| ECT301 | LINEAR INTEGRATED CIRCUITS | CATEGORY | L | T | P | CREDITS |
|---|---|---|---|---|---|---|
| | | PCC | 3 | 1 | 0 | 4 |

**Preamble:** This course aims to develop the skill to design circuits using operational amplifiers and other linear ICs for various applications.

**Prerequisite**: EC202 Analog Circuits

**Course Outcomes:** After the completion of the course the student will be able to

| | |
|---|---|
| **CO 1** | Understand Op Amp fundamentals and differential amplifier configurations |
| **CO 2** | Design operational amplifier circuits for various applications |
| **CO 3** | Design Oscillators and active filters using opamps |
| **CO4** | Explain the working and applications of timer, VCO and PLL ICs |
| **CO5** | Outline the working of Voltage regulator IC's and Data converters |

**Mapping of course outcomes with program outcomes**

| | PO 1 | PO 2 | PO 3 | PO 4 | PO 5 | PO 6 | PO 7 | PO 8 | PO 9 | PO 10 | PO 11 | PO 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **CO 1** | 3 | 3 | 1 | 2 | | | | | | | | 1 |
| **CO 2** | 3 | 3 | 2 | 2 | 2 | | | | | | | 1 |
| **CO 3** | 3 | 3 | 2 | 2 | 2 | | | | | | | 1 |
| **CO 4** | 3 | 3 | 1 | 2 | 2 | | | | | | | 1 |
| **CO 5** | 3 | 3 | 2 | 2 | 2 | | | | | | | 1 |

**Assessment Pattern**

| **Bloom's Category** | | **Continuous Assessment Tests** | | **End Semester Examination** |
|---|---|---|---|---|
| | | **1** | **2** | |
| Remember | K1 | 10 | 10 | 10 |
| Understand | K2 | 30 | 30 | 60 |
| Apply | K3 | 10 | 10 | 30 |
| Analyse | K4 | | | |
| Evaluate | | | | |
| Create | | | | |

**Mark distribution**

| **Total Marks** | **CIE** | **ESE** | **ESE Duration** |
|---|---|---|---|
| **150** | **50** | **100** | **3 hours** |

**Continuous Internal Evaluation Pattern:**

| | |
|---|---|
| Attendance | : 10 marks |
| Continuous Assessment Test (2 numbers) | : 25 marks |
| Assignment/Quiz/Course project | : 15 marks |

**End Semester Examination Pattern:** There will be two parts; Part A and Part B. Part A contain 10 questions with 2 questions from each module, having 3 marks for each question. Students should answer all questions. Part B contains 2 questions from each module of which student should answer any one. Each question can have maximum 2 sub-divisions and carry 14 marks.

**Course Level Assessment Questions**

**Course Outcome 1 (CO1): Analyze differential amplifier configurations**.

1. Explain the working of BJT differential amplifiers.
2. Calculate the input resistance, output resistance, voltage gain and CMRR of differential amplifiers.
3. Explain the non-ideal parameters of differential amplifiers.
4. Derive CMRR, input resistance and output resistance of a dual input balanced output differential amplifier configuration.

**Course Outcome 2 (CO2): Design operational amplifier circuits for various applications.**

1. Design an opamp circuit to obtain an output voltage $V_0=-(2V_1+4V_2 + 3V_3)$
2. A 741C op-amp is used as an inverting amplifier with a gain of 50. The voltage gain vs frequency curve of 741C is flat upto 20kHz.What maximum peak to peak input signal can be applied without distorting the output?
3. With the help of a neat circuit diagram, derive the equation for the output voltage of an Instrumentation amplifier.
4. With the help of circuit diagrams and graphs, explain the working of a Full wave Precision rectifier.

**Course Outcome 3 (CO3): Design active filters using opamps**

1. Derive the design equations for a second order Butterworth active low pass filter.
2. Design a Notch filter to eliminate power supply hum (50 Hz).
3. Design a first order low pass filter at a cut-off frequency of 2kHz with a pass band gain of 3

**Course Outcome 4 (CO4): Explain the working and applications of specialized ICs**

1. With the help of internal diagram explain the monostable operation of timer IC 555. Draw the input and different output waveforms. Derive the equation for pulse width.
2. Explain the operation of Phase Locked Loop. What is lock range and capture range? Realize a summing amplifier to obtain a given output voltage.

3. Design a circuit to multiply the incoming frequency by a factor of 5 using 565 PLL.

**Course Outcome 5 (CO5): Outline the working of Voltage regulator IC's and Data converters**

1. What is the principle of operation of Dual slope ADC. Deduce the relationship between analogue input and digital output of the ADC.
2. Explain how current boosting is achieved using I.C 723
3. Explain the working of successive approximation ADC

**SYLLABUS**

**Module 1:**

**Operational amplifiers(Op Amps):** The 741 Op Amp, Block diagram, Ideal op-amp parameters, typical parameter values for 741, Equivalent circuit, Open loop configurations, Voltage transfer curve, Frequency response curve.

**Differential Amplifiers:** Differential amplifier configurations using BJT, DC Analysis- transfer characteristics; AC analysis- differential and common mode gains, CMRR, input and output resistance, Voltage gain. Constant current bias, constant current source; Concept of current mirror-the two transistor current mirror, Wilson and Widlar current mirrors.

**Module 2:**

**Op-amp with negative feedback**: General concept of Voltage Series, Voltage Shunt, current series and current shunt negative feedback, Op Amp circuits with voltage series and voltage shunt feedback, Virtual ground Concept; analysis of practical inverting and non-inverting amplifiers for closed loop gain, Input Resistance and Output Resistance.
**Op-amp applications:** Summer, Voltage Follower-loading effects, Differential and Instrumentation Amplifiers, Voltage to current and Current to voltage converters, Integrator, Differentiator, Precision rectifiers, Comparators, Schmitt Triggers, Log and antilogamplifiers.

**Module 3:**

**Op-amp Oscillators and Multivibrators:** Phase Shift and Wien-bridge Oscillators, Triangular and Sawtooth waveform generators, Astable and monostable multivibrators.
**Active filters**: Comparison with passive filters, First and second order low pass, High pass, Band pass and band reject active filters, state variable filters.

**Module 4 :**

**Timer and VCO:** Timer IC 555- Functional diagram, Astable and monostable operations;. Basic concepts of Voltage Controlled Oscillator and application of VCO IC LM566,
**Phase Locked Loop –** Operation, Closed loop analysis, Lock and capture range, Basic building blocks, PLL IC 565, Applications of PLL.

**Module 5:**

**Voltage Regulators:** Fixed and Adjustable voltage regulators, IC 723 – Low voltage and high voltage configurations, Current boosting, Current limiting, Short circuit and Fold-back protection.
**Data Converters:** Digital to Analog converters, Specifications, Weighted resistor type and R-2R Ladder type.
Analog to Digital Converters: Specifications, Flash type and Successive approximation type.

**Text Books**

1. Roy D. C. and S. B. Jain, Linear Integrated Circuits, New Age International, 3/e, 2010

**Reference Books**

1. DFranco S., Design with Operational Amplifiers and Analog Integrated Circuits, 3/e, Tata McGraw Hill, 2008
2. Gayakwad R. A., Op-Amps and Linear Integrated Circuits, Prentice Hall, 4/e, 2010
3. Salivahanan S. and V. S. K. Bhaaskaran, Linear Integrated Circuits, Tata McGraw Hill, 2008.
4. Botkar K. R., Integrated Circuits, 10/e, Khanna Publishers, 2010
5. C.G. Clayton, Operational Amplifiers, Butterworth & Company Publ. Ltd. Elsevier, 1971
6. David A. Bell, Operational Amplifiers & Linear ICs, Oxford University Press, 2nd edition, 2010
7. R.F. Coughlin & Fredrick Driscoll, Operational Amplifiers & Linear Integrated Circuits, 6th Edition, PHI, 2001
8. Sedra A. S. and K. C. Smith, Microelectronic Circuits, 6/e, Oxford University Press, 2013.

**Course Contents and Lecture Schedule**

| No | Topic | No. of Lectures |
|---|---|---|
| **1** | **Operational amplifiers** | **(9)** |
| 1.1 | The 741 Op Amp, Block diagram, Ideal op-amp parameters, typical parameter values for 741 | 1 |
| 1.2 | Equivalent circuit, Open loop configurations, Voltage transfer curve, Frequency response curve. | 1 |
| 1.3 | Differential amplifier configurations using BJT, DC Analysis- transfer characteristics | 2 |
| 1.4 | AC analysis- differential and common mode gains, CMRR, input and output resistance, Voltage gain | 2 |
| 1.5 | Constant current bias and constant current source | 1 |
| 1.6 | Concept of current mirror, the two transistor current mirror Wilson and Widlar current mirrors. | 2 |
| 2 | **Op-amp with negative feedback and Op-amp applications** | **(11)** |

| | | |
|---|---|---|
| 2.1 | General concept of Voltage Series, Voltage Shunt, current series and current shunt negative feedback | 1 |
| 2.2 | Op Amp circuits with voltage series and voltage shunt feedback, Virtual ground Concept | 1 |
| 2.3 | Analysis of practical inverting and non-inverting amplifier | 2 |
| 2.4 | Summer, Voltage Follower-loading effect | 1 |
| 2.5 | Differential and Instrumentation Amplifiers | 1 |
| 2.6 | Voltage to current and Current to voltage converters | 1 |
| 2.7 | Integrator, Differentiator | 1 |
| 2.8 | Precision rectifiers-half wave and full wave | 1 |
| 2.9 | Comparators, Schmitt Triggers | 1 |
| 2.10 | Log and antilog amplifier | 1 |
| **3** | **Op-amp Oscillators and Multivibrators** | **(10)** |
| 3.1 | Phase Shift and Wien-bridge Oscillators, | 2 |
| 3.2 | Triangular and Sawtooth waveform generators, Astable and monostable multivibrators | 2 |
| 3.3 | Comparison, design of First and second order low pass and High pass active filters | 2 |
| 3.4 | Design of Second Order Band pass and band reject filters | 2 |
| 3.5 | State variable filters | 2 |
| **4** | **Timer, VCO and PLL** | **(9)** |
| 4.1 | Timer IC 555- Functional diagram, Astable and monostable operations. | 2 |
| 4.2 | Basic concepts of Voltage Controlled Oscillator | 1 |
| 4.3 | Application of VCO IC LM566 | 2 |
| 4.4 | PLL Operation, Closed loop analysis Lock and capture range. | 2 |
| 4.5 | Basic building blocks, PLL IC 565, Applications of PLL | 2 |
| **5** | **Voltage regulators and Data converters** | **(9)** |
| 5.1 | Fixed and Adjustable voltage regulators | 1 |
| 5.2 | IC 723 – Low voltage and high voltage configurations, | 2 |
| 5.3 | Current boosting, Current limiting, Short circuit and Fold-back protection. | 2 |
| 5.4 | Digital to Analog converters, Specifications, Weighted resistor type and R-2R Ladder type. | 2 |
| 5.5 | Analog to Digital Converters: Specifications, Flash type and Successive approximation type. | 2 |

**Assignment:**

Assignment may be given on related innovative topics on linear IC, like Analog multiplier- Gilbert multiplier cell, variable trans-conductance technique, application of analog multiplier IC AD633., sigma delta or other types of ADC etc. At least one assignment should be simulation of opamp circuits on any circuit simulation software. The following simulations can be done in QUCS, KiCad or PSPICE.(The course instructor is free to add or modify the list)

1. Design and simulate a BJT differential amplifier. Observe the input and output signals. Plot the AC frequency response
2. Design and simulate Wien bridge oscillator for a frequency of 10 kHz. Run a transient simulation and observe the output waveform.
3. Design and implement differential amplifier and measure its CMRR. Plot its transfer characteristics.
4. Design and simulate non-inverting amplifier for gain 5. Observe the input and output signals. Run the ac simulation and observe the frequency response and 3− db bandwidth.
5. Design and simulate a 3 bit flash type ADC. Observe the output bit patterns and transfer characteristics
6. Design and simulate R − 2R DAC circuit.
7. Design and implement Schmitt trigger circuit for upper triggering point of +8 V and a lower triggering point of −4 V using op-amps.

**Model Question**

**APJ ABDUL KALAM TECHNOLOGICAL UNIVERSITY**

FIFTH SEMESTER B.TECH DEGREE EXAMINATION, (**Model Question Paper)**

**Course Code: ECT301**

**Program: Electronics and Communication Engineering**
**Course Name: Linear Integrated Circuits**

Max. Marks: 100 Duration: 3 Hours

**PART A**

Answer ALL Questions. Each Carries 3 mark.

1. Draw and list the functions of 741 IC pins K1
2. Define slew rate with its unit. What is its effect at the output signal? K2
3. How the virtual ground is different from actual ground? K2
4. A differential amplifier has a common mode gain of 0.05 and difference mode gain of 1000.Calculate the output voltage for two signals V1 = 1mV and V2 = 0.9Mv K3
5. Design a non-inverting amplifier for a gain of 11 K3
6. Design a second order Butterworth Low Pass Filter with $f_H$= 2KHz K3
7. Draw the circuit of monostable multivibrator using opamp. K1
8. What is the principle of VCO?. K1
9. Mention 3 applications of PLL. K2
10. Define the following terms with respect to DAC (i)Resolution (ii)Linearity (iii) Full scale output voltage K2

Differentiate between line and load regulations. K3

**PART – B**

Answer one question from each module; each question carries 14 marks.

| | | | | |
|---|---|---|---|---|
| | **Module I** | | | |
| 11. a) | Derive CMRR, input resistance and output resistance of a dual input balanced output differential amplifier configuration. | 7 | CO1 | K3 |
| 11. b) | What is the principle of operation of Wilson current mirror and its advantages? Deduce the expression for its current gain. | 7 | CO1 | K2 |
| | **OR** | | | |
| 12.a) | Draw the equivalent circuit of an operational amplifier. Explain voltage transfer characteristics of an operational amplifier. | 6 | CO1 | K3 |
| 12.b) | Explain the following properties of a practical opamp (i) Bandwidth (ii) Slew rate (iii) Input offset voltage (iv) Input offset current | 8 | CO1 | K2 |
| | **Module II** | | | |

| | | | | |
|---|---|---|---|---|
| 13. a) | Design a fullwave rectifier to rectify an ac signal of 0.2V peak-to-peak. Explain its principle of operation. | 7 | CO2 | K3 |
| 13. b) | Draw the circuit diagram of a differential instrumentation amplifier with a transducer bridge and show that the output voltage is proportional to the change in resistance. | 7 | CO2 | K2 |
| | **OR** | | | |
| 14.a) | Derive the following characteristics of voltage shunt amplifier:<br>i) Closed loop voltage gain ii)Input resistance<br>iii) Output resistance iv)Bandwidth | 7 | CO2 | K3 |
| 14.b) | Explain the working of an inverting Schmitt trigger and draw its transfer characteristics. | 7 | CO2 | K2 |
| | **Moduel III** | | | |
| 15 a) | Derive the equation for frequency of oscillation (f0) of a Wein Bridge oscillator. Design a Wein Bridge oscillator for f0 = 1KHz. | 7 | CO3 | K3 |
| 15 b) | Derive the equation for the transfer function of a first order wide Band Pass filter. | 7 | CO3 | K3 |
| | **OR** | | | |
| 16a | Derive the design equations for a second order Butterworth active low pass filter. | 7 | CO3 | K3 |
| 16b | Design a circuit to generate 1KHz triangular wave with 5V peak. | 7 | CO3 | K3 |
| | **Module IV** | | | |
| 17 a) | Design a circuit to multiply the incoming frequency by a factor of 5 using 565 PLL. | 8 | CO4 | K3 |
| 17 b) | With the help of internal diagram explain the monostable operation of timer IC 555. Draw the input and output waveforms. Derive the equation for pulse width. | 6 | CO4 | K2 |
| | **OR** | | | |
| 18 a) | Design a monostable multi-vibrator for a pulse duration of 1ms using IC555. | 7 | CO4 | K3 |
| 18 b) | Explain the operation of Phase Locked Loop. What is lock range and capture range? | 7 | CO4 | K2 |
| | **Module V** | | | |
| 19 a) | Explain the working of R-2R ladder type DAC. In a 10 bit DAC, reference voltage is given as 15V. Find analog output for digital input of 1011011001. | 7 | CO5 | K2 |
| 19 b) | Explain how short circuit, fold back protection and current boosting are done using IC723 voltage regulator. | 7 | CO5 | K2 |
| | **OR** | | | |
| 20 a) | With a functional diagram, explain the principle of operation of Successive approximation type ADC. | 7 | CO5 | K2 |
| 20 b) | With a neat circuit diagram, explain the operation of a 3-bit flash converter. | 7 | CO5 | K2 |