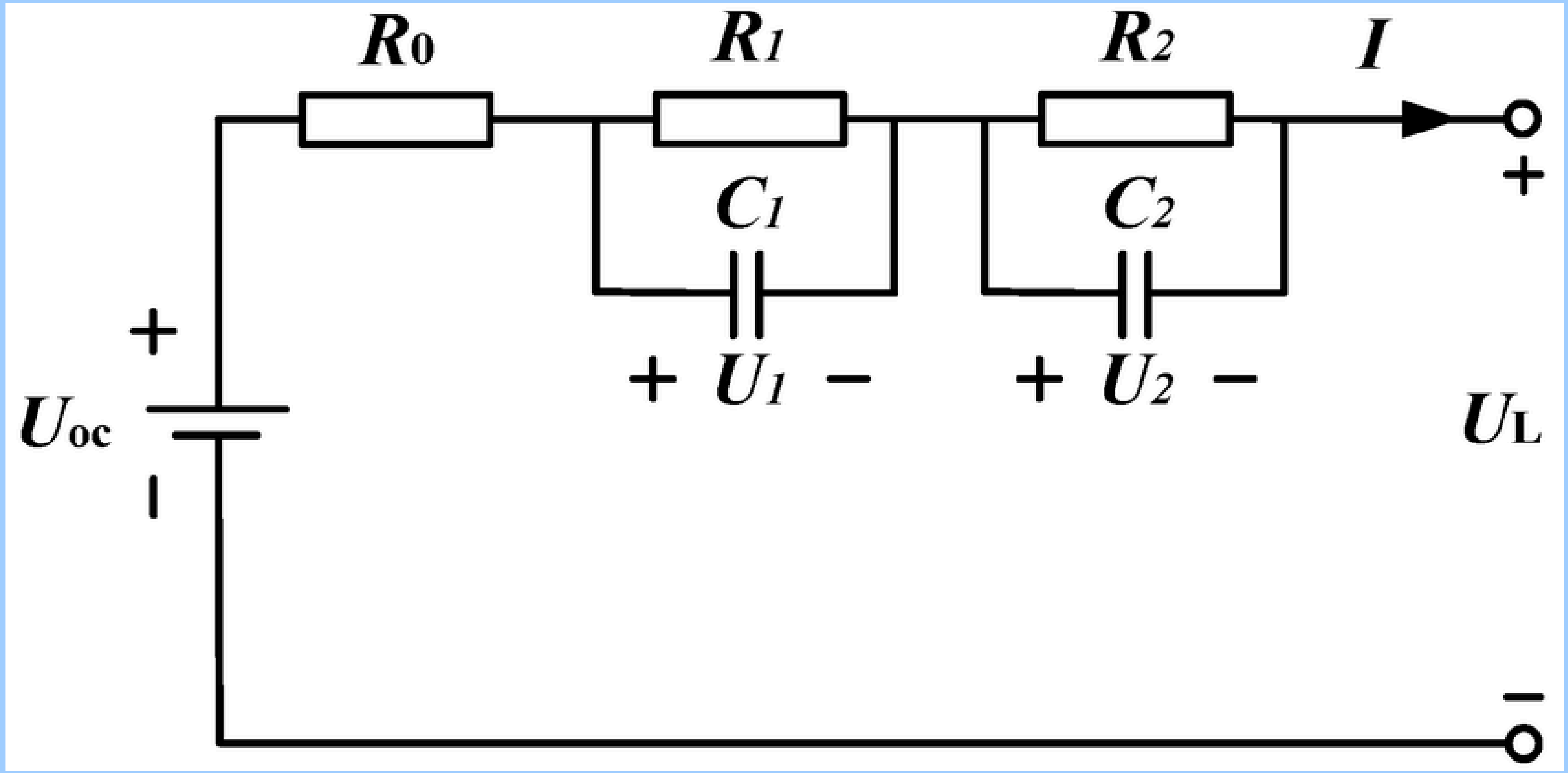
2nd Order RC Circuit

Second Order RC Circuit Using Laplace Transform

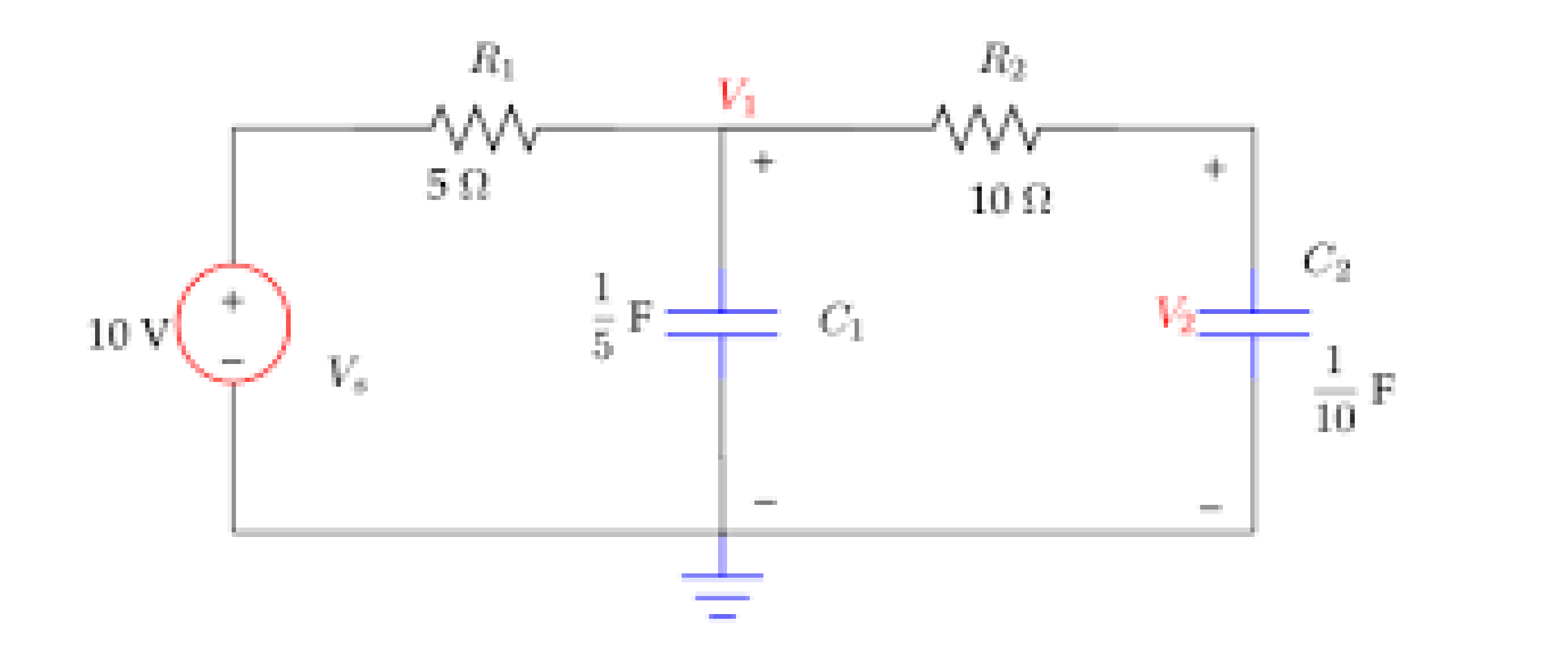
- A second-order circuit contains two independent energy storage elements
- In RC circuits, energy storage elements are capacitors
- Two capacitors ⇒ second-order system

Laplace Transform:

- Converts differential equations to algebra
- Simplifies analysis of higher-order circuits



Basic Second-Order RC Circuit Structure



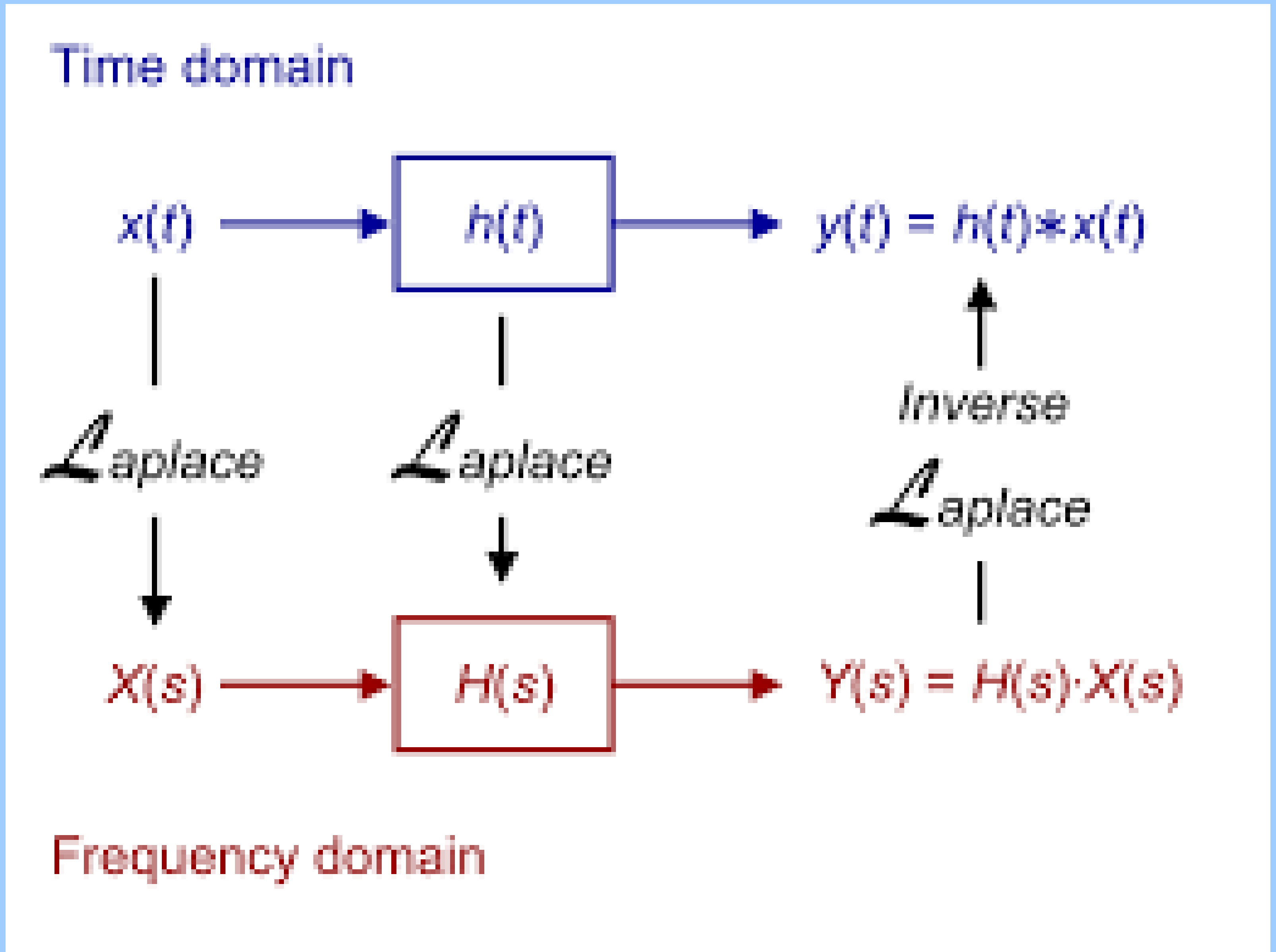
- Contains:

  Resistors: R1, R2R_1,\ R_2R1, R2

  Capacitors: C1, C2C_1,\ C_2C1, C2
- Input: Vi(t), Output: Vo(t)
- Two capacitors ⇒ two energy storage states
- Leads to a second-order differential equation

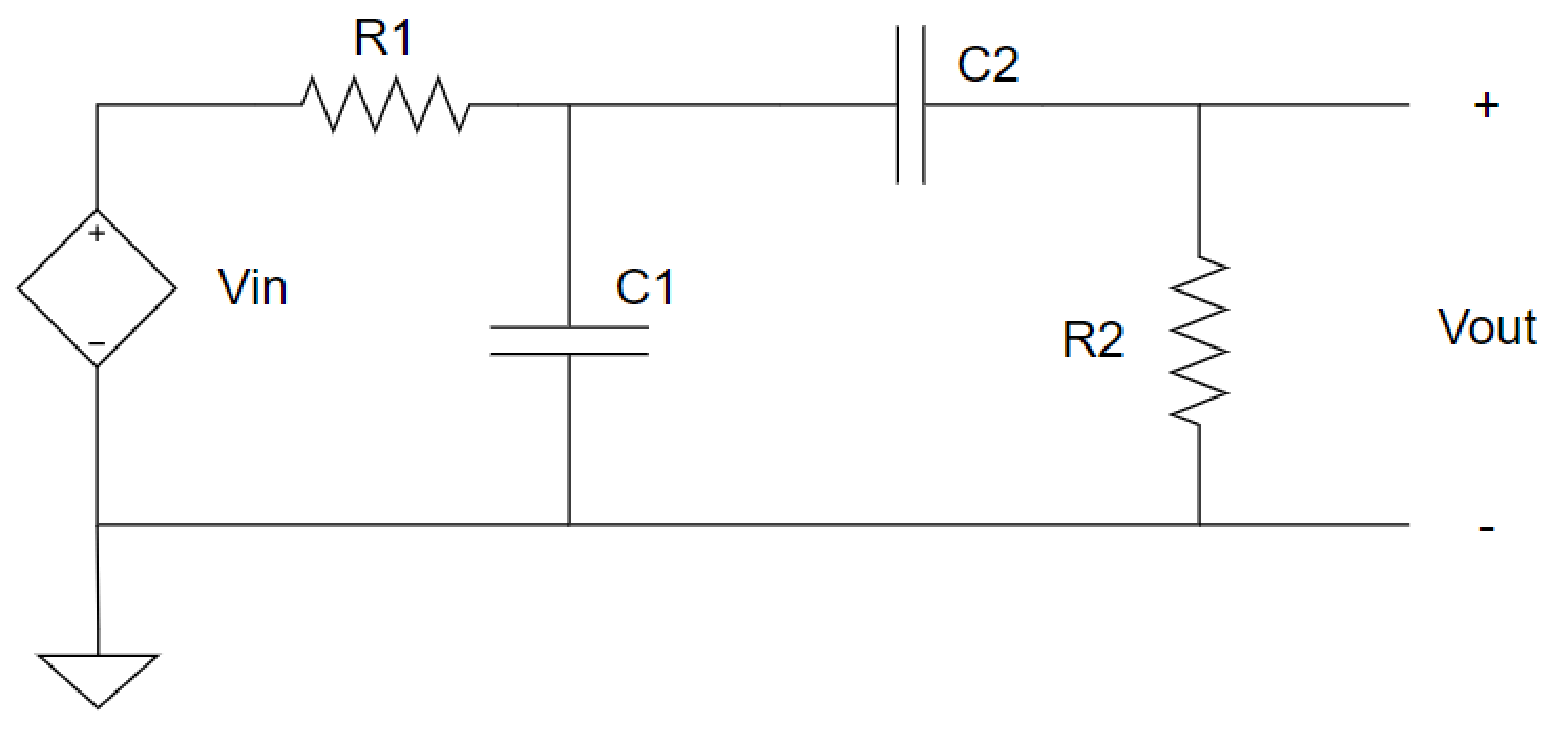
Why Use Laplace Transform?

- Time domain equations include derivatives:
- i(t)=Cdv(t)/dt, d{squrv(t)}/{dtsqure}i(t) = C
- Two capacitors → second-order differential equation
- Laplace Transform:
- Converts differentiation to multiplication by s
- Handles initial conditions
- Makes algebraic circuit equations



Laplace Domain Model of Second-Order RC

- Impedance in s-domain:
  ZR=R , ZC=1/sC
- Solve using voltage division
  or mesh equations
- Final transfer function:
  H(s)=Vo(s)/Vi(s)=K/s^2+as+b



Where:

- a=sum of resistive & capacitive terms
- b= product of resistive and capacitive terms

Conclusion:

Highest power of s is 2 ⇒ second-order circuit

- **Denominator:**

  s2+as+b=0s^2 + a s + b = 0s2+as+b=0

- **Roots determine behavior:**

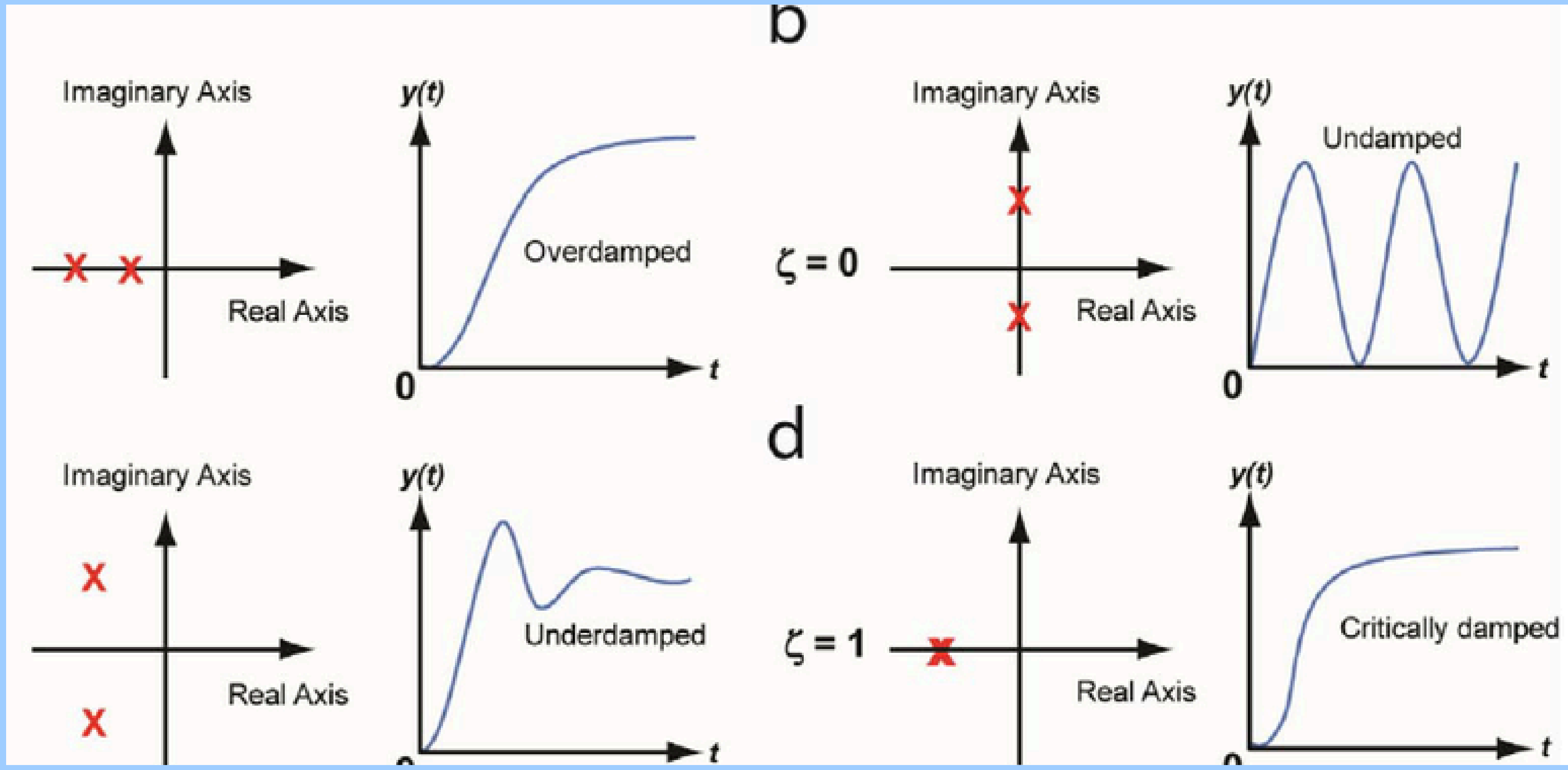
  Real & distinct ⇒ Overdamped

  Real & equal ⇒ Critically damped

- **Complex conjugate ⇒ Underdamped**
- **RC networks usually show**

 overdamped/critically damped behavior (no oscillation)

- **Key Insight:**
- **Response shaped by two poles**



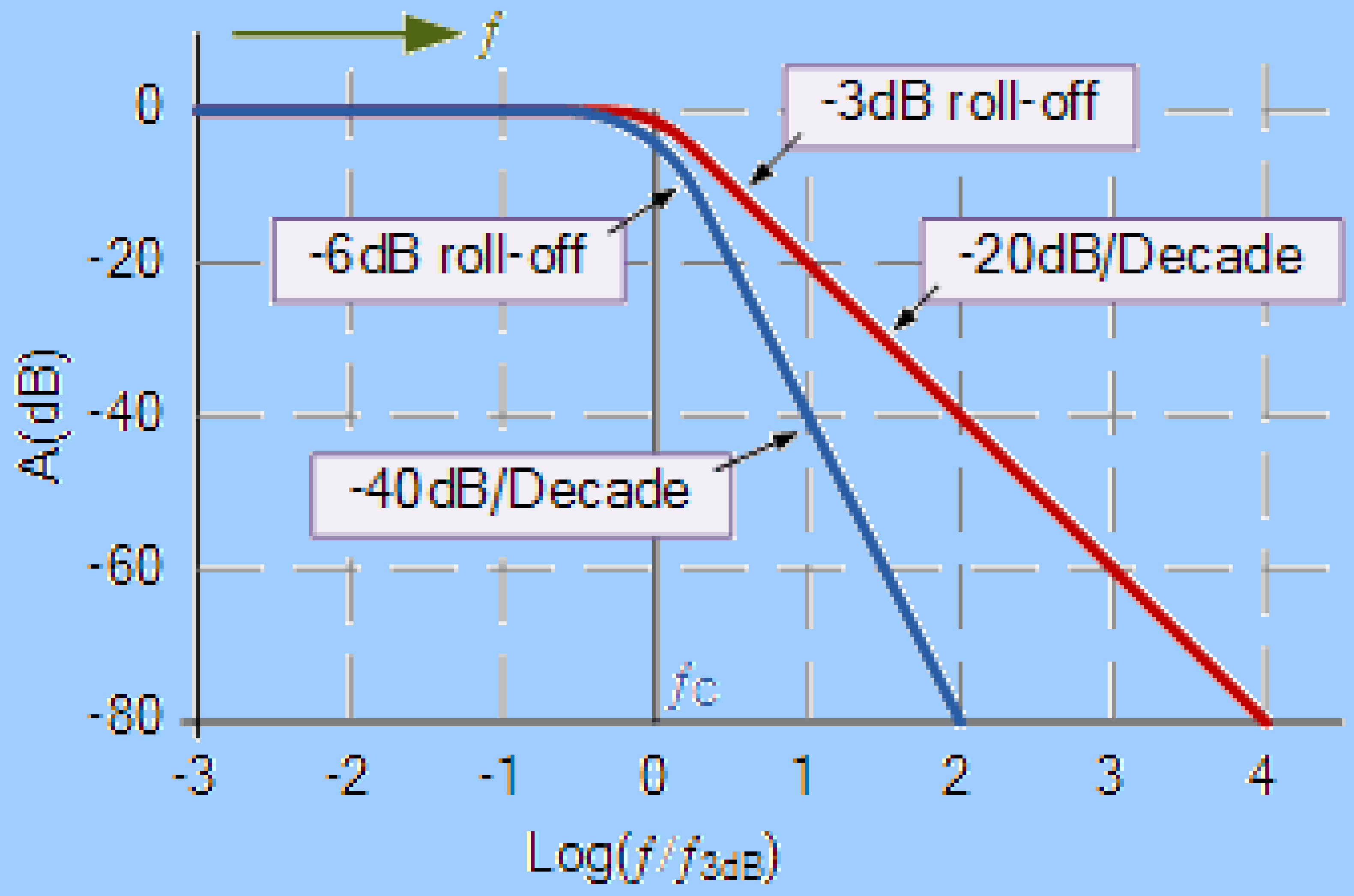
Frequency Response & Practical Uses

- Second-order RC can be: Low-pass, High-pass
- Band-pass depending on configuration
- Compared to first order: Steeper attenuation

  Better filtering
- Roll-off: −40 dB/decade

Applications

- Power supply noise filtering
- Audio signal conditioning
- Communication circuits



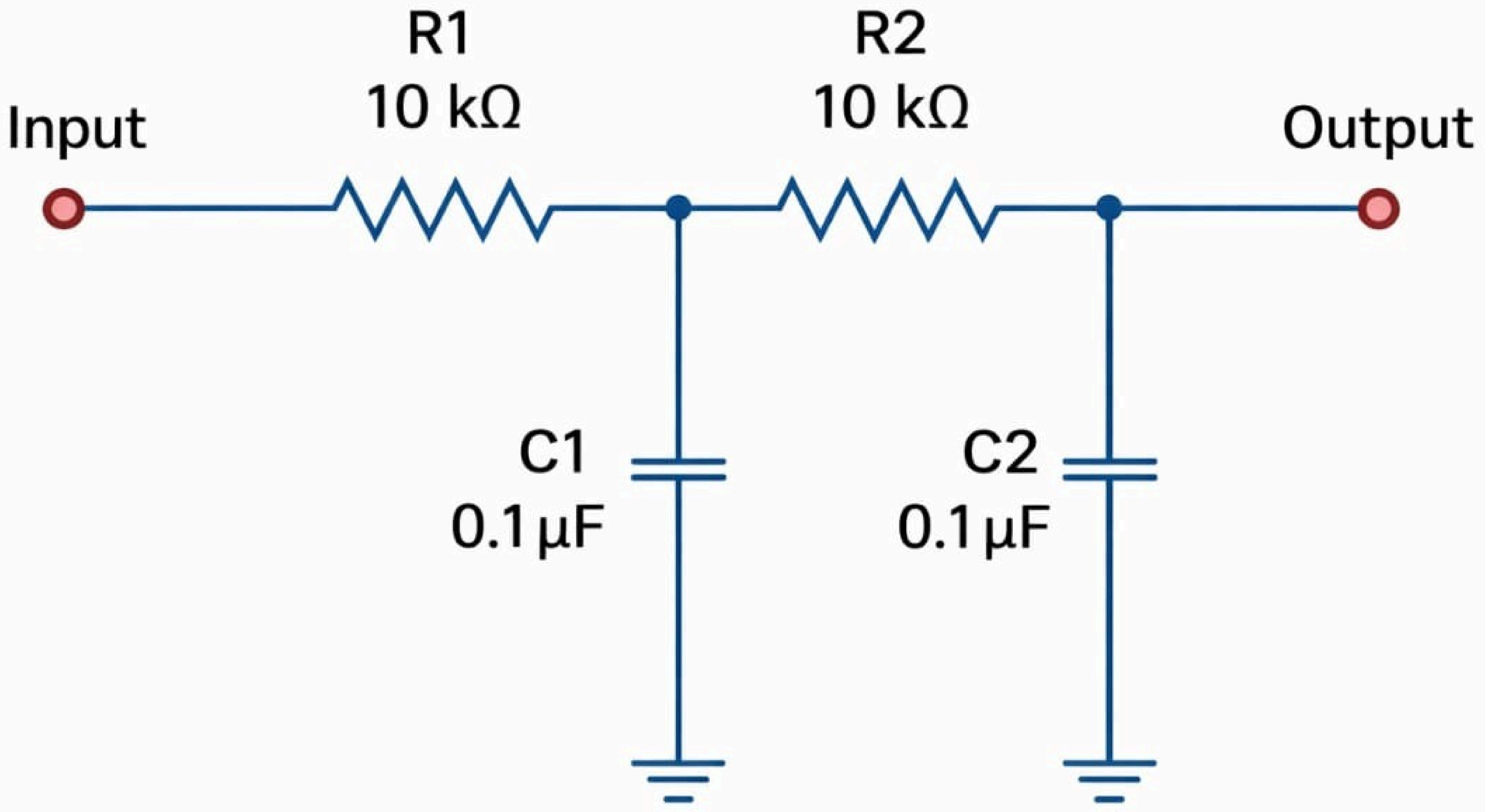
Application :Passive Noise Reduction Using Second Order RC Circuit

- Noise is an unwanted high-frequency
  signal present in electrical systems
- Passive noise reduction uses R and C elements only
- Second order RC circuits provide:
- Better noise attenuation than first order circuits
- Sharper frequency roll-off
- Laplace Transform is used to:
- Model noise filtering behavior mathematically
- Analyze system response efficiently

Objective

- To demonstrate how a second-order RC
- circuit reduces noise using Laplace Transform

Second-Order RC Low-Pass Filter Circuit



Second Order RC Low-Pass Filter Configuration

Circuit consists of:

- Two resistors: R1,R2R_1, R_2R1,R2
- Two capacitors: C1,C2C_1, C_2C1,C2
- Two cascaded RC sections

Each RC section contributes:

- One pole

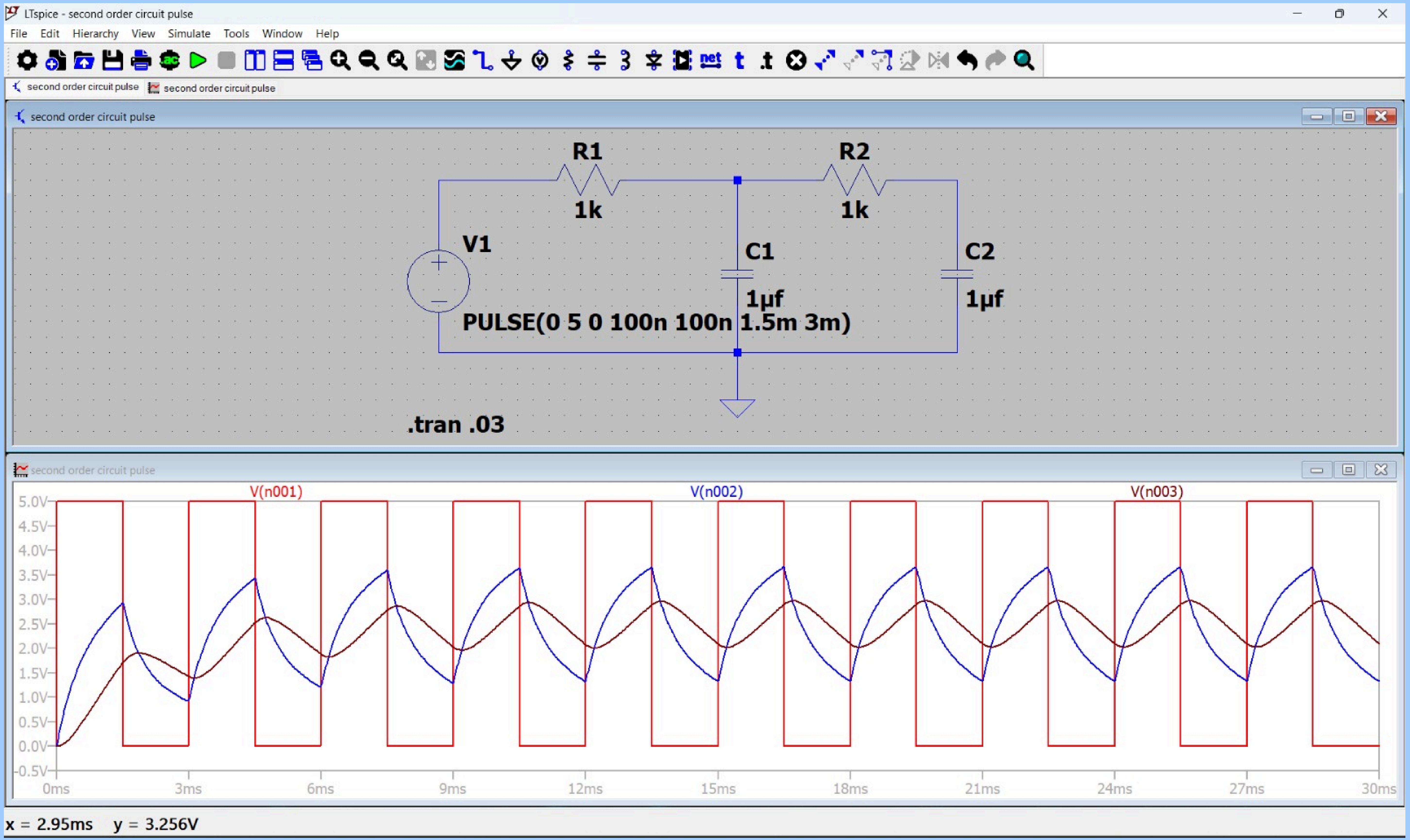
Total system order:

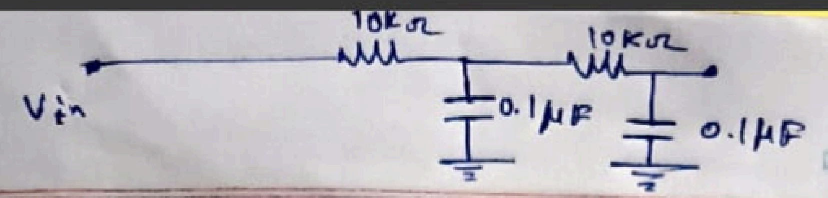
- Two poles → second-order system

Filtering Action

- Low-frequency signals pass with minimal attenuation
- High-frequency noise is significantly reduced

Simulation and theoretical approch





Given in

parameter	values
Input voltage	1.5 V_{pp}
Frequency	1.5 KHZ
Output voltage	40mV_{pp}
R	10 kΩ
C	0.1 μF
Circuit	2^{nd} Order RC

Theoretical Calculation

~~Cutoff frequency~~

$$f_c = \frac{1}{2\pi RC} = \frac{1}{2\pi \times (10k)(0.1\mu F)} = 159\,Hz$$

Frequency ratio

$$\frac{f}{f_c} = \frac{1500}{159} \approx 9.43$$

Gain of 2nd order RC filter.

$$= |H(jw)| = \frac{1}{1+(\omega RC)^2}$$

$$= \frac{1}{1+(9.43)^2}$$

$$= \frac{1}{1+88.9} = 0.011$$

Expected Output voltage

$$V_{out} = 1.5 \times 0.0111$$

$$V_{out} = 0.0267V \approx 27mV.$$

Practical value (we got)

$$V_{out} = 40mV$$

The variation is due to Capacitor tolerance of ±20%.