

INSTITUTE OF AERONAUTICAL ENGINEERING

(Autonomous)

Dundigal - 500 043, Hyderabad, Telangana

COURSE CONTENT

LINEAR IC APPLICATIONS LABORATORY								
IV Semester: ECE								
Course Code	Category	Hours / Week			Credits	Maximum Marks		
AECD16	Core	L	Т	Р	С	CIA	SEE	Total
		-	-	2	1	40	60	100
Contact Classes: Nil	Tutorial Classes: Nil	Practical Classes: 45				Total Classes: 45		
Prerequisite: Electronic Devices and Circuits, Digital System Design								

I. COURSE OVERVIEW:

This course imparts hands-on knowledge for integrated circuit applications. It enables the students to design linear and non-linear applications using op-amp and pulse generation circuits using timer IC. Provide the capability to use vivado tool for performing the combinational and sequential circuits.

II. COURSES OBJECTIVES:

The students will try to learn

- I. Implement different circuits and verify circuit concepts
- II. Study the concepts of multi vibrators and filters
- III. Verify the operations of the 555 timers and PLLs and their applications.
- IV. Design and verify combinational and sequential circuits.

III. COURSE OUTCOMES:

At the end of the course students should be able to:

- CO 1 Design linear Integrated circuits to perform mathematical operations and voltage gain calculations using IC741.
- CO 2 Plot the frequency response of second order active filters using IC 741
- CO 3 Examine the input and output characteristics of transistor (BJT and FET) configurations for determining input output resistances.
- CO 4 Obtain the capture range and lock-in range of phase locked loop circuit using IC565
- CO 5 Construct the low and high voltage regulators to find the percentage of regulation using IC723
- CO 6 Implement combinational and sequential circuits using digital ICs to verify their functionality

EXERCISES FOR IC APPLICATIONS LABORATORY

Note: Students are encouraged to bring their own laptops for laboratory practice session

This laboratory enables design and testing of digital and analog integrated circuits. Initially Op-Amp based Inverting & Non inverting amplifiers, Integrators and Differentiators laboratory exercises are covered. It focuses on design of advanced filters, phase locked loops, multi-vibrators and data converters. Develops the capability to construct and validate the Linear & digital using hardware and Multisim simulation tools.

1. INVERTING AND NON-INVERTING OPERATIONAL AMPLIFIERS

Inverting operational amplifiers are used to amplify and invert input signals in applications such as audio systems, signal conditioning, and active filters. They also serve in differential amplifiers for precise measurement and noise rejection, as well as in summing amplifiers to combine multiple signals. Non-inverting op-amps, on the other hand, provide amplification without inversion, making them ideal for buffering and impedance matching in high-impedance sources. They are commonly used in voltage followers to isolate circuit stages and in precision amplifiers where signal polarity needs to be preserved. Both configurations find extensive use in analog computing, control systems, and audio processing. Together, these op-amps form the backbone of many signal processing and measurement systems.

1.1 Design an inverting amplifier circuit with OP AMP 741C for gain of 10.

Plot the waveforms, observe the phase reversal, measure the gain for the circuit shown in Figure.1.1.1.



Figure 1.1.1: Inverting Amplifier

1.2 Design of Non-Inverting amplifier with OP AMP741C for gain of 11.

Plot the waveforms, observe the phase reversal, measure the gain for the circuit shown in Figure 1.2.1.



Figure 1.2.1: Inverting Amplifier

1.3. What is the output of the summing amplifier in Figure 1.2.2, with the given DC input voltages? Compare the values obtained from Simulation and Practical values.



Figure.1.2.2

Hint : The easy way to approach this is to just treat the circuit as three inverting voltage amplifiers, and then add the results to get the final output.

Try

1. Design a simple difference amplifier with an input impedance of 10 k per leg, and a voltage gain of 26 dB

- 2. Design Adder/ Subtractor Circuits
- Hint: If inverting and non- inverting summing amplifiers are combined using the differential amplifier topology, an adder/subtractor results. Normally, all resistors in an adder/subtractor are the same value.

2. INTEGRATORS

Op-amp integrators are widely used in analog signal processing for tasks such as generating ramp signals, where the output voltage continuously increases or decreases in response to an input signal. They are key components in analog computing, enabling operations like integration in systems that simulate mathematical functions. In control systems, integrators are used to create integration action in PID (Proportional-Integral-Derivative) controllers for maintaining system stability and accuracy. They also serve in audio signal processing, such as in the creation of low-pass filters or smoothing circuits. Additionally, integrators are used in waveform generators to produce triangle or sawtooth waves, and in data acquisition systems to convert time-varying signals into proportional outputs. Op-amp integrators are also found in frequency analysis applications, where they help with phase detection or differentiation in complex signal processing. Their ability to perform continuous integration of input signals makes them essential in both control and measurement systems.

2.1. Design of integrator circuit for periodic signal with a frequency of 5 kHz

Draw the input and output waveforms for different time constants for the basic integrator circuit shown in Figure.2.1.



Figure 2.1: Basic Integrator

2.2. Design lossy integrator so that the peak gain is 20dB and the gain is 3dB down from its peak when W= 10,000 rad/sec. use a capacitance of 0.01µF in hardware and multisim.



Figure 2.2: Practical Integrator

2.3. Design Summing integrator to give output as per the following equation using Multisim.

$$v_{o}(t) = -\frac{1}{C_{f}} \int_{0}^{t} \left(\frac{v_{1}(t)}{R_{1}} + \frac{v_{2}(t)}{R_{2}} + \frac{v_{3}(t)}{R_{3}} \right) dt + v_{o}(0)$$

Try

1. The circuit that integrates the input signal twice is called double integrator. The design of double integrator requires two reactive portions for obtaining double integration. Design double integrator in mutisim /pspice to produce output as per the equation as shown below.

$$v_o(t) = -\frac{4}{(RC)^2} \iint v_i(t) dt$$

 Elaborate practical integrator circuit and state the advantages of practical integrator over ideal integrator. Using simulation with multisim determine R1 and Rf for a given lossy integrator for a peak gain of 30dB and the gain is 3dB down from its peak when W = 5000 rad/sec with a capacitance of 0.01micro farads.

3. DIFFERENTIATORS

Operational amplifier (Op-amp) differentiators are widely used in signal processing and control systems. They are employed in analog computers for solving differential equations, waveform shaping circuits to generate sharp pulses or detect edges in signals, and audio systems for high-frequency emphasis. In instrumentation, they are used to measure rate-of-change signals such as velocity from position or acceleration from velocity. Additionally, differentiators find applications in sensors and signal conditioning to process rapid signal variations effectively.

3.1. Design of Differentiator circuit for periodic signal with a frequency of 5 kHz

Draw the input and output waveforms for different time constants for the basic Differentiator circuit shown in Figure.3.1.



Figure 3.1: Basic Differentiator

3.2. Design a differentiator using op-amp to differentiate an input signal with fmax = 200 Hz. Also draw the output waveforms for a sine-wave and a square-wave input of 1 V peak at 200 Hz. Compare the values obtained from Simulation and Practical values.



Figure 3.2: Practical Differentiator

3.3. Construct a differentiator for a given differential input signal that varies in frequency from 100 Hz to about 5 KHz with a sine wave of 10V peak at 2k Hz is applied to this differentiator. Also draw the required waveforms.

Try

- 1. Sketch the output waveform of a differentiator for a sinusoidal signal of 3V peak at 250Hz. Compare the values obtained from Simulation and Practical values.
- 2. Determine the useful range for differentiation in the circuit of Figure 3.3. Also determine the output voltage if the input signal is a 2 V peak sine wave at 3 kHz.



Figure 3.3

3. Given the circuit of Figure 3.4 carryout the simulation and analyse the output waveforms if the input is a 100 Hz, 1 V peak triangle wave.



Figure 3.4

4.INSTRUMENTATION AMPLIFIER

Instrumentation amplifiers are essential in precision measurement systems due to their high input impedance, low noise, and excellent common-mode rejection. They are widely used in medical equipment, such as ECG and EEG machines, to amplify weak physiological signals without distortion. In industrial automation, they measure small signals from sensors like thermocouples, strain gauges, and pressure transducers. They are also crucial in data acquisition systems for accurate signal processing. Additionally, instrumentation amplifiers are used in bioengineering, weighing systems, and test equipment where precision and stability are critical. Their ability to operate in noisy environments makes them ideal for monitoring low-level signals in harsh conditions. These amplifiers ensure signal integrity in applications requiring high accuracy and reliability.

4.1. Build and verify the operation of instrumentation amplifier using IC 741 as per Figure 4.1



Figure 4.1.Instrumentation Amplifier

4.2 Design a differential instrumentation amplifier using a transducer bridge. Given data R1=1k ohms, R f=4.7 k ohms, RA = RB = RC = 100 k ohms, VDC=5V.

Try

1. Design an instrumentation amplifier with following specifications: R1=10Kohms, R2=5Kohms, R3=10Kohms.



Figure 4.2. Instrumentation Amplifier Practical Circuit Diagram.

5.DIGITAL TO ANALOG CONVERTER

Digital-to-Analog Converters (DACs) are vital in converting digital data into analog signals for various applications. They are widely used in audio and video systems, such as digital music players and televisions, to produce analog sound and images. In communication systems, DACs help generate analog waveforms for signal transmission. They are also integral in control systems to drive analog actuators and in instrumentation to produce precise test signals. Additionally, DACs are used in medical devices and embedded systems requiring accurate analog outputs.

5.1. To design and verify the operation of R-2R and Inverted R-2R DAC Converter as per Figure 5.1







Figure 5.1. DAC (a) Non-inverted (b) Inverted

5.2Construct a 4 bit R-2R ladder type DAC. Plot the transfer characteristics between binary input and output. Let R = 10 k.

5.3 Experimentally design inverted R–2R ladder has $R = Rf = 10k\Omega$ and VR = 10 V. Calculate the total current delivered to the op-amp and the output voltage when the binary input is 1110.

Try

- 1. Design the 4-bit digital to analog converter with the following input digital words, when 4-bit D/A converter with Vr=10V, $Rf=10K\Omega$ is considered i) 0001 ii) 0110 iii) 1010
- 2. Construct a 4 bit R-2R ladder type DAC. Plot the transfer characteristics between binary input and output. Let R = 10 k

6 ASTABLE MULTIVIBRATORS USING 555

Astable multivibrators using 555 timers are widely used to generate square wave signals in electronic circuits. They serve as clock pulse generators in digital systems and are used in flashing LED circuits for visual indicators. In communication systems, they create frequency-modulated signals and carrier waves. Additionally, they are used in tone generators for alarms and sound effects. Their versatility also makes them ideal for time-delay circuits and pulse-width modulation (PWM) applications.

6.1. Design astable multi-vibrators using timer IC 555 shown in figure below:



Figure. 6.1.Astable Multivibrator with 555 timer

Hint: The easy way to approach this is to select the appropriate resistor and capacitor values.

6.2. Design 2 kHz clock with 50 percent duty cycle using 555 timer:

6.3. Measure the output frequency and duty cycle of a 555 timer which is configured to run in astable mode with R1 = 10k, R2 = 60 and $C = 0.5 \mu$ F. Compare the values in hardware and Simulation using Multisim.

Try

- 1. Find the output frequency and duty cycle of a 555 timer which is configured to run in astable mode with R1 = 10k, R2 = 60 and $C = 0.5 \mu$ F.
- 2. Design a 555 timer an astable multivibrator with an output signal frequency of 800hz and 60% duty cycle.

7.MONOSTABLE MULTIVIBRATORS USING 555

Monostable multivibrators using 555 timers are widely used in timing and pulse generation applications. They serve as one-shot pulse generators in digital circuits, producing precise timing intervals for triggering events. In communication systems, they are used for signal shaping and synchronization. They also find applications in creating time delays for industrial automation and control systems. Additionally, monostable circuits are employed in debounce circuits for switches and in generating single pulses for testing and calibration.

7.1. To design and construct mono stable multi-vibrators using IC 555.

The circuit template is given below.



Figure 7.1.Monostable Multivibrator with 555 timer

Hint: To design this multivibrator adjust R1, R2, and C values based on your specific requirements. Adjust R1, R2, and C values based on your specific requirements. The RESET pin can be connected to Vcc if not used.

7.2 Construct monostable multivibrator to produce output pulse 15ms wide with hardware and Multisim software.

7.3 Design monostable multivibrator to produce output pulse 10 ms wide using hardware

Try

1 IC555 timer used as a monostable has R = 20kohms, and $C = 0.01 \ \mu$ F. What is the duration of output pulse in simulation and compare it with theoretical values.

8. SCHMITT TRIGGER USING 555

Schmitt triggers are widely used in signal conditioning to convert noisy or analog signals into clean digital signals. They are essential in waveform shaping circuits to create square waves from sine or triangular inputs. In digital electronics, they are employed for debounce circuits to stabilize inputs from mechanical switches. Schmitt triggers are also used in oscillators to generate stable frequencies for timing and control applications. In communication systems, they help in signal restoration and noise immunity. Additionally, they are integral in analog-to-digital conversion processes to ensure reliable and precise signal transitions.

8.1. To design Schmitt trigger using NE555 Timer

Construct the circuit as per schematic 8.1.(a). The expected input and output waveforms are shown in Figure. 8.1(b).





Figure 8.1.Schmiit Trigger (a) Connection Diagram (b) Wave Forms

8.2. Design Schmitt trigger circuit to achieve upper and lower threshold voltage as 1.5V

Hint: The formula for the threshold voltages in an astable multivibrator configuration (which can be used as a Schmitt trigger) is:

$$V_{\mathrm{TH}} = rac{R_1}{R_1+R_2} imes V_{\mathrm{CC}}$$

8.3. Design Schmitt trigger circuit to achieve upper and lower threshold voltage as 3 volts. Hint: Adjust R1, R2, and C1 values as needed to achieve the desired upper and lower threshold voltages and frequency of oscillation.

Try

1. Design a Schmitt trigger with upper and lower threshold voltages of 2.5 volts and 1.5 volts, respectively, and a frequency of oscillation around 1 kHz.

Hint: Calculate resistor ratios, choose proper capacitor value and calculate the frequency.

 Design a Schmitt trigger using a 555 timer IC with the following specifications: Upper Threshold Voltage (VUP): 3.0 volts Lower Threshold Voltage (V_{LOW}): 1.0 volts Oscillation Frequency (f): 2 kHz

9. SECOND ORDER ACTIVE LOW-PASS FILTERS

Active low-pass filters are widely used in signal processing to allow low-frequency signals while attenuating high-frequency noise. They are essential in audio systems to separate bass frequencies and improve sound quality. In communication systems, they eliminate high-frequency interference, ensuring clean signal transmission. These filters are used in instrumentation to process signals from sensors, removing unwanted noise for accurate measurements. In power supplies, active low-pass filters smooth out voltage fluctuations, providing stable output. They also play a role in biomedical applications, such as ECG and EEG systems, to filter out high-frequency artifacts. Additionally, they are employed in control systems to remove noise and enhance the stability of feedback loops.

9.1. Design of First Order Low pass Filter with roll of rate 20 db /decade

Determine the roll of rate for the first order Low pass filter through simulation and hardware for the circuit shown in Figure. 9.1.



Figure 9.1: Low Pass Filter First order

9.2. Design of Second Low pass Filter with roll of rate 40 db/decade. Also design a second-order low-pass Butterworth filter with a cut-off frequency of 10 kHz and unity gain at low frequency. Hint. The circuit is shown in Figure. 9.2.



Figure 9.2: Second Order Low Pass Filter

9.3 Design a second order butter-worth low-pass filter having upper cut-off frequency 1 kHz. Plot the frequency response. Given parameters: fh=1 kHz, C=0.1F, R=1.6Kohms and damping factor =1.414

Try

- 1. Design a second order Butterworth low-pass filter having upper cut-off frequency of 2 kHz.
- 2. A third order and a fourth order low-pass Butterworth filters have a cut-off frequency of 10 kHz and unity gain at low frequency. Determine the magnitude of the voltage transfer function in dB at 12 kHz for each filter.
- 3. Design a Butterworth second-order LPF with following specifications.
 - I. Sallen-Key equal component configuration
 - II. Critical frequency wC = 1 radian/s.
 - III. Cut-off frequency fC of 1.6 kHz
 - IV. Damping factor a = 1.0

10. SECOND ORDER ACTIVE HIGH-PASS FILTERS

Active high-pass filters are widely used in signal processing to allow high-frequency signals while blocking low-frequency noise or interference. They are essential in audio systems to enhance treble frequencies and remove bass rumble. In communication systems, they eliminate low-frequency interference and ensure effective signal transmission. These filters are used in instrumentation to isolate high-frequency components of sensor signals for precise analysis. In biomedical applications, such as ECG and EEG systems, they help remove baseline drift and other low-frequency artifacts. Active high-pass filters also find use in seismology to isolate high-frequency vibrations for detailed study. Additionally, they are employed in control systems to suppress low-frequency disturbances, improving overall system performance.

10.1. Design of First Order High pass Filter with roll of rate 20 db/decade at a cutoff frequency of 2 kHz with a pass band gain of 2. Also, plot its frequency response for the circuit shown in Figure 10.1.



Figure 10.1: High Pass Filter First order

10.2. Construct a butter-worth high-pass filter of second order with lower cutoff frequency 5 kHz. Given parameters: fl=12 kHz, C=0.1 μ F, R=3k Ohms and damping factor =1.625. Determine Rf, Ri and frequency response. Also determine the roll of rate for the Second order high pass filter through simulation and hardware. The standard circuit is shown in Figure. 10.2.



Figure 10.2: Second Order High Pass Filter

10.3. Find the lower cut-off frequency fL for the second order high-pass Butterworth filter shown in Figure. 5.3. Also, find the pass band gain of the filter, and plot the frequency response of the filter through simulation.



Figure 10.3: Second Order High Pass Filter

Try

- 1. Design a fourth order high-pass Butterworth filter with unity gain having a cut-off frequency of 50 kHz. Determine the frequency at which the voltage transfer function magnitude is 2% of its maximum value.
- 2. Design a second-order, high-pass Bessel filter, with a break frequency (f3dB) of 5 kHz through simulation.

11. PLL USING IC 565

Phase-Locked Loops (PLLs) are widely used in communication systems for frequency synthesis, modulation, and demodulation. They play a crucial role in clock generation and synchronization for digital circuits, ensuring stable timing. PLLs are integral in radio, television, and wireless communication to lock onto carrier frequencies and recover signals. In data transmission, they help in bit synchronization, enabling accurate data decoding. They are also used in motor speed control systems to maintain precise rotational speeds. In instrumentation, PLLs aid in generating stable oscillations for testing and measurement. Additionally, they are employed in frequency multipliers and dividers for advanced signal processing applications.

11.1.For the phase locked loop circuit of Figure 11.1. estimate the capture range and lock-in range using simulation and compare theoretical and practical values.



Figure 11.1.PLL with LM 565

11.2. Design phase locked loop circuit for estimating the capture range and lock-in range.

11.3. Measure the output frequency, lock range and capture range of a 565 PLL if R = 10 K ohms, CT = 0.01uf and C = 10 uf.

Try

1. Design the phase locked loop circuit with the basic operating frequency of 2kHz and cutoff frequency of 1kHz?

2. Measure the output frequency, lock range and capture range of a 565 PLL if R=10K Ω ohms, C1 = 0.01 μ F and C = 10 μ F.

3. For PLL 565, given the free-running frequency as 100 kHz, the demodulation capacitor of 2 μ F and supply voltage is ± 6 V, determine the lock and capture frequencies and identify the component values.

12 SECOND ORDER ACTIVE BAND PASS FILTERS

Active band-pass filters are widely used in signal processing to allow signals within a specific frequency range while attenuating frequencies outside it. They are essential in communication systems for channel selection and noise reduction, ensuring clear signal transmission. In audio systems, they isolate specific frequency bands to enhance sound quality in equalizers and crossover networks. These filters are used in biomedical applications, such as EEG and ECG systems, to extract relevant frequency components from physiological signals. In instrumentation, they analyze specific signal frequencies, such as vibrations or harmonics, for diagnostics. Active band-pass filters also find applications in radar and sonar systems for detecting and analyzing target signals. Additionally, they are employed in wireless receivers for filtering and tuning desired frequency bands.

12.1. Design a wide band pass filter using operational amplifier 741 as per Figure 12.1



12.1. Band pass Filter

12.2. Design a narrow band pass filter using operational amplifier 741 as per the Figure 12.2



12.2. Narrow Band pass Filter and it's response

12.3. Given a band pass filter with the component values shown in Figure. 9.3, find its (a) resonant frequency and (b) bandwidth.



12.3 Band pass Filter

- 1 Given a band pass filter with resonant frequency fr of 1000 Hz and a bandwidth (B) of 3000 Hz, find its (a) quality factor, (b) lower cut-off frequency and (c) higher cut-off frequency by hardware
- 2 Construct band pass filter with resonant frequency fr of 1500 Hz and a bandwidth (B) of 3500 Hz, find its (a) lower cut-off frequency and (b) higher cut-off frequency using Multisim.

13. SECOND ORDER WIDE BAND REJECT FILTERS

Active band-pass filters are widely used in signal processing to allow signals within a specific frequency range while attenuating frequencies outside it. They are essential in communication systems for channel selection and noise reduction, ensuring clear signal transmission. In audio systems, they isolate specific frequency bands to enhance sound quality in equalizers and crossover networks. These filters are used in biomedical applications, such as EEG and ECG systems, to extract relevant frequency components from physiological signals. In instrumentation, they analyze specific signal frequencies, such as vibrations or harmonics, for diagnostics. Active band-pass filters also find applications in radar and sonar systems for detecting and analyzing target signals. Additionally, they are employed in wireless receivers for filtering and tuning desired frequency bands.

13.1. To design and verify the operation of the Band reject filters:

The Circuit and expected wave forms are shown in Figure 13.1(a) &13.1(b) respectively.



Try



Figure 13.1.Wide band reject Filter Trigger (a) Connection Diagram (b) Wave Forms

13.2. Design a wide band pass filter having fl=400Hz, fh=2kHz and pass band gain of 4.

13.3. Construct a wide band reject filter with fh=500Hz, fl=4kHz with a pass band gain of 2 using Multisim

Try

1. Design a wide band reject filter with fh=1000Hz, fl=8kHz with a pass band gain of 4 by simulation.

14. SECOND ORDER NARROW BAND REJECT FILTERS

Second-order narrow band reject filters, also known as notch filters, are used to eliminate a specific, narrow range of frequencies while allowing all other frequencies to pass. In communication systems, they are essential for removing narrow-band interference, such as eliminating hum from power lines (50/60 Hz) in audio or radio signals. They are used in biomedical applications, like ECG and EEG, to filter out power line interference or other specific noise sources. In audio systems, these filters help remove unwanted resonant frequencies or narrow-band distortions. In industrial applications, narrow band reject filters are used to eliminate specific harmonic frequencies in machinery or control systems. They are also employed in radio and television systems to eliminate interfering signals within a specific frequency band. Additionally, these filters are used in precision measurement systems to enhance signal quality by rejecting unwanted narrow-band noise.

14.1. To design and verify the operation of the Narrow Band reject filters:

Hint: The narrowband band-reject filter, often called the notch filter, is the twin-T network cascaded with the voltage follower as shown in Figure. 14.1(a). The frequency response characteristic of the wideband band-reject filter is shown in Figure. 14.1(b).



(b)

Figure 14.1.Narrow band reject Filter Trigger (a) Connection Diagram (b) Wave Forms

14.2. Design a wide band pass filter having fL=1.5kHz, fh=2kHz and pass band gain of 4 using Multisim.

14.3 Construct a Narrow band reject filter with fh=1000Hz, fl=1500Hz with a pass band gain of 2.

Try

- 1. Design a Narrow band reject filter with fh=4kHz, fl=4500Hz with a pass band gain of 3 by simulation.
- 2. Using hardware build Narrow band reject filter with fh=5kHz, fl=5500Hz with a pass band gain of 3 by simulation.

REFERENCE BOOKS:

- D. Roy Chowdhury, "Linear Integrated Circuits", New age international (p) Ltd, 2nd Edition, 2003.
- 2. Ramakanth A.Gayakwad, "Op-Amps & Linear ICs", PHI, 3rd Edition, 2003.
- John F.Wakerly, "Digital Design Principles and practices", Prentice Hall, 3rd Edition, 2005.

WEB REFERENCES:

Salivahanan, "Linear Integrated Circuits and Applications", TMH, 1st Edition, 2008.

ELECTRONICS RESOURCES:

- 1. https://nptel.ac.in/courses/108108111
- 2. https://archive.nptel.ac.in/courses/108/108/108108112/