SNS COLLEGE OF TECHNOLOGY

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COIMBATORE-641 035, TAMIL NADU

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

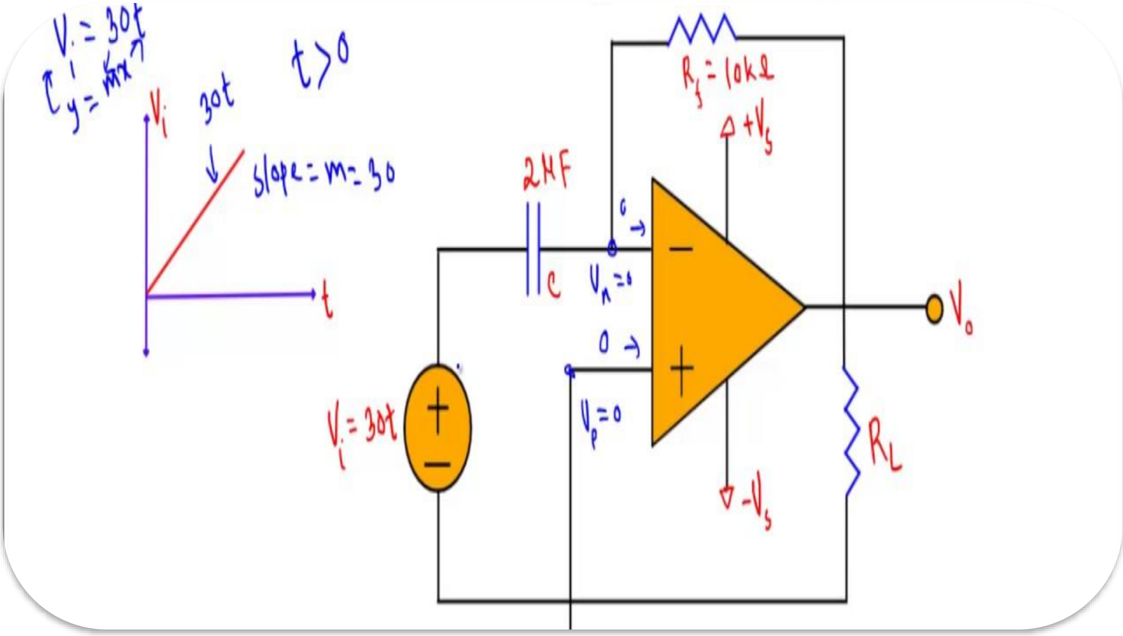
Course Name: 23ECT203 LINEAR INTEGRATED CIRCUITS

II YEAR/VI SEMESTER

UNIT II –APPLICATIONS OF OPERATIONAL AMPLIFIERS

Topic : Differentiator and Integrator, Instrumentation amplifier

Stage 1: Empathize



Understand User Needs

Gain requirements, bandwidth specifications, noise tolerance

Performance Requirements

Gain accuracy, frequency response, speed, precision

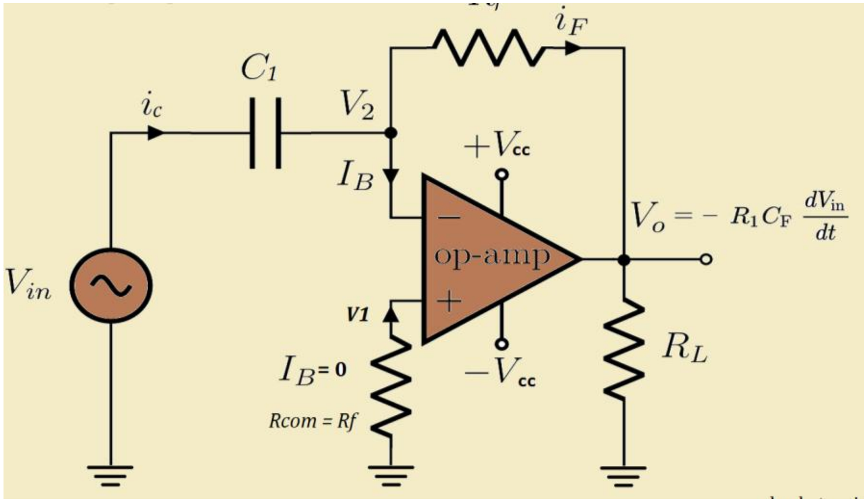
Identify Constraints

Power consumption, temperature range, size limitations, cost

Practical Applications

Medical equipment, industrial controls, automotive systems

Stage 2: Define



Problem Definition

- Circuit function
- Application needs
- Performance gaps

Impedance Specs

- High input Z
- Low output Z
- Matching loads

CMRR & Gain

- CMRR > 80dB
- Gain accuracy
- Bandwidth

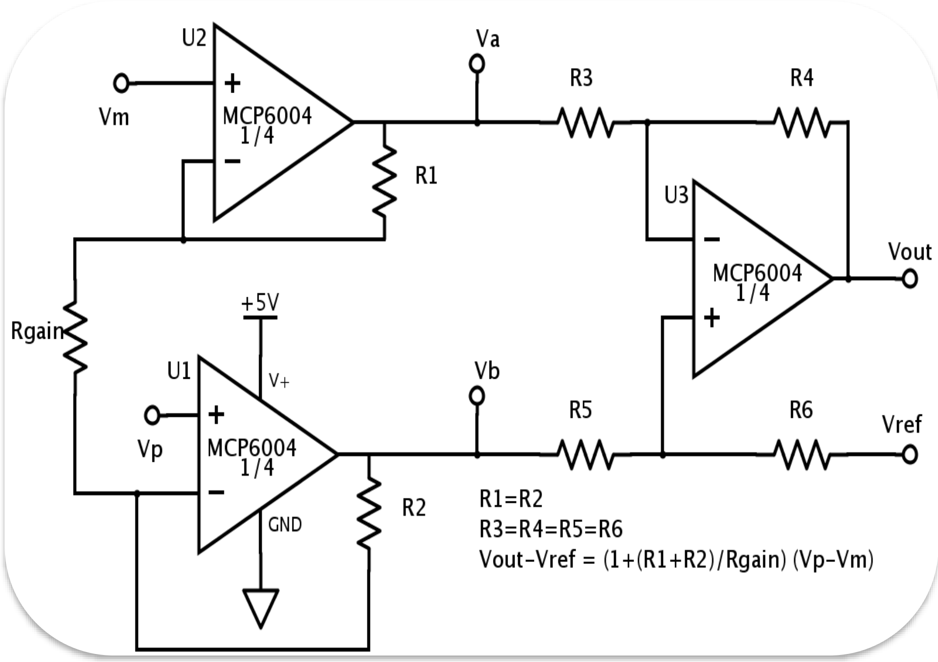
Success Criteria

- Metrics defined
- Test standards
- Tolerance limits

Design Goals Established

Optimize performance, minimize noise, ensure stability, meet power and thermal constraints

Stage 3: Ideate



Circuit Configurations

- Differential pairs
- Feedback networks
- Multiple stages

Circuit Topologies

- Inverting configuration
- Non-inverting config
- Cascaded stages

Component Selection

- Precision op-amps
- Matched resistors
- Temperature-stable caps

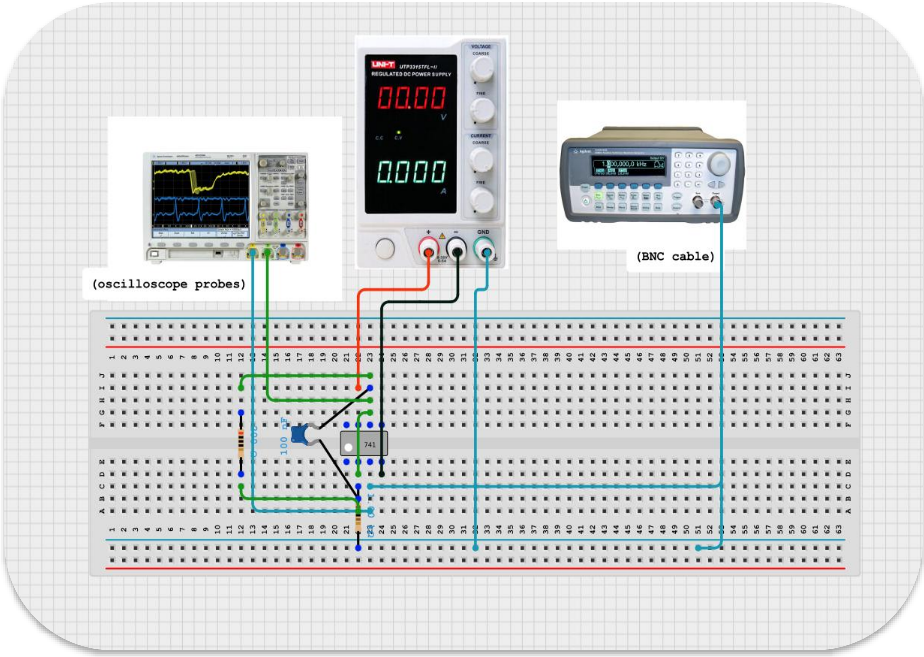
Innovative Approaches

- Current-mode design
- Chopper stabilization
- Auto-zeroing techniques

Creative Solution Generation

Explore multiple circuit concepts, evaluate trade-offs, select optimal approach for specific

Stage 4: Prototype



Simulation Tools

- SPICE analysis
- Multisim modeling
- Proteus design

Breadboarding

- Modular testing
- Stage-by-stage
- Real-time debugging

Testing Methods

- Frequency response
- Transient analysis
- Noise measurement

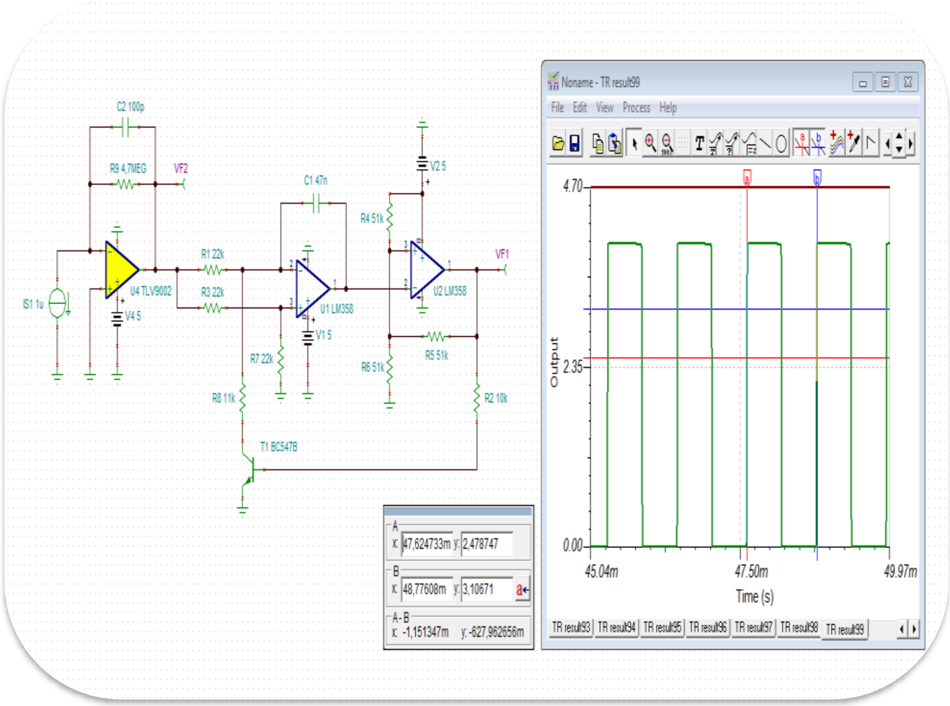
Iterative Refinement

- Component matching
- Precision selection
- Performance tuning

Rapid Prototyping Process

Simulate → Breadboard → Test → Refine → Validate circuit performance before final implementation

Stage 5: Test



Performance Testing

- Gain measurement
- Bandwidth analysis
- Noise evaluation
- Slew rate testing

Frequency Response

- Bode plot analysis
- Gain vs. frequency
- Phase margin check
- Stability testing

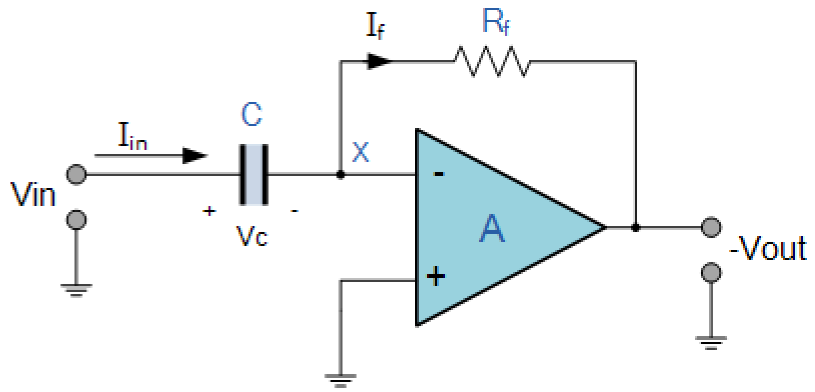
Noise Characterization

- Input noise density
- Output noise measurement
- Signal-to-noise ratio

CMRR & PSRR

- Common-mode rejection
- Power supply rejection
- Differential gain

Differentiator Circuit



Output Formula

$$V_{out} = -RC \left(\frac{dV_{in}}{dt}\right)$$

Configuration

- Capacitor in input
- Resistor in feedback
- Op-amp based

Characteristics

- Differentiates signal
- High pass filter
- Noise sensitive

Applications

- Slope detection
- Edge detection
- Pulse shaping

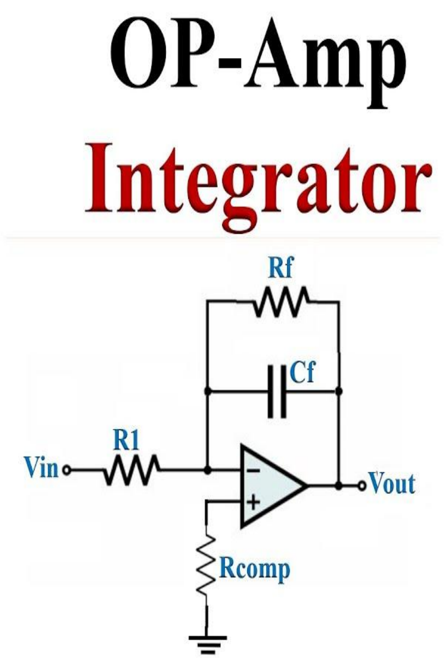
Exam Points

- Gain ∝ frequency
- RC time constant
- Low-noise needed

Limitations

- High-frequency noise
- Stability issues
- Bandwidth limited

Integrator Circuit



Output Formula

Vout = -(1/RC)∫Vin dt

Configuration

- Resistor in input
- Capacitor in feedback
- Op-amp based

Characteristics

- Integrates signal
- Low pass filter
- Accumulates input

Applications

- Analog computation
- Ramp generation
- Average value

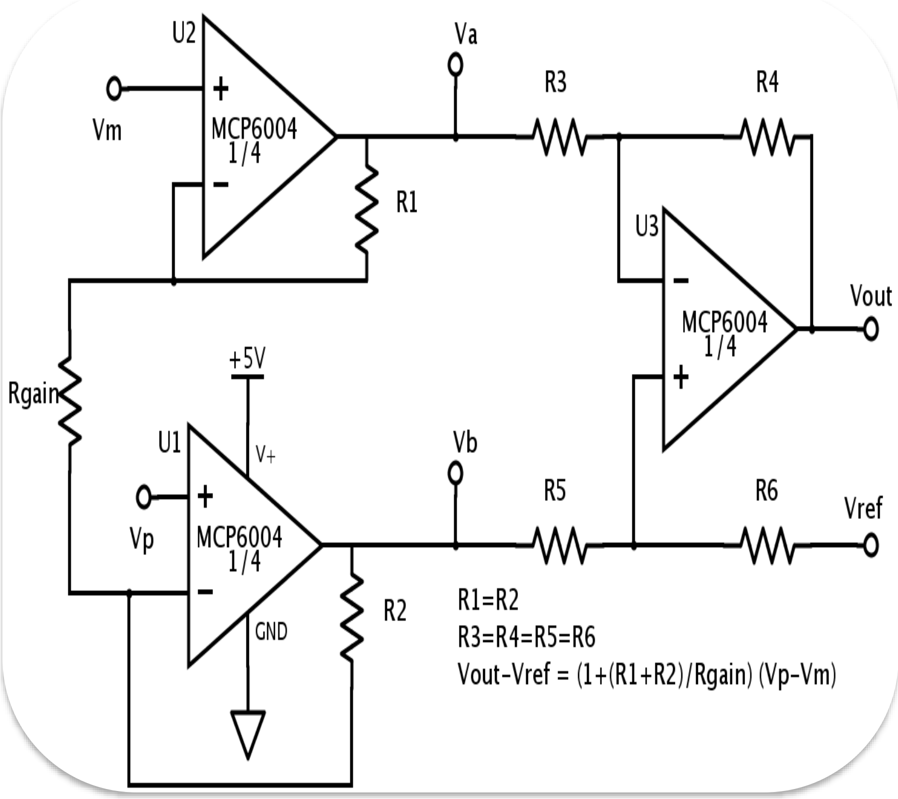
Exam Points

- RC time constant
- Integration rate
- DC offset issue

Note

- Prevents saturation
- Need reset circuit
- Frequency limit

Instrumentation Amplifier



Output Formula

$$Vout = (1 + 2R/Rg)(V2 - V1)$$

Configuration

- Three op-amp design
- Input buffers
- Differential output

Characteristics

- High input Z
- High CMRR
- Precision gain

Applications

- Sensor interfacing
- Bridge measurements
- Biomedical

Gain Control

- Single resistor Rg
- Adjustable gain
- Wide range

Exam Points

- Gain formula
- Differential input
- Buffer stage

Comparison of Amplifiers

Differentiator

Function

Differentiates input signal

Filter Type

High Pass Filter

Noise Immunity

Low - Sensitive

Applications

Edge detection, slope detection, pulse shaping

Integrator

Function

Integrates input signal over time

Filter Type

Low Pass Filter

Noise Immunity

High - Rejects

Applications

Analog computation, ramp generation, averaging

Instrumentation

Function

Differential amplification

Filter Type

Differential Filter

Noise Immunity

Very High (CMRR)

Applications

Sensor interfacing, biomedical, bridge measurements

When to Use Each Circuit

Differentiator: Edge detection, slope measurement, high-frequency signals

Integrator: Signal averaging, ramp generation, analog computation

Instrumentation: Precision measurements, sensor interfacing, differential signals

Assessment & Review

Design Thinking Stages

- Explain how Empathize applies to circuit design
- Define problem for amplifier circuits
- Ideate multiple circuit configurations
- Prototype simulation and testing methods
- Validate performance requirements

Differentiator Circuit

- Derive Vout = -RC(dVin/dt) formula
- Explain high-pass filter characteristics
- Discuss noise sensitivity issues
- Applications in edge detection

Integrator Circuit

- Derive Vout = -(1/RC)∫Vin dt formula
- Explain low-pass filter characteristics
- Discuss signal accumulation effect
- Applications in analog computation

Instrumentation Amplifier

- Explain CMRR importance
- Derive gain formula Vout = (1+2R/Rg)(V2-V1)
- Discuss high input impedance advantage
- Applications in sensor interfacing

Activity: Design Thinking Applied to Amplifier Circuits

1

THINK

2 minutes

Individual Reflection

- Compare advantages and disadvantages of differentiator, integrator, and instrumentation amplifiers
- Consider noise immunity, frequency response, and application suitability
- Identify key differentiating factors for exam preparation

2

PAIR

2 minutes

Partner Discussion

- Which amplifier is best for sensor interfacing? Why?
- Compare differentiator vs integrator for pulse shaping
- Discuss trade-offs for high-noise environments

3

SHARE

1 minute

Group Presentation

- Present your group's amplifier selection decision
- Explain design thinking reasoning used
- Share key insights with the class

Mind Map - Design Thinking & Amplifier Circuits

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Design Thinking & Amplifier Circuits

Empathize
Understand user needs

Integrator
Vout = -(1/RC)∫Vin dt

Low pass filter

Define
Identify problems

Test
Validate solutions

Differentiator
Vout = -RC(dVin/dt)

High pass filter

Ideate
Generate solutions

Instrumentation
Vout = (1+2R/Rg)(V2-V1)

High CMRR

Prototype
Build models

References & Further Reading

SNS INSTITUTIONS
www.snsgroups.com

Textbooks

1. **D. Roy Choudhry & Shail Jain**
   "Linear Integrated Circuits"
2. **Sergio Franco**
   "Design with Operational Amplifiers"
3. **Ramakant A. Gayakwad**
   "OP-AMP and Linear ICs"
4. **Robert F. Coughlin & Frederick F. Driscoll**
   "Operational Amplifiers and Linear Integrated Circuits"

Online Resources

- **Texas Instruments**
  Op-Amp Design Handbook
- **Analog Devices**
  Op-Amp Applications Handbook
- **Electronics Tutorials**
  Operational Amplifier Circuits
- **NPTEL**
  Linear Integrated Circuits Course

Thank You