Oscillator** :- An electronic circuit which generates non-sinusoidal waves such as star wave, square wave, saw tooth wave, ... known as non-sinusoidal oscillator or relaxation oscillator.



2. Based on fundamental mechanism involved.

(a) Negative resistance oscillator :-

Note:- Negative resistance devices : UJT, SCR, tunnel diode,..



" The oscillator uses -ve resistance device "

Eg:- UJT relaxation time oscillator, tunnel diode osci.

(b) Feedback Oscillator :- The oscillator uses +ve feedback, which satisfied required conditions

3. Based on frequency of generation.

(a) Audio frequency oscillator :- 20 Hz - 20 kHz

(b) Radio frequency oscillators :- 20 kHz - 30 MHz

(c) Very high freq. Oscillators :- 30 MHz - 300 MHz

(d) Ultra high freq. Oscillators :- 300 MHz - 3 GHz

(e) Microwave Freq. Oscillators :- above 3 GHz

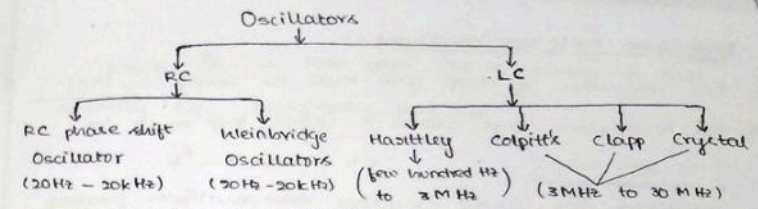
4. Based on type of circuits used.

(a) RC Oscillators : The oscillator uses RC elements in feedback network.

Eg:- RC phase shift oscillator, Weinbridge Oscillator

(b) LC Oscillator :- The oscillator uses L, C elements in feedback ntw

Eg:- Colpitts oscillator, clapp osci, Hartley Osci.



* Initiallization of Oscillators :-

Every resistance has some free $\bar{e}$ at room temperature. These free $\bar{e}$ will move randomly in all directions. Due to this movement a noise voltage is produced since oscillator uses +ve feedback the noise voltage is amplified & o/p wave form is generated.

Syllabus

* Conditions for Oscillations [Barkhausen criterion]

Consider an inverting amplifier which provides 180° phase shift b/w i/p & o/p

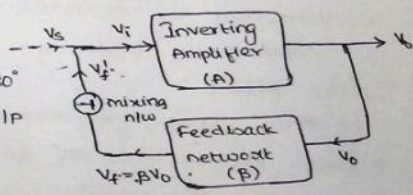


Fig:- Block diag. of Oscillator

feedback voltage, $V_f = \beta V_o$

$V_f = A\beta V_i$ [$\because V_o = AV_i$]

→ To achieve +ve feed back the signal is given to mixing ntw i.e., $V_f' = -V_f$

$$\boxed{V_f' = -A\beta V_i}$$

→ For an oscillator, feedback signal acts as i/p signal

$V_f' = V_i$

$-A\beta V_i = V_i$

$\Rightarrow \boxed{A\beta = -1}$

$A\beta = -1 + j(0)$

magnitude, $|A\beta| = \sqrt{1^2 + 0^2} = 1$

$|A\beta| = 1$

Phase angle $\angle AB = \tan^{-1}\left(\frac{0}{-1}\right)$

$= 0°$ or $360°$ or $2\pi^c$

Barkhausen Criterion Conditions :-

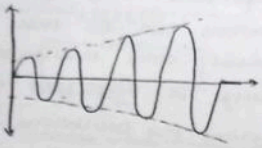
1. The magnitude of loop gain must be unity i.e., $|A\beta|=1$
2. The total phase shift around a closed loop must be 0° or 360° or $n\pi^c$

Satisfying the above conditions the oscillator produces sustained oscillations

Effect of value of $A\beta$ on oscillations :-

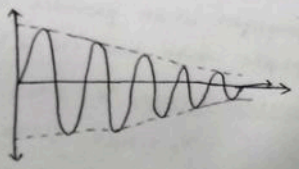
i. $|A\beta|>1$

The total phase shift around a closed loop is 0° or 360° & $A\beta>1$ then the circuit oscillates but the oscillations are exponentially increasing



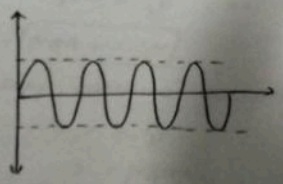
Case ii :- $|A\beta|<1$

The total phase shift around a closed loop is 0° or 360° & $A\beta<1$ then the circuit oscillates with exponentially decreasing



Case iii :- $|A\beta|=1$

The phase shift around a closed loop is 0° or 360° & $A\beta=1$ then the circuit oscillates with constant amplitude & frequency i.e., sustained oscillations.

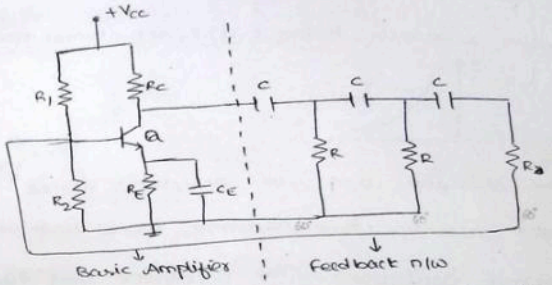


Note :-

→ For a practical oscillator the value of $A\beta$ is kept slightly higher than unity, to compensate temperature and ageing effect.

9/11/15

* **RC Phase shift Oscillators :-**



The above circuit consists of single stage CE amplifier & feedback network. Since CE amplifier provides 180° phase shift so the feedback n/w must provide a phase shift of 180° to obtain total phase shift around a loop is 0° or 360°

→ 1 RC n/w provides 60° phase shift, To obtain a phase shift of 180°, a three such RC n/w's are connected in cascade

Analysis :- $\left[f=\frac{1}{2\pi RC\sqrt{6+4K}}\right]$

Let $K=\frac{R_c}{R}$ & $\alpha=\frac{1}{\omega RC}$

Apply KVL for loop 1 :-

$$R_cI_1+\frac{1}{j\omega C}I_1+R(I_1-I_2)=-h_{fe}I_bR_c$$

$$R\left[\frac{R_c}{R}I_1-\frac{j}{\omega RC}I_1+I_1-I_2\right]=-h_{fe}I_bR_c$$

$$KI_1-j\alpha I_1+I_1-I_2=-h_{fe}I_b\frac{R_c}{R}$$

$$I_1(1+K-j\alpha)-I_2=-h_{fe}I_bK \longrightarrow (1)$$

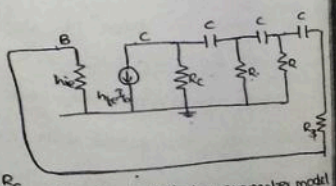


Fig :- Equivalent h-parameter model

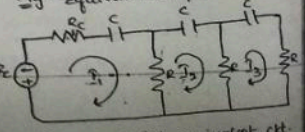


Fig :- Simplified equivalent ckt.

Apply KVL for loop ② :-

$$R(I_2 - I_1) + \frac{1}{j\omega C} I_2 + R(I_2 - I_3) = 0$$

$$I_2 - I_1 + \left(\frac{-j}{\omega RC}\right) I_2 + I_2 - I_3 = 0$$

$$I_2 - I_1 - j\alpha I_2 + I_2 - I_3 = 0$$

$$I_1 (2 - j\alpha) - I_1 - I_3 = 0$$

$$I_1 - (2 - j\alpha) I_2 + I_3 = 0 \longrightarrow ②$$

Apply KVL for loop ③

$$R(I_3 - I_2) + \frac{1}{j\omega C} I_3 + R I_3 = 0$$

$$I_3 - I_2 - \frac{j}{\omega RC} I_3 + I_3 = 0$$

$$I_3 - I_2 - j\alpha I_3 + I_3 = 0$$

$$I_3 (2 - j\alpha) - I_2 = 0$$

$$I_2 = I_3 (2 - j\alpha) \longrightarrow ③$$

Sub eqⁿ ③ in eqⁿ ②

$$I_1 - (2 - j\alpha)(2 - j\alpha) I_3 + I_3 = 0$$

$$I_1 - I_3 [4 + 4j\alpha - \alpha^2] + I_3 = 0$$

$$I_1 = I_3 (3 - 4j\alpha - \alpha^2) \longrightarrow ④$$

Sub ③ & ④ in ①

$$I_3 (3 - 4j\alpha - \alpha^2)(1 + k - j\alpha) - I_3 (2 - j\alpha) = -h_{fe} I_b k$$

$$I_3 [3 + 3k - 3j\alpha - 4j\alpha - 4j\alpha k - 4\alpha^2 - \alpha^2 k + j\alpha^3 - 2 + j\alpha] = -h_{fe} I_b k$$

$$I_3 [(1 + 3k - 5\alpha^2 - k\alpha^2) + j(\alpha^3 - 6\alpha - 4\alpha k)] = -h_{fe} I_b k$$

$$\frac{I_3}{I_b} = \frac{-h_{fe} \cdot k}{[(1 + 3k - (5+k)\alpha^2) + j(\alpha^3 - 6\alpha - 4\alpha k)]}$$

Where $\frac{I_3}{I_b}$ is loop gain. It is always a real quantity i.e., imaginary part = 0

$$\alpha^3 - \alpha(6 + 4k) = 0$$

$$\alpha^2 = 6 + 4k$$

$$\alpha = \sqrt{6 + 4k}$$

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

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

where $k = \frac{R_c}{R}$

* Conditions for sustained oscillations :-

$$\frac{I_3}{I_b} = \frac{-h_{fe} \cdot k}{1 + 3k - (5+k)\alpha^2}$$

$$= \frac{-h_{fe} \cdot k}{1 + 3k - (5+k)(6+4k)} \quad [\because \alpha^2 = 6 + 4k]$$

$$= \frac{-h_{fe} k}{1 + 3k - 30 - 20k - 6k - 4k^2}$$

$$= \frac{h_{fe} k}{4k^2 + 23k + 29}$$

$$\boxed{\frac{I_3}{I_b} = \frac{h_{fe}}{4k + 23 + \frac{29}{k}}}$$

For sustained oscillations, $|A\beta| \geq 1$ i.e., $\frac{I_3}{I_b} \geq 1$

$$\frac{h_{fe}}{4k + 23 + \frac{29}{k}} \geq 1$$

$$\boxed{h_{fe} \geq 4k + 23 + \frac{29}{k}}$$

To determine h_{fe} min, $h_{fe} = 4k + 23 + \frac{29}{k}$

diff w.r.t 'k'

$$\frac{dh_{fe}}{dk} = 4 - \frac{29}{k^2} = 0 \Rightarrow 4 = \frac{29}{k^2} \Rightarrow k^2 = \frac{29}{4}$$

$$k \simeq 2.7$$

Sub h value in h_{fe}

$h_{fe(min)} = 4(2\cdot8) + 3\cdot3 + \frac{2\cdot9}{2\cdot8}$

$h_{fe(min)} = 44\cdot5$

→ To obtain sustained oscillations the value of h_{fe} must be 44·5

* Advantages :-

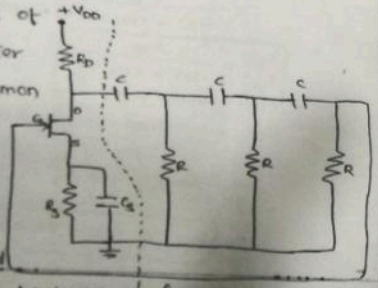
1. It doesn't require transformers or inductors hence it is simple.
2. It is suitable for audio frequency only i.e., (20 - 20k) Hz

Disadvantages :-

1. It is a fixed frequency oscillator i.e., three resistors & capacitors must change simultaneously to change the frequency of oscillation.
2. To obtain sustained oscillations the transistor with $h_{fe(min)} = 44\cdot5$ is required.

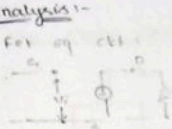
* RC phase shift oscillator using FET :-

The above circuit consists of common source FET amplifier & feedback n/w. Since common source FET amp. provides 180° phase shift. The feedback n/w should also give 180° phase shift so that cascaded 3 RC components are used inorder to make the total phase shift around the loop as 0° or 360°.



Analysis :-

For ac ckt :



G & S are connected in E-S so diode acts as open ckt, $R = \infty$

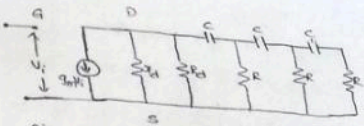
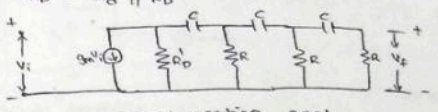
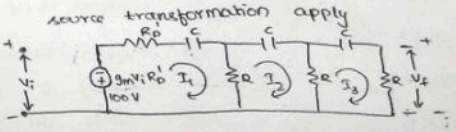


Fig:- Equivalent small signal model

let $R_D' = r_d \,||\, R_D$



source transformation apply



let $\alpha = \frac{1}{\omega RC}$; $R_D' << R_1$ so neglect R_D'

$\frac{1}{j\omega c} I_1 + R(I_1 - I_2) + g_m V_i R_D' = 0$

$\frac{1}{j\omega RC} I_1 + I_1 - I_2 + \frac{g_m V_i R_D'}{R} = 0$

$\frac{-j}{\omega RC} I_1 + I_1 - I_2 = -\frac{g_m V_i R_D'}{R}$

$-j\alpha I_1 + I_1 - I_2 = -\frac{g_m V_i R_D'}{R}$

$I_1(1 - j\alpha) - I_2 = -\frac{g_m V_i R_D'}{R}$ ⟶ ①

Apply KVL to loop ②

$R(I_2 - I_1) + \frac{1}{j\omega c} I_2 + R(I_2 - I_3) = 0$

$I_2 - I_1 - \frac{j}{\omega RC} I_2 + I_2 - I_3 = 0$

$2I_2 - I_1 - j\alpha I_2 - I_3 = 0$

$I_2(2 - j\alpha) - I_1 - I_3 = 0$ ⟶ ②

Apply KVL to loop ③

$\frac{1}{j\omega c} I_3 + RI_3 + R(I_3 - I_2) = 0$

$\frac{-j}{\omega RC} I_1 + I_2 + I_3 - I_2 = 0$

$I_2 (2 - j\alpha) - I_3 = 0$

$I_2 = I_3 (2 - j\alpha) \longrightarrow ③$

sub eq^n ③ in eq^n ⑤

$I_3 (2 - j\alpha)(2 - j\alpha) - I_1 - I_3 = 0$

$I_3 (4 - 4j\alpha - \alpha^2) - I_1 - I_3 = 0$

$I_3 (3 - 4j\alpha - \alpha^2) = I_1 \longrightarrow ④$

sub eq^n ④ & ② in ①

$I_3 (3 - 4j\alpha - \alpha^2)(1 - j\alpha) - I_3 (2 - j\alpha) = \frac{-g_m V_i R_D'}{R}$

$I_3 [3 - 3j\alpha - 4j\alpha - 4\alpha^2 - \alpha^2 + j\alpha^3] - I_3 (2 - j\alpha) = \frac{-g_m V_i R_D'}{R}$

$I_3 [3 - 7j\alpha - 5\alpha^2 + j\alpha^3 - 2 + j\alpha] = \frac{-g_m V_i R_D'}{R}$

$I_3 [1 - 6j\alpha - 5\alpha^2 + j\alpha^3] = \frac{-g_m V_i R_D'}{R}$

$I_3 \cdot R [1 - 5\alpha^2 - j(6\alpha - \alpha^3)] = -g_m V_i R_D'$

The feedback voltage, $V_f = I_3 R$ then the above eq^n becomes

$V_f [1 - 5\alpha^2 - j(6\alpha - \alpha^3)] = -g_m V_i R_D'$

the loop gain, $= \frac{V_f}{V_i} = \frac{o/p}{i/p}$

$\frac{V_f}{V_i} = \frac{-g_m R_D'}{1 - 5\alpha^2 - j(6\alpha - \alpha^3)}$

the loop gain must be real quantity

$\Rightarrow 6\alpha^3 - \alpha^3 = 0 \Rightarrow \alpha^2 = 6$

$\alpha = \sqrt{6}$

$\frac{1}{\omega RC} = \sqrt{6}$

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

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

Condition for sustained Oscillations :-

$\frac{V_f}{V_i} = \frac{-g_m R_D'}{1 - 5\alpha^2}$ (to get condtn equate imaginary part to zero)

$\Rightarrow \alpha^2 = 6$

$\frac{V_f}{V_i} = \frac{-g_m R_D'}{1 - 5(6)} = \frac{-g_m R_D'}{-29}$

For sustained oscillations $A\beta$ must be greater than (or) equal to one i.e., $|A\beta| \geq 1$

$\therefore \frac{g_m R_D'}{29} \geq 1$

$g_m R_D' \geq 29$

Advantages of RC phase shift Oscillator using FET :-

1. It does not require transformers (or) inductors hence it is simple.
2. It is suitable for audio frequency range i.e., 20 to 20k Hz.

Disadvantages :-

1. It is a fixed frequency oscillator i.e., 3 resistors & capacitors must change simultaneously to change the frequency of oscillators.
2. To obtain sustained oscillations the T/F's with h_{fe} (min) = 44.8.

P:- A FET phase shift oscillator has transconductance $g_m = 5\,mV$, drain resistance $r_d = 50\,k\Omega$ & feed back resistor, $R = 100\,k\Omega$, Feedback capacitor $C = 0.5\,pF$ then Calculate frequency of oscillations & value of R_D.

Sol:- Given $g_m = 5\,mV$, $r_d = 50\,k\Omega$; $R = 100\,k\Omega$

$C = 0.5 \times 10^{-12}\,F$

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

$$= \frac{1}{2\pi\sqrt{6}\,(100\times10^{3})\,(65\times10^{-12})}$$

$$= 9996.128\,\Omega$$

$$= 9.99\,k\Omega$$

$$R_D' = \frac{r_d \cdot R_D}{r_d + R_D}$$

$$g_m R_D' = 29$$

$$R_D' = \frac{29}{g_m} = \frac{29}{5\times10^{-3}} = 5800$$

Now $$R_D' = \frac{r_d R_D}{r_d + R_D}$$

$$r_d R_D = R_D'(r_d + R_D)$$

$$r_d R_D - R_D' R_D = R_D' r_d$$

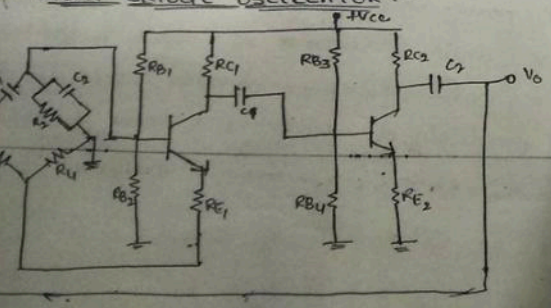
$$R_D(r_d - R_D') = R_D' r_d$$

$$R_D = \frac{R_D' r_d}{r_d - R_D'} = \frac{5800\times50\times10^{3}}{50\times10^{3} - 5800}$$

$$= 6561.085$$

$$= 6.5\,k\Omega$$

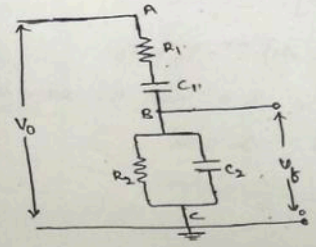
* WEIN BRIDGE OSCILLATOR :-

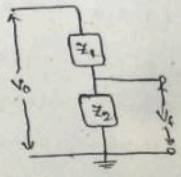


The wein bridge oscillator consists of two stage RC coupled amplifier and feedback n/w. The amplifier provides a phase shift of 0° or 360°. so the feedback n/w has no need to introduce any additional phase shift (Lead n/w $-60°$, lag n/w $-60°$ so both will cancel each other). The feedback n/w consists of lead lag n/w (R_1C_1 & R_2C_2) and voltage divider network (R_3 & R_4).

The lead lag n/w provides +ve feedback to the base of Q_2. The voltage divider n/w provides -ve feedback for emitter of Q_1.

Analysis :-





Let $$Z_1 = R_1 + \frac{1}{j\omega C_1}$$

$$= \frac{R_1 j\omega C_1 + 1}{j\omega C_1}$$

$$Z_2 = R_2 \parallel \frac{1}{j\omega C_2}$$

$$= \frac{R_2\left(\frac{1}{j\omega C_2}\right)}{R_2 + \frac{1}{j\omega C_2}}$$

$$= \frac{R_2}{R_2 j\omega C_2 + 1}$$

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

$$= \frac{1}{2\pi\sqrt{6}\,(100\times10^{3})\,(65\times10^{-12})}$$

$$= 9996.128\,\Omega$$

$$= 9.99\,k\Omega$$

$$R_D' = \frac{r_d\, R_D}{r_d + R_D}$$

$$g_m R_D' = 29$$

$$R_D' = \frac{29}{g_m} = \frac{29}{5\times10^{-3}} = 5800$$

Now $$R_D' = \frac{r_d\, R_D}{r_d + R_D}$$

$$r_d R_D = R_D'(r_d + R_D)$$

$$r_d R_D - R_D' R_D = R_D' r_d$$

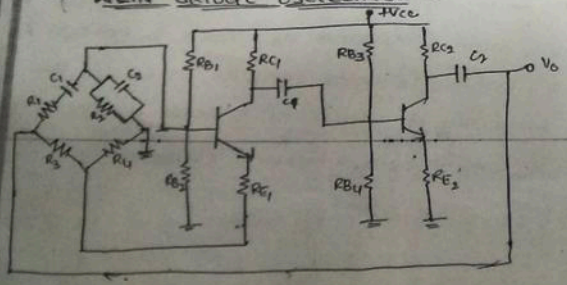
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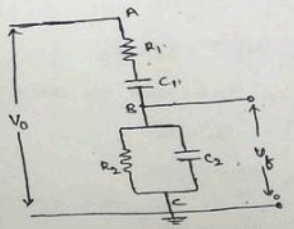
WEIN BRIDGE OSCILLATOR :-

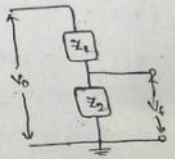


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The lead lag n/w provides +ve feedback to the base of Q_2. The voltage divider n/w provides -ve feedback for emitter of Q_1.

Analysis :-





Let $$Z_1 = R_1 + \frac{1}{j\omega C_1}$$

$$= \frac{R_1 j\omega C_1 + 1}{j\omega C_1}$$

$$Z_2 = R_2 \,//\, \frac{1}{j\omega C_2}$$

$$= \frac{R_2\left(\frac{1}{j\omega C_2}\right)}{R_2 + \frac{1}{j\omega C_2}}$$

$$= \frac{R_2}{R_2 j\omega C_2 + 1}$$

From voltage division principle,

$$V_f = V_o \cdot \frac{Z_2}{Z_2 + Z_1}$$

$$\frac{V_f}{V_o} = \frac{Z_2}{Z_2 + Z_1} = \frac{\frac{R_2}{1+j\omega C_2 R_2}}{\frac{R_2}{1+j\omega C_2 R_2} + \frac{1+j\omega C_2 R_2}{j\omega C_1}}$$

$$= \frac{\frac{R_2}{1+j\omega C_2 R_2}}{\frac{j\omega C_1 R_2 + 1 + j\omega C_2 R_2 + j\omega C_1 R_1 + j^2\omega^2 C_1 R_1 C_2 R_2}{(1+j\omega C_2 R_2)(j\omega C_1)}}$$

$$= \frac{R_2 (j\omega C_1)}{j\omega C_1 R_2 + 1 + j\omega C_2 R_2 + j\omega C_1 R_1 + (-1)\omega^2 C_1 R_1 C_2 R_2}$$

let $R_2 = R_1 = R$

$C_1 = C_2 = C$

$$\frac{V_f}{V_o} = \frac{j\omega RC}{j\omega RC + 1 + j\omega RC + j\omega RC - \omega^2 R^2 C^2}$$

$$\frac{V_f}{V_o} = \frac{j\omega RC}{3j\omega RC - \omega^2 R^2 C^2 + 1}$$

feed back, ratio $\beta = \frac{V_f}{V_o}$

$$\beta = \frac{j\omega RC}{1 + j3\omega RC - \omega^2 R^2 C^2}$$

For sustained oscillations, $A\beta = 1$

$$A\beta = \frac{A \cdot j\omega RC}{1 + j3\omega RC - \omega^2 R^2 C^2} = 1$$

$$\Rightarrow jA\omega RC = 1 + 3j\omega RC - \omega^2 R^2 C^2$$

equating imaginary parts

$$A\omega RC = 3\omega RC$$

$$\Rightarrow \boxed{A = 3}$$

From this $A\beta$ must be greater than 3.

equating real parts on both sides,

$$0 = 1 - \omega^2 R^2 C^2$$

$$\omega^2 R^2 C^2 = 1$$

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

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

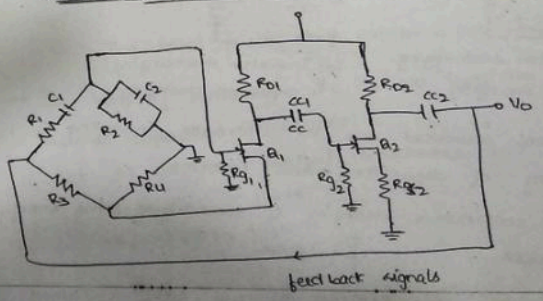
Advantages:-

1. The gain is high (increases) since two stage amplifier is used.
2. Variable frequency oscillator (mounting the capacitors on common shaft)

Disadvantages:-

1. Circuit is complex because more components are required.
2. Not suitable for high frequency applications.

WEIN BRIDGE OSCILLATOR USING FET :-

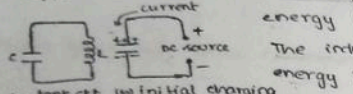


* LC OSCILLATORS :-

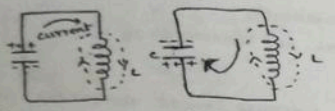
LC oscillators use L & C elements as feedback n/w. LC circuit is also called as "tank circuit" (or) "Resonating circuit".

These oscillators are suitable for high frequency applications.

→ The capacitor stores electrostatic energy in the form of electric field. The inductor stores electromagnetic energy in the form of magnetic field.

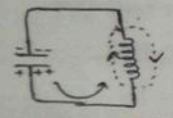


(a) tank ckt (b) initial charging



(c) cap discharging inductor charging

(d) Inductor discharging capacitor charging



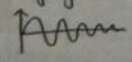
(e) capacitor discharging inductor charging



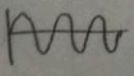
(d) Inductor discharging & capacitor charging

→ Oscillations produced due to alternate charging & discharging of capacitors and inductor.

→ Due to continuous charging & discharging, the energy is reduced.



→ Amplifier provides energy & we get sustained oscillations.



15/4/19

* Generalised Analysis of LC Oscillators :-

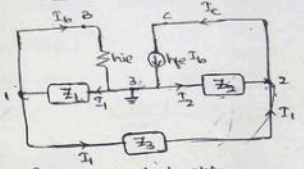


Fig:- equivalent ckt

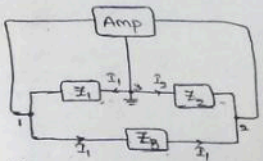


Fig:- Generalised ckt of LC oscillator

where Z_1, Z_2, Z_3 are reactive elements which determines the frequency of oscillator.

Here Z_1 & hie are connected in parallel

$$Z' = Z_1 \,||\, hie$$

$$Z' = \frac{Z_1\, hie}{Z_1 + hie}$$

The load impedance, $Z_L = Z_2 \,||\, (Z' + Z_3)$

$$\Rightarrow \frac{1}{Z_L} = \frac{1}{Z_2} + \frac{1}{Z' + Z_3}$$

$$= \frac{1}{Z_2} + \frac{1}{\frac{Z_1\, hie}{Z_1 + hie} + Z_3}$$

$$= \frac{1}{Z_2} + \frac{Z_1 + hie}{Z_1\, hie + Z_3 (Z_1 + hie)}$$

$$\frac{1}{Z_L} = \frac{hie\,(Z_1 + Z_2) + Z_1 Z_2 + Z_2 (Z_1 + hie)}{Z_2 \left[hie\,(Z_1 + Z_3) + Z_1 Z_3 \right]}$$

$$\frac{1}{Z_L} = \frac{hie\,(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3}{Z_2 \left[hie\,(Z_1 + Z_3) + Z_1 Z_3 \right]}$$

$$\Rightarrow \boxed{Z_L = \frac{Z_2 \left[hie\,(Z_1 + Z_3) + Z_1 Z_3 \right]}{hie\,(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3}}$$

Voltage gain without feedback :-

$$A_v = \frac{A_I R_L}{R_I}$$

$$\boxed{A_v = \frac{-h_{fe} \cdot R_L}{h_{ie}}}$$

The o/p voltage w.r.t the terminals 2 & 3 in terms of current I_1

$$V_o = -I_1 (Z' + Z_3)$$

$$= -I_1 \left[\frac{Z_1 h_{ie}}{Z_1 + h_{ie}} + Z_3 \right]$$

$$= -I_1 \left[\frac{Z_1 h_{ie} + Z_1 Z_3 + Z_3 h_{ie}}{Z_1 + h_{ie}} \right]$$

$$\boxed{V_o = -I_1 \left[\frac{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}{Z_1 + h_{ie}} \right]}$$

Feedback voltage w.r.t terminals 1 & 3 :

$$V_f = -I_1 Z'$$

$$\boxed{V_f = -I_1 \left[\frac{Z_1 h_{ie}}{Z_1 + h_{ie}} \right]}$$

Feedback ratio, $\beta = \frac{V_f}{V_o}$

$$\beta = \frac{Z_1 h_{ie}}{Z_1 + h_{ie}} \times \frac{Z_1 + h_{ie}}{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}$$

$$\boxed{\beta = \frac{Z_1 h_{ie}}{h_{ie}(Z_1 + Z_3) + Z_1 Z_3}}$$

For sustained oscillations :-

$$A\beta = 1$$

$$\frac{-h_{fe} \cdot Z_3 [h_{ie}(Z_1 + Z_2) + Z_1 Z_2]}{h_{ie}[h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3]} \times \frac{Z_1 h_{ie}}{h_{ie}(Z_1 + Z_2) + Z_1 Z_2} = 1$$

$$\frac{-h_{fe} Z_1 Z_2}{h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3} = 1$$

$$\Rightarrow h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 + Z_1 Z_3 + h_{fe} Z_1 Z_2 = 0$$

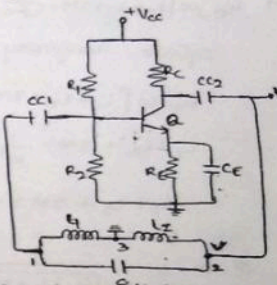
$$\boxed{h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0}$$

Solution : This is the generalised eqn of LC oscillator.

* Hartley Oscillator :-

CC_1 , CC_2 – coupling capacitors

C_E – bi pass capacitor



→ Hartley Oscillator consists of CE amplifier & feedback n/w

→ The feedback n/w consists of inductors L_1, L_2 & capacitor C which determines the frequency of oscillator.

→ CE amplifier provides a phase shift of 180°. The phase difference b/w the terminals 1 & 2 is always 180°.

∴ The total phase shift around a loop is 360° or 0°.

→ In hartley oscillator, Z_1, Z_2 are inductive reactances & Z_3 is capacitive reactance.

Let M be the mutual inductance b/w inductors.

$$Z_1 = j\omega L_1 + j\omega M$$

$$Z_2 = j\omega L_2 + j\omega M$$

$$Z_3 = \frac{1}{j\omega C} = \frac{-j}{\omega C}$$

The generalised eqn of LC oscillator,

$$h_{ie}(Z_1 + Z_2 + Z_3) + Z_1 Z_2 (1 + h_{fe}) + Z_1 Z_3 = 0$$

$\Rightarrow h_{ie}\left[j\omega L_1 + j\omega M + j\omega L_2 + j\omega M - \frac{j}{\omega C}\right] + (j\omega L_1 + j\omega M)(j\omega L_2 + j\omega M)(1+h_{fe}) + (j\omega L_1 + j\omega M)\left(\frac{-j}{\omega C}\right) = 0$

$\Rightarrow j\omega h_{ie}\left[L_1 + L_2 + 2M - \frac{1}{\omega^2 C}\right] - \omega^2 (L_1+M)(L_2+M)(1+h_{fe}) + \frac{L_1+M}{C} = 0$

$\Rightarrow h_{ie}\, j\omega\left[L_1 + L_2 + 2M - \frac{1}{\omega^2 C}\right] - \omega^2 (L_1+M)\left[(L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C}\right] = 0$

Equate imaginary part to zero,

$h_{ie}\,\omega\left[L_1 + L_2 + 2M - \frac{1}{\omega^2 C}\right] = 0$

$L_1 + L_2 + 2M - \frac{1}{\omega^2 C} = 0$

$L_1 + L_2 + 2M = \frac{1}{\omega^2 C}$

$\Rightarrow \omega = \frac{1}{\sqrt{(L_1+L_2+2M)C}}$

$$f = \frac{1}{2\pi\sqrt{(L_1+L_2+2M)C}}$$

If mutually inductance is neglected then

$$f = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$$ — This eqn gives the frequency of oscillations.

Condition for sustained Oscillations :-

Equate real part to zero.

$\omega^2 (L_1+M)\left[(L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C}\right] = 0$

$(L_2+M)(1+h_{fe}) - \frac{1}{\omega^2 C} = 0$

$(L_2+M)(1+h_{fe}) = \frac{1}{\omega^2 C}$

$L_2 + M + (L_2+M)h_{fe} = L_1 + L_2 + 2M$

$$h_{fe} = \frac{L_1+M}{L_2+M}$$

P:- In a hartley oscillator, the inductance $L_1 = 0.4\,mH$ & $C = 0.04\,\mu F$ & oscillating frequency = 120 kHz then find L_2.

Sol:- $f = \frac{1}{2\pi\sqrt{(L_1+L_2)C}}$

$4\pi^2 (L_1+L_2)C = \frac{1}{f^2} \Rightarrow L_1 + L_2 = \frac{1}{4\pi^2 f^2 C}$

$\Rightarrow L_2 = \frac{1}{4\pi^2 f^2 C} - L_1$

$= \frac{1}{4\times\pi^2\times 120^2\times 10^6\times 0.04\times 10^{-6}} - 0.4\times 10^{-3}$

$= -0.36\,mH$

P:- In a transistorised hartley oscillator, $L_1 = 2mH$, $L_2 = 20\,\mu H$ while the freq. is to be changed from 950 kHz to 2050 kHz. Calculate the range over which the capacitor is varied.

Sol:- Given $L_1 = 2mH$, $L_2 = 20\,\mu H$, $f_1 = 950\,kHz$, $f_2 = 2050\,kH$

$C_1 = \frac{1}{4\pi^2 f^2 (L_1+L_2)} = \frac{1}{4\times\pi^2\times 950^2\times 10^6\times(2m+20\mu)}$

$= 0.0139\,nF$

$C_2 = \frac{1}{4\times\pi^2\times 2050^2\times 10^6\times(2m+20\mu)}$

$= 2.98\,pF$

Result: The range of capacitor varies from 0.0139nF to 2.98 pF.

*** Hartley Oscillator using FET :-**

$f = \frac{1}{2\pi\sqrt{LC}}$; $L = L_1 + L_2 + 2M$

Analysis same as BJT transistor.

Advantages :-

1. The frequency can be adjusted by variable capacitance.
2. It is suitable for frequency range from few hundred kHz to 3MHz

Disadvantages :-

1. Mutual Inductance is a problem.
2. It is not suitable for very high frequencies.

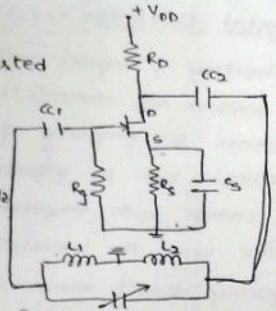


Fig:- Hartley using FET

* Colpitt's Oscillator :-

→ Colpitt's Oscillator consists of CE amplifier & feedback n/w.

→ The feedback n/w consists of 2 capacitors C_1, C_2 & 1 inductor L which determines the frequency of oscillator.

→ CE amp. provides a phase shift of 180°. The phase difference b/w the terminals 1 & 2 is always 180°.

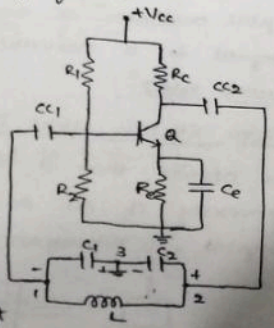
∴ The total phase shift around a loop is 0° or 360°.

→ In Colpitt's Oscillator, Z_1, Z_2 are capacitors & Z_3 is inductance.

$$Z_1 = \frac{1}{j\omega C_1} = \frac{-j}{\omega C_1}, \quad Z_2 = \frac{1}{j\omega C_2} = \frac{-j}{\omega C_2}, \quad Z_3 = j\omega L$$

The generalised eqn for LC oscillator is

$$h_{ie}(Z_1 + Z_2 + Z_3) + (Z_1 Z_3)(1 + h_{fe}) + Z_1 Z_3 = 0$$



$$h_{ie}\left[\frac{-j}{\omega C_1} - \frac{j}{\omega C_2} + j\omega L\right] + \left(\frac{-j}{\omega C_1}\right)\left(\frac{-j}{\omega C_2}\right)(1 + h_{fe}) + \left(\frac{-j}{\omega C_1}\right)(j\omega L) = 0$$

$$-jh_{fe}\left[\frac{1}{\omega C_1} + \frac{1}{\omega C_2} - \omega L\right] - \frac{1 + h_{fe}}{\omega^2 C_1 C_2} + \frac{L}{C_1} = 0$$

$$jh_{fe}\left[\frac{1}{\omega C_1} + \frac{1}{\omega C_2} - \omega L\right] + \left[\frac{1 + h_{fe}}{\omega^2 C_1 C_2} - \frac{L}{C_1}\right] = 0$$

Equating imaginary part to '0'.

$$\Rightarrow \frac{1}{\omega C_1} + \frac{1}{\omega C_2} - \omega L = 0$$

$$\frac{1}{\omega}\left[\frac{1}{C_1} + \frac{1}{C_2}\right] = \omega L$$

$$\frac{C_1 + C_2}{C_1 C_2} = \omega^2 L$$

$$\omega = \sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

$$f = \frac{1}{2\pi}\sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

$$\boxed{f = \frac{1}{2\pi\sqrt{L C_{eq}}}} \quad \text{where } C_{eq} = \frac{C_1 C_2}{C_1 + C_2}$$

condition for sustained oscillations :-

Equate real part to '0'.

$$\frac{1 + h_{fe}}{\omega^2 C_1 C_2} - \frac{L}{C_1} = 0$$

$$\frac{1 + h_{fe}}{\omega^2 C_1 C_2} = \frac{L}{C_1} \Rightarrow \omega^2 = \frac{1 + h_{fe}}{C_2 \cdot L}$$

$$\frac{C_1 + C_2}{C_1 C_2 L} = \frac{1 + h_{fe}}{C_2 L}$$

$$\Rightarrow h_{fe} = \frac{C_1 + C_2}{C_1} - 1 = \frac{C_2}{C_1}$$

$$\boxed{h_{fe} = \frac{C_2}{C_1}}$$

* Advantages :-

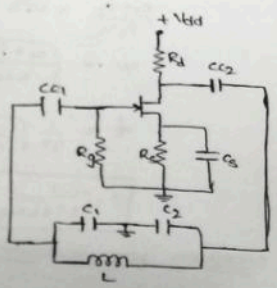
1. Problem of mutual inductance is avoided.
2. It is suitable for frequency ranges from 1 MHz to 100 MHz.
3. It is used as local oscillator in super hetrodyne receiver.

Disadvantages :-

1. The system gain depends on feedback elements which is undesirable.

Colpitt's Oscillator using FET :-

$$f = \frac{1}{2\pi\sqrt{LC}} \quad ; \quad C = \frac{C_1 C_2}{C_1 + C_2}$$



Problem

1- In a colpitt's oscillator, $C_1 = 0.2\,\mu F$, $C_2 = 0.02\,\mu F$, $f = 10\,kHz$. Find the value of inductor & gain required for oscillator.

Sol:- Given $C_1 = 0.2\,\mu F$, $C_2 = 0.02\,\mu F$, $f = 10\,kHz$

$$f = \frac{1}{2\pi}\sqrt{\frac{C_1 + C_2}{L C_1 C_2}}$$

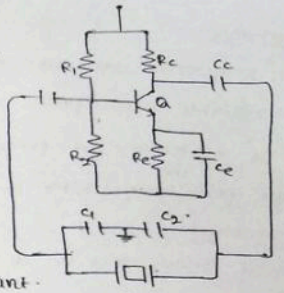
$$10 \times 10^3 = \frac{1}{2\pi} \times \sqrt{\frac{0.2 \times 10^{-6} + 0.02 \times 10^{-6}}{L \times 0.2 \times 0.02 \times 10^{-12}}}$$

$$\therefore L = 0.0139\ H$$

$$\text{gain, } A_{fe} = \frac{C_2}{C_1} = \frac{0.02\,\mu}{0.2\,\mu} = 0.1$$

* Crystal Oscillator :-

In Hartley & colpitt's oscillator the feedback n/w elements (L,C) determines the frequency of oscillations but LC values may change with temperature & time hence the oscillating frequency doesn't remain constant.



→ In order to achieve high degree of frequency stability crystal oscillator is essentially used.

→ Crystal is a material which exhibits "Piezo electric effect".

→ Piezo Electric Effect Principle :- If a mechanical force is applied then a voltage is generated across it. conversely if an AC voltage is applied to the crystal, it produces vibrations / oscillations.

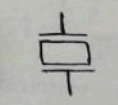


Fig :- Symbol

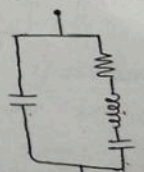


Fig :- equivalent ckt

① When the crystal is not vibrating it is equivalent to a capacitor C_m.

② When the crystal is vibrating then it is equivalent to a series RLC circuit.

Series Resonant Frequency (f_s) :-

It occurs when $X_L = X_C$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC} \Rightarrow \omega = \frac{1}{\sqrt{LC}}$$

$$\boxed{f_s = \frac{1}{2\pi\sqrt{LC}}}$$

Parallel Resonant Frequency (f_p) :-

$$f_p = \frac{1}{2\pi\sqrt{LC_{eq}}} \quad \text{where} \quad C_{eq} = \frac{C \cdot C_m}{C + C_m}$$

Advantages :-

1. High frequency stability
2. The quality factor of crystal is high.

Disadvantages :-

1. The cost of crystal is highly expensive

solving

* Frequency stability of an Oscillator :-

The ability of an oscillator to maintain desired frequency for a long time is known as frequency stability of an oscillator.

→ The main drawback of transistor oscillator is that the oscillating freq is not stable.

→ The stability is affected due to following factors :-

1. Variation in temperature :-
2. Variation in power supply :-

Due to change in supply voltage, the oscillating frequency changes.

3. Change in O/P load :-

The effective resistance of tank circuit changed when load is connected

4. Effect of internal capacitances :- The junction capacitance of transistor changes the capacitance of tank circuit

→ The variation of frequency with temperature is given by

$$S_{\omega,T} = \frac{\Delta\omega/\omega_0}{\Delta T/T_0}$$

$\omega_0 \rightarrow$ desired frequency $T_0 \rightarrow$ operating temperature

$\Delta\omega \rightarrow$ change in freq. $\Delta T_0 \rightarrow$ change in temperature

→ The frequency stability is defined as

$$S_\omega = \frac{d\theta}{d\omega}$$

where $d\theta$ is change in phase shift for small change in frequency.

→ Larger the value of $\frac{d\theta}{d\omega}$, better stability.

solu 60

UNIT- V

POWER AMPLIFIER

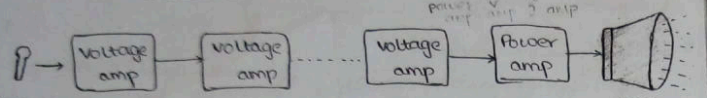


Fig:- Public addressing system

→ The microphone converts audio signals into electrical signal (in the order of mV) this weak signal is amplified by multistage voltage amplifier but it can't drive the load (load speaker). Hence the last stage must be a power amplifier.

→ Power amplifier drives the load by providing sufficient power (load power) to the load. It is also called as large signal amplifier since it deals with large voltages & current swings.

→ Power amplifier is also defined as the circuit which coverts DC power to AC power & whose action is controlled by i/p signal.

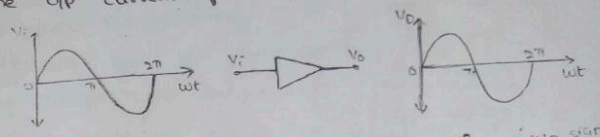
* Classification of Power Amplifiers :-

Based on biasing conditions & Q-point position the power amplifiers can be classified as

1. Class A P.A
2. Class B P.A
3. Class AB P.A
4. Class C P.A
5. Class D P.A
6. Class S P.A

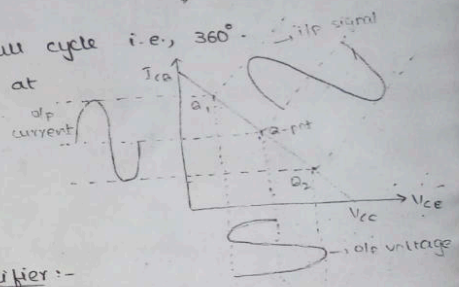
1. Class A Power Amplifier :-

The transistor is biased in such a way that the o/p current flows for complete cycle of i/p signal.



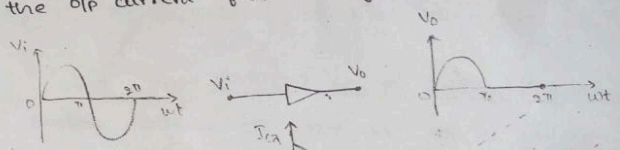
→ It conducts for full cycle i.e., 360°.

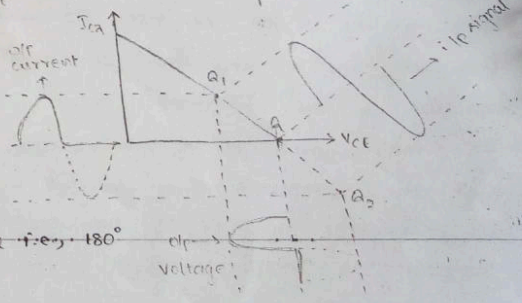
→ Q-point is selected at centre of the load line.



2. Class B Power Amplifier :-

The transistor is biased in such a way that the o/p current flows only for half cycle.





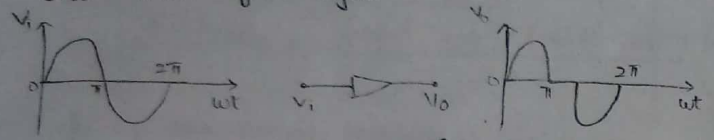
→ Q-point is selected on x-axis.

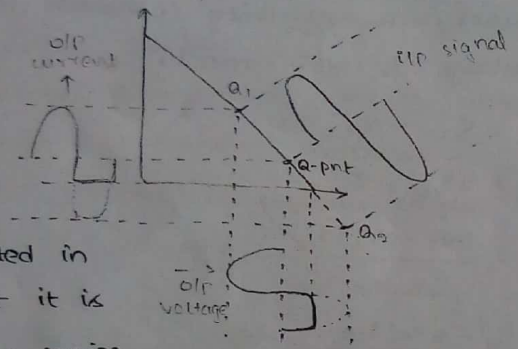
→ It conducts for half cycle i.e., 180°

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3. Class AB Power Amplifier :-

The transistor is biased in such a way that the o/p current flows for more than half cycle & less than full cycle.





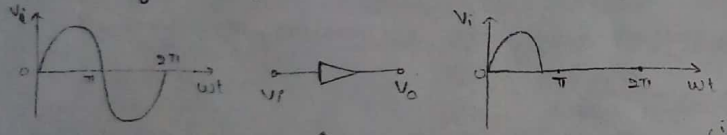
→ It conducts for more than 180° & less than 360°

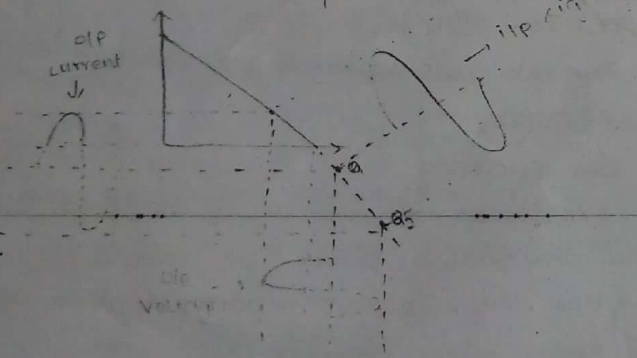
→ ~~Cut of~~

→ Q-point is selected in such a way that it is above the cut off region.

4. Class C Power Amplifier :-

The transistor is biased in such a way that the o/p current flows for less than half cycle.





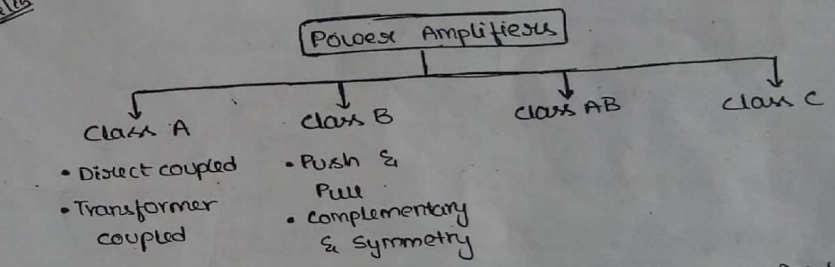
- It conducts less than 180°
- Q point is selected, beyond the cutoff region.

* Class D & Class S Amplifiers :-

These are switched mode power amplifiers.

Power Amp	Conducting angle	Q-point position
class A	360°	middle of load line
class B	180°	on x-axis
class AB	180° – 360°	above cut off region & below middle of load line
class C	< 180°	beyond cut off region

2 rules

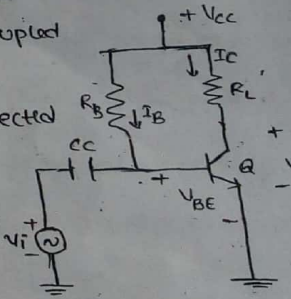


* Direct Coupled (or) Series fed Class A Power Amplifier :-

→ The above circuit is direct coupled class A amplifier.

→ since the load is directly connected to the collector circuit.

→ The values of biasing resistor, R_B & supply voltage V_{cc} are selected in such a way that the Q-point must be in the middle of load line.



DC Analysis :-

Apply KVL to B-E loop,

$$V_{cc} = I_B R_B + V_{BE}$$

$$I_B = \frac{V_{cc} - V_{BE}}{R_B}$$

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(17)

$$I_{BQ} = \frac{V_{CC} - 0.7}{R_B}$$

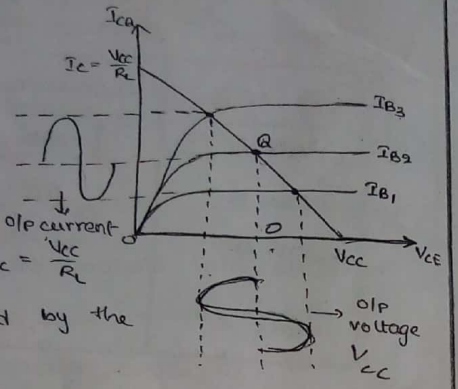
Apply KVL for C-E loop

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

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

If $I_C = 0$; $V_{CE} = V_{CC}$

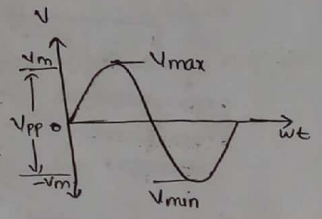
If $V_{CE} = 0$; $V_{CC} = I_C R_L \Rightarrow I_C = \frac{V_{CC}}{R_L}$



The DC i/p power is supplied by the source, V_{CC}.

$$\boxed{P_{DC} = V_{CC} \times I_{CQ}} \longrightarrow (1)$$

AC Analysis :-



- The peak-to-peak value of AC o/p voltage is

$$V_{pp} = V_{max} - V_{min}$$

- The amplitude of AC o/p voltage is

$$V_m = \frac{V_{p-p}}{2} = \frac{V_{max} - V_{min}}{2}$$

- The R.M.S value of AC o/p voltage is $V_{rms} = \frac{V_m}{\sqrt{2}}$
- The peak-to-peak value of AC o/p current is

$$I_{p-p} = I_{max} - I_{min}$$

- The amplitude of AC o/p current is

$$I_m = \frac{I_{p-p}}{2} = \frac{I_{max} - I_{min}}{2}$$

- The RMS value of AC o/p current is $I_{rms} = \frac{I_m}{\sqrt{2}}$
- The AC o/p power, $P_{ac} = V_{rms} \cdot I_{rms}$

$$= \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$$

$$\boxed{P_{ac} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}}$$

* Efficiency :- It is the ratio of AC power delivered to the load to the power supplied by the DC source.

$$\boxed{\eta = \frac{\text{AC power delivered to the load}}{\text{power supplied by DC source}}}$$

$$\therefore \% \eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 \times V_{CC} I_{CQ}} \times 100$$

To obtain max. efficiency consider max. swings of o/p voltage & o/p current.

$V_{max} = V_{CC}$; $V_{min} = 0$

$I_{max} = 2I_{CQ}$; $I_{min} = 0$

$$\% \eta = \frac{(V_{CC} - 0)(2I_{CQ} - 0)}{8 \cdot V_{CC} \cdot I_{CQ}} \times 100$$

$$= \frac{2 V_{CC} I_{CQ}}{8 V_{CC} I_{CQ}} \times 100$$

$$\boxed{\% \eta = 25 \%}$$

The direct coupled class A amp. has conversion efficiency 25%.

Note :-

For practical amp, the conversion $\eta < 25\%$ i.e., 10-15%.

Advantages :-

1. It is simple & cheap
2. The o/p is available for complete cycle of I/p signal.

Disadvantages :-

1. low efficiency
2. Since load is directly connected to collector circuit the considerable power is wasted.
3. Has high o/p impedance & low impedance matching.
4. High power dissipation.

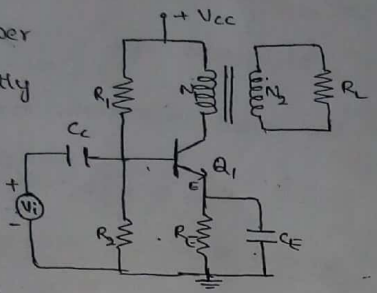
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* Transformer Coupled Class A Power Amplifier :-

→ In direct coupled class A power amplifier, the load R_L is directly connected to the collector circuit

→ The ~~Q-point~~ Quiescent current I_{CQ} passes through this resistant as a result considerable amount of power is wasted across the load.

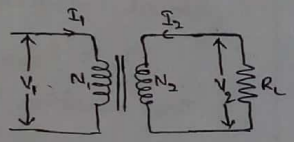


→ The DC current passing through the load is undesireable

→ It doesn't provide any impedance matching.

→ To overcome these problems "Transformer coupled class A amplifier" is used.

Transformer :-



$$\frac{V_2}{V_1} = \frac{N_2}{N_1} = n \quad ; \quad \frac{I_2}{I_1} = \frac{N_1}{N_2} = \frac{1}{n}$$

$$V_1 = V_2 \cdot \frac{N_1}{N_2} \quad ; \quad I_1 = I_2 \cdot \frac{N_2}{N_1}$$

$$\frac{V_1}{I_1} = \frac{V_2 \cdot \frac{N_1}{N_2}}{I_2 \cdot \frac{N_2}{N_1}} = \frac{V_2}{I_2}\left(\frac{N_1}{N_2}\right)^2$$

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

where R_L is load resistance
R_L' is reflected resistance
R_L' is always higher than R_L for step down T/F.

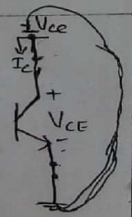
$$\boxed{R_L' = \frac{1}{n^2} \cdot R_L}$$

The impedance matching can be achieved by modifying turns ratio.

DC Analysis :-

Let us assume the winding resistance of T/F is zero.

Hence no DC voltage is dropped across primary winding.



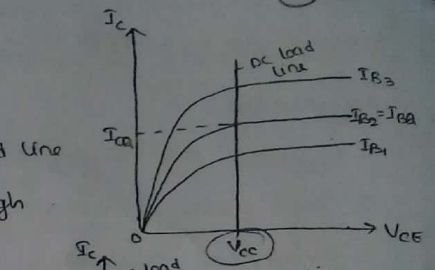
Apply KVL, $V_{cc} = V_{CE}$

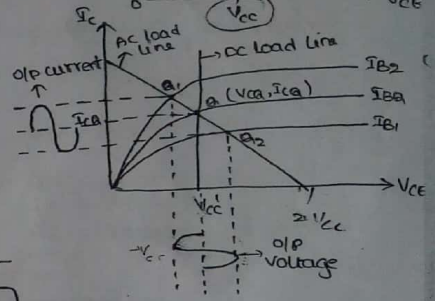
$$I_c = 0 \; ; \quad I_c = \frac{V_{cc}}{R_d} = \frac{V_{cc}}{0} = \infty$$

The DC i/p power, $\boxed{P_{DC} = V_{cc} I_{CQ}}$

AC Analysis :-

For AC Analysis, draw AC load line with slope $\frac{-1}{R_L'}$ & passing through Q-point.





The AC power delivered to the load $P_{AC} = V_{rms} \cdot I_{rms}$

$$P_{AC} = \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} = \frac{V_m I_2}{2}$$

$$P_{AC} = \frac{\left(\frac{V_{max} - V_{min}}{2}\right) \cdot \left(\frac{I_{max} - I_{min}}{2}\right)}{2}$$

$$\boxed{P_{AC} = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8}}$$

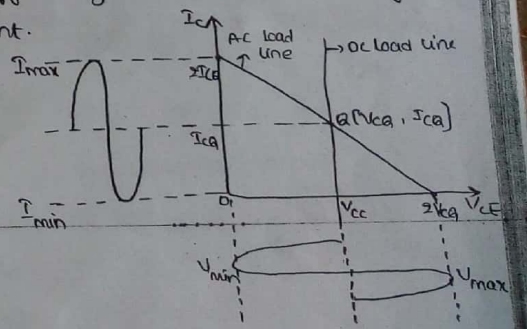
Efficiency (η) :-

$$\eta = \frac{\text{AC power delivered to the load}}{\text{Power supplied by the DC source}}$$

$$\eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{cc} I_{CQ}}$$

$$\% \eta = \frac{(V_{max} - V_{min})(I_{max} - I_{min})}{8 V_{cc} I_{CQ}} \times 100$$

To obtain the maximum efficiency consider max. swings of o/p voltage & o/p current.



$V_{max} = 2V_{cc}$, $V_{min} = 0$

$I_{max} = 2I_{CQ}$, $I_{min} = 0$

$$\% \eta = \frac{(2V_{cc} - 0)(2I_{CQ} - 0)}{8 V_{cc} I_{CQ}} \times 100$$

$$= \frac{4}{8} \times 100$$

$$\boxed{\% \eta = 50 \%}$$

The max. conversion efficiency of a T/F coupled class A

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Note:- For practical amp, $\eta = 35 - 40\%$.

Advantages:-

1. Efficiency is higher than direct coupled.
2. The power wastage across the load is avoided ~~reduced~~.
3. Impedance matching is achieved.

Disadvantages:-

1. The T/F makes the circuit bulky & costly.
2. The T/F noise is added to the o/p signal. Hence the frequency response is poor.

Analysis

* Harmonic Distortion:-

→ Harmonic distortion means the presence of frequency components in the o/p waveform which are not present in the i/p signal.

→ The component with frequency same as i/p signal is called fundamental frequency component.

→ The additional frequency components having frequencies which are integer multiples of fundamental frequency components. The fundamental freq. component is not considered as harmonic.

→ As the order of harmonic increases its amplitude decreases.

→ Out of all the freq. components, the 2nd harmonic has the higher amplitude.

→ let B_1 is the amplitude of the fundamental component.

B_2 " " " " " 2nd harmonic.

⋮

B_N " " " " " nth harmonic

→ Now distortion of 2nd harmonic $\%\ D_2 = \frac{|B_2|}{|B_1|} \times 100$

Distortion of 3rd harmonic, $\%\ D_3 = \frac{|B_3|}{|B_1|} \times 100$

⋮

Distortion of nth harmonic, $\%\ D_n = \frac{|B_n|}{|B_1|} \times 100$

→ The total distortion, $D = \sqrt{D_2^2 + D_3^2 + \cdots + D_n^2}$

$$\%\ D = \sqrt{D_2^2 + D_3^2 + \cdots + D_n^2} \times 100$$

* Second Harmonic Distortion:-

The distortion occurs due to the non-linear characteristics of the transistor.

Ac Analysis:-

Let us consider a cosinesoidal signal produces base current

$$I_b = I_{bm} \cos\omega t$$

The relation b/w I_c & I_b is

$$i_c = G_1 i_b + G_2 i_b^2$$

$$i_c = G_1 I_{bm} \cos\omega t + G_2 I_{bm}^2 \cos^2\omega t$$

$$= G_1 I_{bm} \cos\omega t + G_2 I_{bm}^2 \left(\frac{1+\cos 2\omega t}{2}\right)$$

$$= G_1 I_{bm} \cos\omega t + \frac{1}{2} G_2 I_{bm}^2 + \frac{1}{2} G_2 I_{bm}^2 \cos 2\omega t$$

$$\therefore i_c = B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t$$

The total current,

$$i_c = I_{CQ} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t$$

$I_{CQ} + B_0 \longrightarrow$ DC level

$B_1 \longrightarrow$ amplitude of fundamental comp.

$B_2 \longrightarrow$ amplitude of 2nd harmonic

at point ①:-

$$\omega t = 0 \quad ; \quad i_c = I_{max}$$

$$I_{max} = I_{CQ} + B_0 + B_1 + B_2 \longrightarrow ①$$

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at point ②:- $\omega t = \frac{\pi}{2}$; $i_c = I_{CQ}$; $I_{CQ} = I_{CQ} + B_0 - B_2$ ⟶ ②

at point ③:- $\omega t = \pi$; $i_c = I_{min}$

$I_{min} = I_{CQ} + B_0 - B_1 + B_2$ ⟶ ③.

From eqn ③ $B_0 = B_2$ ⟶ ④

① − ③

$I_{max} - I_{min} = 2B_1$

$\Rightarrow \boxed{B_1 = \frac{I_{max} - I_{min}}{2}}$

① + ③

$I_{max} + I_{min} = 2I_{CQ} + 2B_0 + 2B_2$

from eqn ④

$\Rightarrow I_{max} + I_{min} = 2I_{CQ} + 4B_2$

$\boxed{B_2 = \frac{I_{max} + I_{min} - 2I_{CQ}}{4}}$

% Distortion $(D_2) = \frac{|B_2|}{|B_1|} \times 100$.

Power due to fundamental component,

$P_1 = \frac{B_1^2 \cdot R_L}{2}$

Power due to second harmonic, $P_2 = \frac{B_2^2 \cdot R_L}{2}$

Total Power, $P = P_1 + P_2 + P_3 + \cdots$

$= \frac{B_1^2 R_L}{2} + \frac{B_2^2 R_L}{2} + \frac{B_3^2 R_L}{2} + \cdots$

$= (B_1^2 + B_2^2 + B_3^2 + \cdots) \cdot \frac{R_L}{2}$

$= \left(1 + \frac{B_2^2}{B_1^2} + \frac{B_3^2}{B_1^2} + \cdots\right) \frac{B_1^2 R_L}{2}$

$P = (1 + D_2^2 + D_3^2 + \cdots) P_1$

total distortion, $D = \sqrt{D_2^2 + D_3^2 + \cdots}$

$\boxed{P = (1 + D^2) P_1}$

P:- A class A amp. has $V_{CC} = 20V$, $V_{CEQ} = 10V$, $I_{CQ} = 600\,mA$ & collector load resistance, $R_L = 16\Omega$, the AC o/p current varies by ± 300 mA with the i/p signal. Determine

a) Power supplied by DC source
d) DC power delivered to the transistor.
b) DC power consumed by the load
c) AC power developed across the load.
e) Overall efficiency. f) collector efficiency.

Sol:-

a) $P_{DC} = V_{CC} \cdot I_{CQ} = 20 \times 600 \times 10^{-3} = 12\,W$

b) $P_{DC(load)} = I_{CQ}^2 R_L = (600)^2 \times 10^{-6} \times 16 = 5.76\,W$

c) $P_{AC} = I_{rms}^2 R_L = (0.21)^2 \times 16 = 0.72\,W$

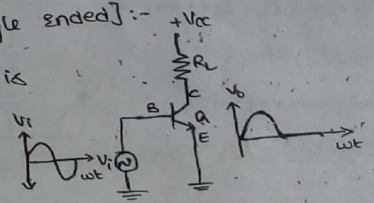
$I_{rms} = \frac{I_m}{\sqrt{2}} = \frac{0.3}{\sqrt{2}} = 0.21\,A$

d) $P_{DC(transistor)} = P_{DC} - P_{DC(load)} = 12 - 5.76 = 6.24\,W$

e) % $\eta = \frac{\text{AC power delivered to the load}}{\text{Power supplied by the DC power}} \times 100 = \frac{0.72}{12} \times 100 = 6\%$.

f) collector efficiency $= \frac{\text{AC Power delivered to the load}}{\text{Power transferred to the collector}} = \frac{0.72}{6.24} = 11.5\%$.

* Class B Power Amplifier [single ended]:-



In class B mode, the Q-point is selected at cut-off region.

→ During +ve half cycle of i/p signal transistor conducts & collector current flows.

→ During −ve half cycle the base emitter junction is reverse biased & the transistor is off then no current flows. since the transistor is biased in cut-off the o/p is available only for half cycle of i/p signal.

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Advantages:-

1. High conversion efficiency i.e., 78.5 %
2. In the absence of i/p signal the transistor doesn't conduct hence low power dissipation. ~~How power~~

Disadvantages:-

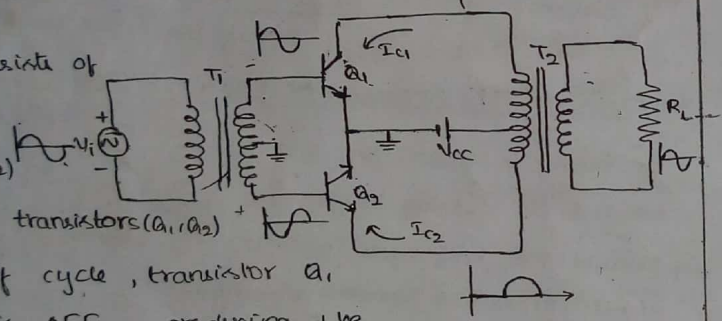
1. since the transistor is biased in cutoff, the o/p is available only for half cycle hence loss of signal occurs
2. The distortion is high.

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* Push Pull Class B Amplifier:-

In Class B operation the Q-point is selected at cut off region, the o/p is available ~~as~~ only for half cycle of input signal. Hence the o/p is distorted.

→ To get full cycle across load two transistors are required. for +ve half cycle 1 transistor conducts, for -ve half cycle 1 transistor conducts. Finally a full cycle is obtained across the load.



→ The circuit consists of 2 centre tapped Transformers (T_1, T_2) and 2 identical transistors (Q_1, Q_2)

→ During +ve half cycle, transistor Q_1 is ON & Q_2 is OFF, producing +ve half cycle across the load.

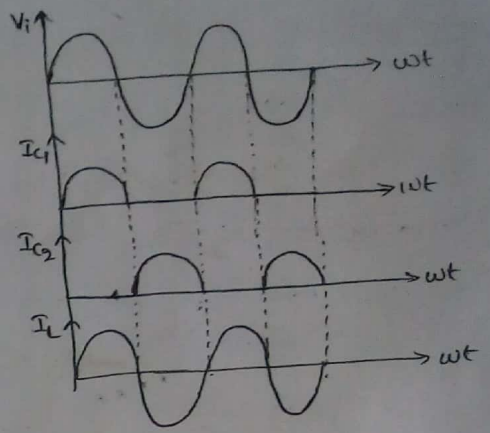
→ During -ve ~~half~~ cycle, transistor Q_1 is OFF & Q_2 is ON producing -ve half cycle across load.

→ Finally a full cycle is obtained across the load.

DC Analysis:-

In Class B operation, the Q-point is selected at cut off region such that $V_{CEQ} = V_{cc}$

$I_{CQ} = 0$



→ Since the o/p of transistor is in the form of half wave rectified wave form

the DC value, $I_{DC} = \frac{I_m}{\pi}$

for two transistors $I_{DC} = \frac{2I_m}{\pi}$

DC i/p power, $P_{DC} = V_{cc} \cdot I_{DC}$

$\therefore$ $P_{DC} = \frac{2I_m}{\pi} \cdot V_{cc}$

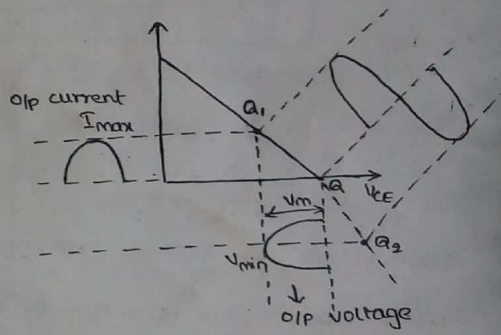
AC Analysis:-

$P_{ac} = V_{rms} \cdot I_{rms}$

$= \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}}$

For max. P_{ac}, $V_m = V_{cc}$

$P_{ac} = \frac{V_{cc} I_m}{2}$

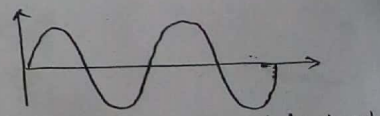


% Efficiency, $\% \eta = \frac{P_{ac}}{P_{dc}} \times 100$

$= \frac{\frac{V_{cc} I_m}{2}}{\frac{2I_m V_{cc}}{\pi}} \times 100$

$= \frac{\pi}{4} \times 100$

$\% \eta = 78.5\ \%$



AC power delivered to load

The maximum conversion of efficiency of push pull Class B amplifier is 78.5 %.

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Advantages :-

1. High efficiency than class A P.A
2. Since the Q-point is in cut off region, if the i/p signal is absent there is no power dissipation.
3. Due to T/F coupling, impedance matching is provided.
4. The Even harmonics get cancelled, hence harmonic distortion reduced.

Disadvantages :-

1. Two centre tapped T/F's are reqd which makes the circuit bulky & costly.
2. The freq. response is poor
3. Two identical transistors are reqd which is practically not possible.

solution

* Cancellation of even harmonics :-

Let the base current is $i_b = I_{bm} \cos\omega t$

For transistor Q_1, $i_{b1} = I_{bm} \cos\omega t$

For transistor Q_2, $i_{b2} = -I_{bm} \cos\omega t$

where -ve sign indicates 180° phase shift

$$i_{b2} = I_{bm} \cos(\omega t + \pi)$$

The collector current,

$$i_c = I_{cq} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + B_3 \cos 3\omega t + \ldots$$

for transistor Q_1, $i_{c1} = I_{cq} + B_0 + B_1 \cos\omega t + B_2 \cos 2\omega t + \ldots$

for transistor Q_2, $i_{c2} = I_{cq} + B_0 + B_1 \cos(\omega t + \pi) + B_2 \cos 2(\omega t + \pi) + \ldots$

$$i_{c2} = I_{cq} + B_0 - B_1 \cos\omega t + B_2 \cos 2\omega t - B_3 \cos 3\omega t + \ldots$$

For load current, $I_L = i_{c1} - i_{c2}$

$$I_L = 2B_1 \cos\omega t + 2B_3 \cos 3\omega t + 2B_5 \cos 5\omega t + \ldots$$

The even harmonics components are get eleminated similarly the DC component is also reduced hence the distortion is reduced.

Total distortion, $D = \sqrt{D_3^2 + D_5^2 + D_7^2 + \ldots}$

Note :- The even harmonics are cancelled only when two transistors are identical.

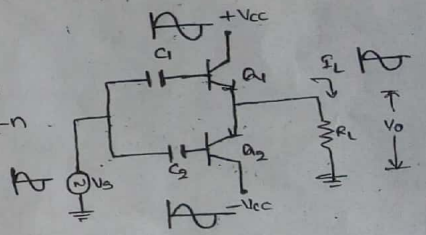
Disadvantages :-

1. T/F's makes the circuit bulky & costly.

Complementary symmetry Class B Amplifier :-

→ In class B push pull amp. a centre tapped T/F's are used which makes the ckt complex & costly. To overcome this problem complementary symmetry class-B amplifier is used

→ In a complementary symmetry class-B amp, a p-n-p, n-p-n transistor pair is used which are connected in common collector configuration to provide impedance matching.



→ During +ve half cycle, transistor Q_1 is ON & Q_2 is OFF. producing +ve half cycle across the load.

→ During -ve half cycle transistor Q_2 is ON & Q_1 is OFF producing -ve half cycle across load.

∴ A complete cycle is available across load for a complete cycle of i/p signal.

Advantages :-

1. Due to T/F less arrangement, the ckt becomes simple.
2. Frequency response is good.

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Disadvantages :-

1. Two separate power supply's are required.
2. It produces cross over distortion.

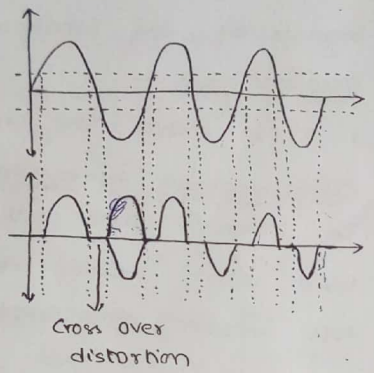
Note :- Analysis same as push pull amplifier.

Cross Over Distortion :-

In class B operation the Q-point is selected at cut off region i.e., no bias is applied to the base emitter junction. so that the i/p signal must exceed cut in voltage of transistor to make transistor to conduct

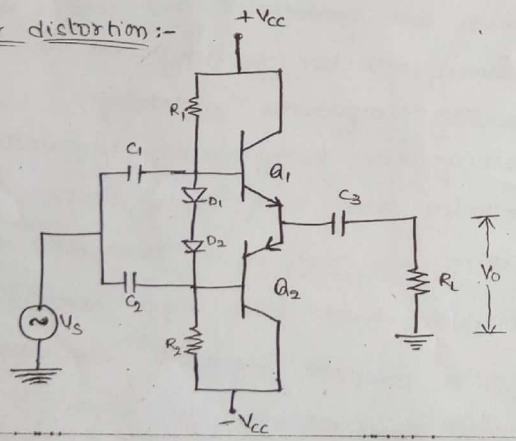
Si : $V_\gamma = 0.7$ V

Ge : $V_\gamma = 0.3$ V



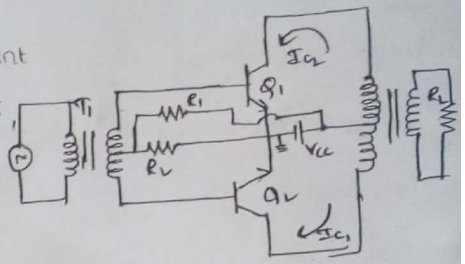
→ One Transistor stops conducting before other transistor begins conducting. The resultant effect is called Cross-over distortion.

Elimination of Cross Over distortion :-



Class AB Power Amplifier :-

In class AB operation the Q-point is selected just above the cut-off region. The values of R_1, R_2 are V_1 selected in such a way that the collector current flows more than half cycle & less than full cycle.



→ The distortion in class AB is less than Class B.

→ class AB is designed specifically to eliminate cross over distortion.

→ The voltage drop across R_1 is approx. equal to cut in voltage, V_γ

Advantages :-

1. Cross over distortion is eliminated.

Disadvantages :-

1. Efficiency is ∞ to 78.5 %.

* Heat Sink :-

Heat sink is a mechanical device which is connected to the case of the transistor that provides large surface area to dissipate power in the form of heat is known as heat sink.

Advantages :-

1. The power handling capacity of transistor increases.
2. The case temperature of transistor decreases.

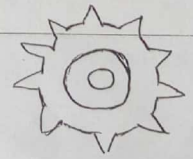
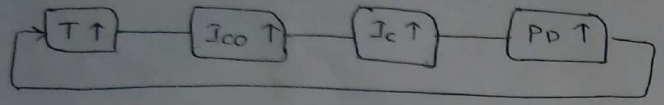


Fig :- Fin type heat sink

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* Thermal Stability:



→ The destruction of transistor by a cummulative effect of rise in temperature is called thermal run away.

→ Power dissipation capability of a transistor depends on its construction.

Ge : 60° – 100°
Si : 150° – 225°

→ The collector junction temperature increases due to
i rise in ambient temp. (p-n junction, atmosphere temp)
ii Power dissipated at collector junction

→ The junction temperature is directly proportional to the power dissipated at the junction.

$$T_J - T_A \propto P_D$$

where T_J – junction temp
T_A – ambient temp
P_D – Power dissipated

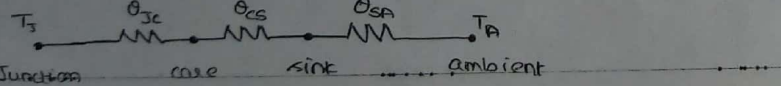
$$T_J - T_A = \theta P_D$$

$$\rightarrow \theta = \frac{T_J - T_A}{P_D} \quad {}^\circ C/W \text{ or } {}^\circ C/mW$$

where θ is called thermal resistance

$\theta = 0.2^\circ C/W$ – for high power transistor

$\theta = 1000^\circ C/W$ – for low power transistor



total thermal resistance,

$$\theta = \theta_{JA} = \theta_{JC} + \theta_{CS} + \theta_{SA}$$

where θ_{JA} → Junction to ambient thermal resistance
θ_{JC} → Junc. to case thermal resistance
θ_{CS} → case to heat sink thermal resist
θ_{SA} → sink to ambient " " "

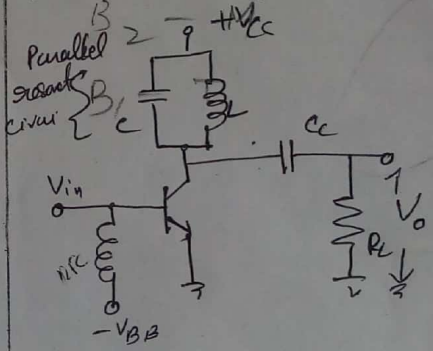
Total power dissipated by the transistor,

$$P_D = \frac{T_J - T_A}{\theta} = \frac{T_J - T_A}{\theta_{JA}}$$

$$P_D = \frac{T_J - T_A}{\theta_{JC} + \theta_{CS} + \theta_{SA}}$$

where, $\theta_{JC} = \frac{T_J - T_C}{P_D}$, $\theta_{CS} = \frac{T_C - T_S}{P_D}$, $\theta_{SA} = \frac{T_S - T_A}{P_D}$

Class-C Tuned Amplifier:



The LC parallel circuit is a parallel resonant circuit. This circuit acts as a load impedance. Due to class c operation, the collector current consists of a series of pulses containing harmonics ie many other frequency components along with the fundamental frequency component of I/P.

The parallel tuned circuit is designed to be tuned to the fundamental I/P frequency. It is also called as RF tuned power Amplifier (RFPA) Efficiency is more $\eta > 78.5\%$.

Purpose of Tank circuit in class C Amplifier:-

1. Tank circuit acts as a load line
2. It should reject harmonics & select only the fundamental
3. Efficiency of tank circuit is $\eta = 1 - \frac{Q_{loaded}}{Q_{unloaded}}$
4. Higher the Q-factor of load better the harmonic rejection but efficiency decreases
$Q_{load} > 10$ (Slightly greater)

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