Program Name : **Electronics Engineering Programme Group**

Program Code : **DE/EJ/ET/EN/EX/EQ/IE/IS/IC**

Semester : **Fourth**

Course Title : **Linear Integrated Circuits**

Course Code : **22423**

1. RATIONALE

Operational Amplifier (Op-Amp) is the most versatile Linear Integrated Circuit (IC) used to develop various application in electronic circuits and equipment. Hence this course is intended to develop the skills to build, test, diagnose and rectify the Op-Amp based electronic circuits.This course deals with various aspects of Linear Integrated circuits used in various industrial,consumer and domestic applications.

2. COMPETENCY

The aim of this course is to help the student to attain the following industry identified competency through various teaching learning experiences:

- **Maintain electronic circuits consisting of Linear Integrated Circuits**.

3. COURSE OUTCOMES (COs)

The theory, practical experiences and relevant soft skills associated with this course are to be taught and implemented, so that the student demonstrates the following ***industry oriented*** COs associated with the above mentioned competency:

a. Use Op-Amp in linear electronic circuits.
b. Use various configurations of Op-Amp for different applications.
c. Troubleshoot various linear applications of Op-Amp for the given specifications.
d. Maintain filters and oscillators used in various electronic circuits.
e. Trooubleshoot specified applications using various linear ICs.

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme			Credit (L+T+P)	Examination Scheme												
				Theory							Practical					
L	T	P		Paper Hrs.	ESE		PA		Total		ESE		PA		Total	
					Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
4	-	2	6	3	70	28	30*	00	100	40	25#	10	25	10	50	20

(*): Under the theory PA, Out of 30 marks, 10 marks are for micro-project assessment to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T** – Tutorial/Teacher Guided Theory Practice; **P** - Practical; **C** – Credit, **ESE** - End Semester Examination; **PA** - Progressive Assessment.*

5. COURSE MAP (with sample COs, PrOs,UOs,ADOs and topics)

This course map illustrates an overview of the flow and linkages of the topics at various levels of outcomes (details in subsequent sections) to be attained by the student by the end of the

course, in all domains of learning in terms of the industry/employer identified competency depicted at the centre of this map.

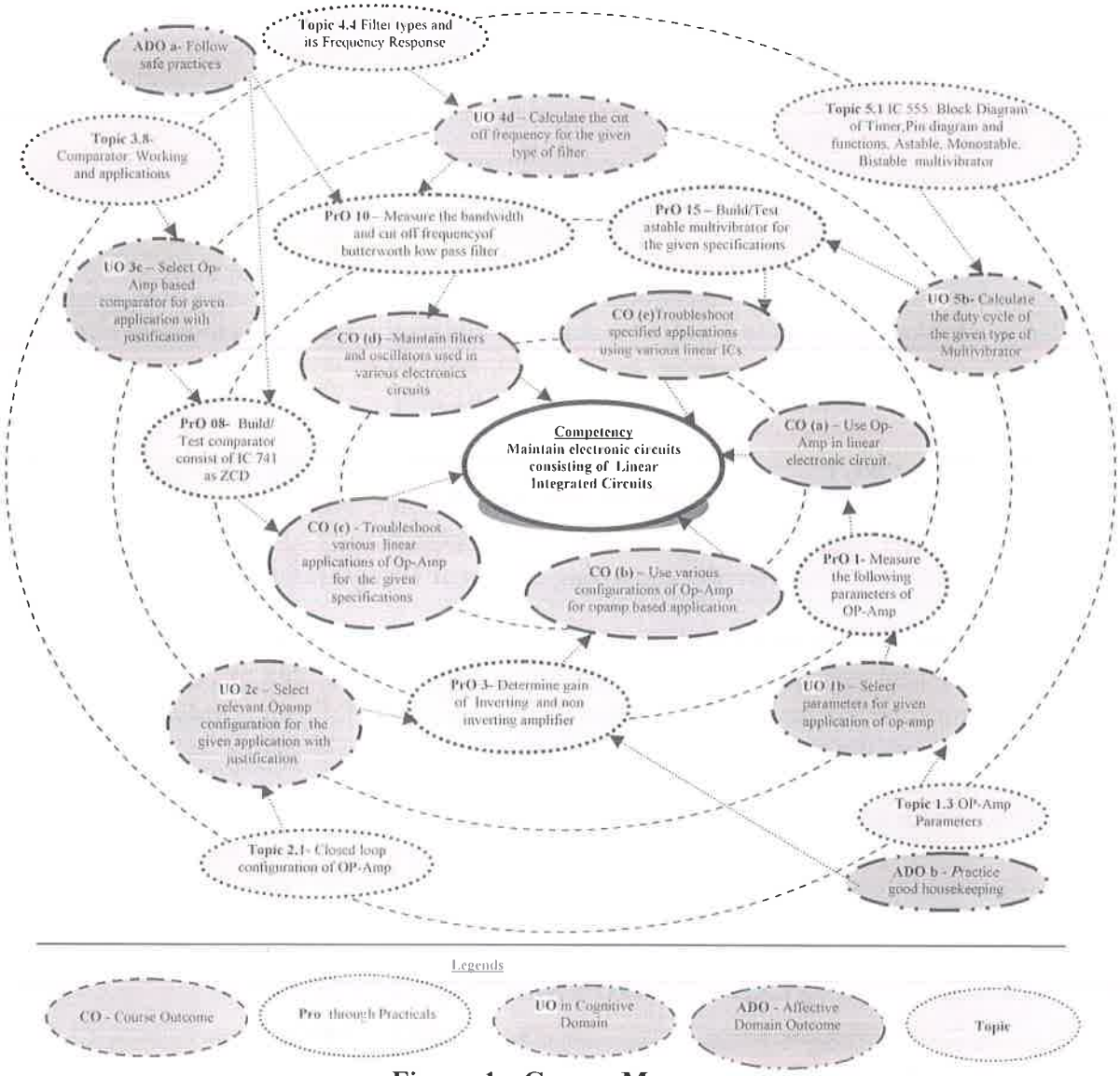

Figure 1 - Course Map

6. SUGGESTED PRACTICALS/ EXERCISES

The practicals in this section are PrOs (i.e. sub-components of the COs) to be developed and assessed in the student for the attainment of the competency:

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
1	Use relevant instruments to measure the differential input resistance, input offset voltage, output offset voltage and common mode rejection ratio (CMRR) of IC741.	I	02*
2	Measure the Output voltage Swing parameter of Op-Amp IC 741.	I	02
3	Use relevant instruments to determine gain of the Inverting amplifier and Non Inverting amplifier consist of IC741.	II	02*
4	Build/Test adder and subtractor circuit consist of IC 741.	II	02*
5	Build/Test Integrator circuit consist of IC741.	II	02

S. No.	Practical Outcomes (PrOs)	Unit No.	Approx. Hrs. Required
6	Build/Test differentiator circuit consist of IC741.	II	02
7	Build/Test Voltage to Current converter and Current to Voltage converter circuit consist of IC 741.	III	02
8	Build/Test comparator circuit consist of IC741 as Zero crossing detector and active positive peak detector.	III	02*
9	Build/Test Instrumentation amplifier circuit using IC LM324.	III	02
10	Use relevant instruments to measure the bandwidth and cutoff frequency of the given first order low pass Butterworth filter .	IV	02*
11	Use relevant instruments to measure the bandwidth and cutoff frequency of the given first order high pass Butterworth filter .	IV	02*
12	Use relevant instruments to measure the cutoff frequency of the given notch filter .	IV	02
13	Use relevant instruments to measure the frequency of oscillation of the given RC Phase shift oscillator circuit using IC741.	IV	02
14	Measure the frequency of oscillation of the given wien bridge oscillator circuit using IC741.	IV	02
15	Build/Test astable multivibrator using IC555 for the given specifications.	V	02*
16	Build/Test monostable multivibrator using IC555 for the given specifications.	V	02
	Total		**32**

Note

i. A suggestive list of PrOs is given in the above table. More such PrOs can be added to attain the COs and competency. A judicial mix of minimum 12 or more practical need to be performed, out of which, the practicals marked as '' are compulsory, so that the student reaches the 'Precision Level' of Dave's 'Psychomotor Domain Taxonomy' as generally required by the industry.*

ii. The 'Process' and 'Product' related skills associated with each PrO is to be assessed according to a suggested sample given below:

S. No.	Performance Indicators	Weightage in %
1	Preparation of experimental set up	20
2	Setting and operation	20
3	Safety measures	10
4	Observations and recording	10
5	Interpretation of result and conclusion	20
6	Answer to sample questions	10
7	Submission of report in time	10
	Total	**100**

The above PrOs also comprise of the following social skills/attitudes which are Affective Domain Outcomes (ADOs) that are best developed through the laboratory/field based experiences:

a. Follow safe practices
b. Practice good housekeeping
c. Practice energy conservation

d. Demonstrate working as a leader/a team member
e. Maintain tools and equipment
f. Follow ethical practices.

The ADOs are not specific to any one PrO, but are embedded in many PrOs. Hence, the acquisition of the ADOs takes place gradually in the student when s/he undertakes a series of practical experiences over a period of time. Moreover, the level of achievement of the ADOs according to Krathwohl's 'Affective Domain Taxonomy' should gradually increase as planned below:

- 'Valuing Level' in 1st year
- 'Organising Level' in 2nd year
- 'Characterising Level' in 3rd year.

7. MAJOR EQUIPMENT/ INSTRUMENTS REQUIRED

The major equipment with broad specification mentioned here will usher in uniformity in conduct of experiments, as well as aid to procure equipment by authorities concerned.

S. No.	Equipment Name with Broad Specifications	PrO. No.
1	Variable DC power supply 0- 30V, 2A	All
2	Cathode Ray Oscilloscope Duel Trace 30Mhz, 1MegaΩ Input Impedance	2,3,5,6,8,9,10, 11,12,16,
3	Digital Storage Oscilloscope 25MHz/40MHz/60MHz/100MHz bandwidth,500MS/s to 1GS/s real time sample rate	2,3,5,6,8,9,10, 11,12,13,14,15 , 16
4	Function Generator 0-2 MHz with Sine , square and triangular output with variable frequency and amplitude range.	2,3,5,6,8,9,10, 11,12,13,14,15 ,16
5	Digital Multimeter : 4 1/2 digit display, 9999 counts digital multimeter measures: V_{ac}, V_{dc} (1000V max) , A_{dc}, A_{ac} (10 amp max)\, Resistance (0 - 100 MΩ)	All
6	Electronic Work Bench : Bread Board 840 1000 contact point, Positive and Negative power rails on opposite side of the board, connecting wires	All

8. UNDERPINNING THEORY COMPONENTS

The following topics are to be taught and assessed in order to develop the sample UOs given below for achieving the COs to attain the identified competency. More UOs could be added.

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit – I Fundamentals of Operational Amplifier(Op-Amp)	1a. Describe with sketches the function of the given block(s) of the Op-Amp. 1b. Select the parameters to be considered for the given applications of the Op-Amp with justification. 1c. Explain with sketches the	1.1 Operational Amplifier, Equivalent Circuit, Circuit symbols and Terminals. 1.2 Op-Amp IC 741 pin diagram and pin function; Op-Amp parameters: Input offset voltage, Input Offset current, Input bias current, Differential input resistence, Input capacitance, Input

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
	working of the given type of Op-Amp configuration. 1d. Describe with sketches the procedure to troubleshoot the given Op-Amp circuit.	voltage range, offset voltage adjustment range, Common Mode Rejetion Ratio (CMRR), Supply Voltage Rejection Ratio (SVRR), Slew Rate, Large Signal Voltage Gain, Supply voltage, Supply Current, Output voltage Swing,Gain Bandwidth Product, Output Short Circuit Current 1.3 Transfer Characterstic- Ideal and Practical Voltage Transfer Curve 1.4 Op-Amp Configuration: Open Loop and Closed loop 1.5 Virtual Ground Concept 1.6 Features, pin diagram and pin function of dual Op Amp IC 747,
Unit-II Applications of Operational amplifier	2a. Explain with sketches the working of the given types of modes of Op-Amp operation. 2b. Calculate the output voltage of the given arithmetic circuit consist of Op-Amp . 2c. Select the relevant Op-Amp configuration for the given application with justification. 2d. Calculate the given parameter for the specified Op-Amp configuration.	2.1 Closed Loop configuration, modes of operations: Inverting and Non-Inverting, 2.2 Diffrential amplifier, Unity Gain Amplifier (voltage follower) 2.3 Arithmatic operations: Addition , Scaling, Averaging , Subtraction Integrator, Diffrentiator 2.4 Concept of frequency compensation of Op-Amp and offset nulling
Unit– III Linear Applications of Op-Amp	3a. Explain with sketches the working of an Instrumentation amplifier for the given application. 3b. Choose relevant Op-Amp converter for the given applications with justification. 3c. Select the Op-Amp based comparator for the given application with justification . 3d. Explain with sketches working of Op-Amp for the given application.	3.1 Op-Amp as an Instrumentation amplifier: Working, Derivation of output voltage, IC LM 324- Pin Configuration, specification and application 3.2 Voltage to Current converter with Floating and Grounded load 3.3 Current to Voltage converter 3.4 Sample and Hold Circuit 3.5 Logarithmic and Antilogarithmic amplifier using diodes 3.6 Analog Divider and analog multiplier 3.7 Comparators: IC LM710 a. Zero Crossing Detector b. Schmitt Trigger c. Window Detector d. Phase Detector e. Active Peak Detector f. Peak to Peak Detector

Unit	Unit Outcomes (UOs) (in cognitive domain)	Topics and Sub-topics
Unit– IV Filters and Oscillators	4a. Explain working of the given type of filter with sketches. 4b. Explain with sketches procedure to identify the given type of filter based on frequency response. 4c. Calculate cut-off frequency for the given type of filter. 4d. Prepare the specifications of the given type of filter with justification. 4e. Explain with sketches the working principle of the given type of oscillator. 4f. Determine the frequency of oscillation of the given type of oscillator with frequency response. 4g. Describe with sketches the the procedure to troubleshoot the given filter/oscillator circuit.	4.1 Filter and its classification 4.2 Merits and demerits of active filters over passive filters 4.3 Filter characterstic terms:order of filter, cut off frequency,Pass band, Stop band, Centre frequency,Roll off rate, Bandwidth, Q factor 4.4 Filter types and its Frequency Response: Low pass(First Order and second order),High Pass (First Order and second order),Band pass(Wide and Narrow), Band Reject(Wide and Narrow), All Pass Filter 4.5 Ocsillator types using IC 741: Phase shift oscillator,Wein Bridge oscillator, Colpitts oscillator, Hartley oscillator
Unit –V Specialized IC Applications	5a. Explain with sketches the working of IC555 for the given application. 5b. Calculate the duty cycle of the given type of multivibrator. 5c. Explain with sketches the working of the given blocks of PLL. 5d. Calculate lock range and capture range of the given PLL. 5e. Describe with sketches the the procedure to troubleshoot the given circuit with IC.	5.1 IC 555: Block Diagram of Timer,Pin diagram and functions,Astable, Monostable, Bistable multivibrator, Schmitt trigger and Voltage Control Oscillator 5.2 Phase Lock Loop (PLL): Block diagram and its operation, lock range and capture range 5.3 Applications of PLL: PLL as a Multiplier, FM Demodulator. 5.4 IC 565: Pin diagram and function

Note: To attain the COs and competency, above listed UOs need to be undertaken to achieve the 'Application Level' and above of Bloom's 'Cognitive Domain Taxonomy'

9. SUGGESTED SPECIFICATION TABLE FOR QUESTION PAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
I	Fundamentals of Operational Amplifiers	10	02	02	04	08
II	Applications of Operational Amplifiers	10	02	04	06	12
III	Linear Applications of Op-Amp	18	02	06	12	20

Unit No.	Unit Title	Teaching Hours	Distribution of Theory Marks			
			R Level	U Level	A Level	Total Marks
IV	Filters and Oscillators	16	02	06	10	18
V	Specialized IC Applications	10	02	04	06	12
Total		**64**	**10**	**22**	**38**	**70**

Legends: *R=Remember, U=Understand, A=Apply and above (Bloom's Revised taxonomy)*
Note*: This specification table provides general guidelines to assist students for their learning and to teachers to teach and assess students with respect to attainment of UOs. The actual distribution of marks at different taxonomy levels (of R, U and A) in the question paper may vary from above table.*

10. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related ***co-curricular*** activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group and prepare reports of about 5 pages for each activity, also collect/record physical evidences for their (student's) portfolio which will be useful for their placement interviews:

a. Prepare journals based on practical performed in laboratory.
b. Follow the safety precautions.
c. Use various meters to test electronic equipment and component
d. Use datasheets ofvarious Linear ICs.
e. Library / Internet survey of Op-Amp based linear circuits and their applications.
f. Prepare power point presentation or animation for understanding different Op-Amp based circuit behavior.

11. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES (if any)

These are sample strategies, which the teacher can use to accelerate the attainment of the various outcomes in this course:

a. Massive open online courses (***MOOCs***) may be used to teach various topics/sub topics.
b. ***'L' in item No. 4*** does not mean only the traditional lecture method, but different types of teaching methods and media that are to be employed to develop the outcomes.
c. About ***15-20% of the topics/sub-topics*** which is relatively simpler or descriptive in nature is to be given to the students for ***self-directed learning*** and assess the development of the COs through classroom presentations (see implementation guideline for details).
d. With respect to item No.10, teachers need to ensure to create opportunities and provisions for ***co-curricular activities***.
e. Guide student(s) in undertaking micro-projects.
f. Demonstrate students thoroughly before they start doing the practice.
g. Encourage students to refer different websites to have deeper understanding of the subject.
h. Observe continuously and monitor the performance of students in Lab.

12. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project are group-based. However, in the fifth and sixth semesters, it should be preferably be ***individually*** undertaken to build up the skill and confidence in every student to become problem solver so

that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should ***not exceed three.*** The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain dated work diary consisting of individual contribution in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than ***16 (sixteen) student engagement hours*** during the course. The student ought to submit micro-project by the end of the semester to develop the industry oriented COs. Micro project report may be of four to five pages.

A suggestive list of micro-projects are given here. Similar micro-projects could be added by the concerned faculty:

a. Build Instrumentation Amplifier (IC LM324) for measurement of tempreture using thermocouple/RTD/Thermister.
b. Develop sound sensor using LM324 and microphone.
c. Develop a shadow sensor circuit using IC741.
d. Develop a temperature control dc fan using IC 741.
e. Develop a remote control for switching devices (use IC 555 and TSOP 1738).
f. Develop sequential timer circuit using multiple timers.
g. Develop clap switch using op-amp.
h. Develop water level controller using IC555.
i. Develop a tone generator using using IC 555.
j. Develop PWM LED Dimmer/ Brightness Control using IC555.
k. Build frequency synthesizer using PLL IC565.
l. Develop FSK modulator and demodulator using PLL IC565
m. Simulate using software LT spice/ P psice / Scilab,/Matlab /Octave or any other open source software linear IC applications

13. SUGGESTED LEARNING RESOURCES

S. No.	Title of Book	Author	Publication
1	Op-Amps and Linear Integrated Circuits	Gayakwad, Ramakant A.	PHI Learning, New Delhi, 2011, ISBN: 9788120320581
2	Operational Amplifiers and Linear ICs	Bell, David A.	Oxford University Press, New Delhi, India,2011,ISBN: 9780195696134
3	Operation Amplifier with Linear Integrated Circuit	Stanley,Willam D.	Pearson Education India, New Delhi, 2002, ISBN: 9788131708453
4	Design with Operational Amplifier and Analog Integrated Circuit	Franco, Sergio.	McGraw-Hill Education, New Delhi, 2014, ISBN: 9780078028168
5	Linear Integrated Circuits	Sivakumar, Senthil M.	S.Chand Publishing,mNew Delhi, 2014, ISBN: 9788121941136
6	Linear Integrated Circuits	RoyChoudhury, D; Jain, Sail B.	New Age International Publisher, New Delhi, 2003, ISBN: 8122414702
7	Linear Integrated Circuits	Salivahanan S.	McGraw Hill, New Delhi, 2008,ISBN: 978-0-07-064818-0

S. No.	Title of Book	Author	Publication
8	Electronics Lab Manual	Navas, K .A.	PHI Learning, New Delhi, 2014 ISBN: 9788120351424
9	Industrial Electronics and Control	Paul, Biswanath	PHI Learning, New Delhi, 2015, ISBN: 9788120349902

14. SUGGESTED SOFTWARE/LEARNING WEBSITES

a. Op-Amp:- http://www.jamia-physics.net/lecnotes/lab/opamp.pdf
b. IC555:-http://www.jamia-physics.net/lecnotes/lab/555.pdf
c. IC 555 data sheet:-http://www.electroschematics.com/650/lm555-datasheet/
d. Op-Amplifier basics:-https://www.khanacademy.org/science/electrical-engineering/ee-amplifiers
e. Data sheet555:-www.engineersgarage.com/electronic-components/ne555-timer-ic-datasheet
f. Vide lecture Op-Amp:-http://freevideolectures.com/Course/3062/Electronics-I/37
g. Voltage control Oscilator:- http://www.electronicshub.org/voltage-controlled-oscillators-vco/
h. Op-Amp:-http://www.talkingelectronics.com/projects/OP-AMP/OP-AMP-1.html


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