Basic Electronic Circuits (IEC-103)

Lecture-04

Operational Amplifiers

Differential & Common Mode Signals

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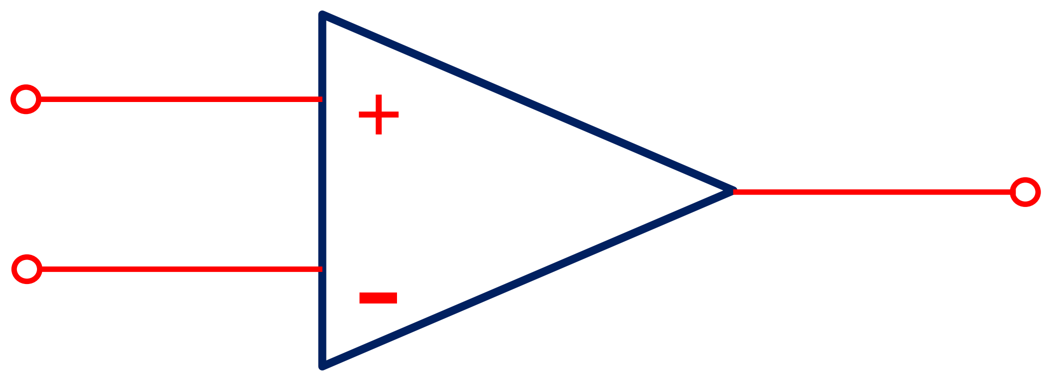
- **Common Mode Input:** In this mode two signals of same amplitude and phase applied to the inputs of the op-amp.

Differential Mode Signal Input



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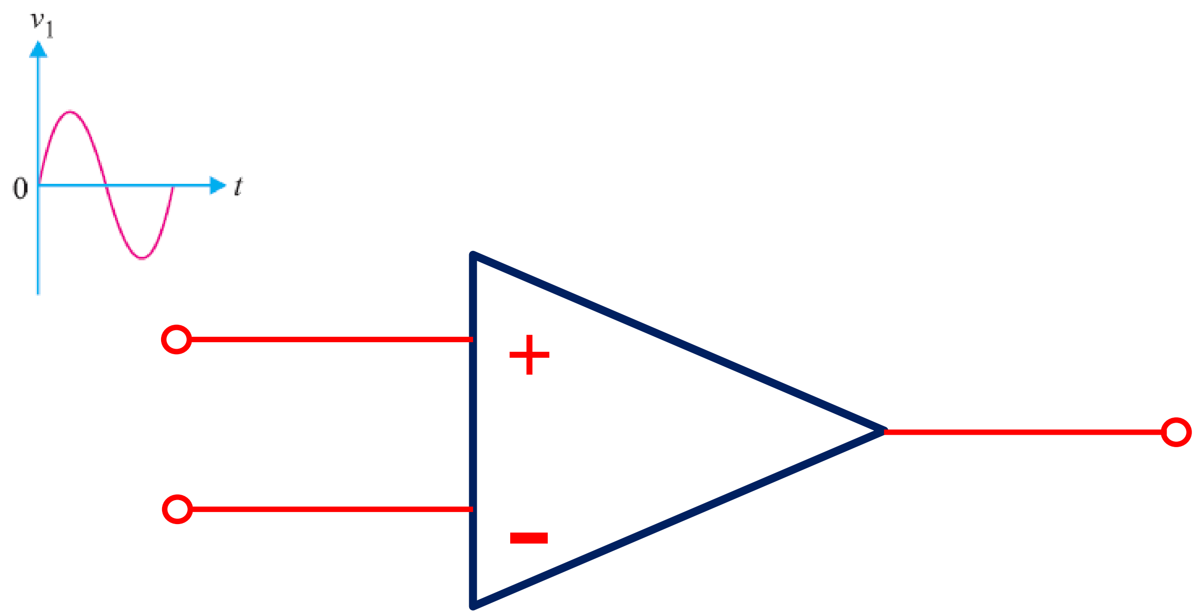

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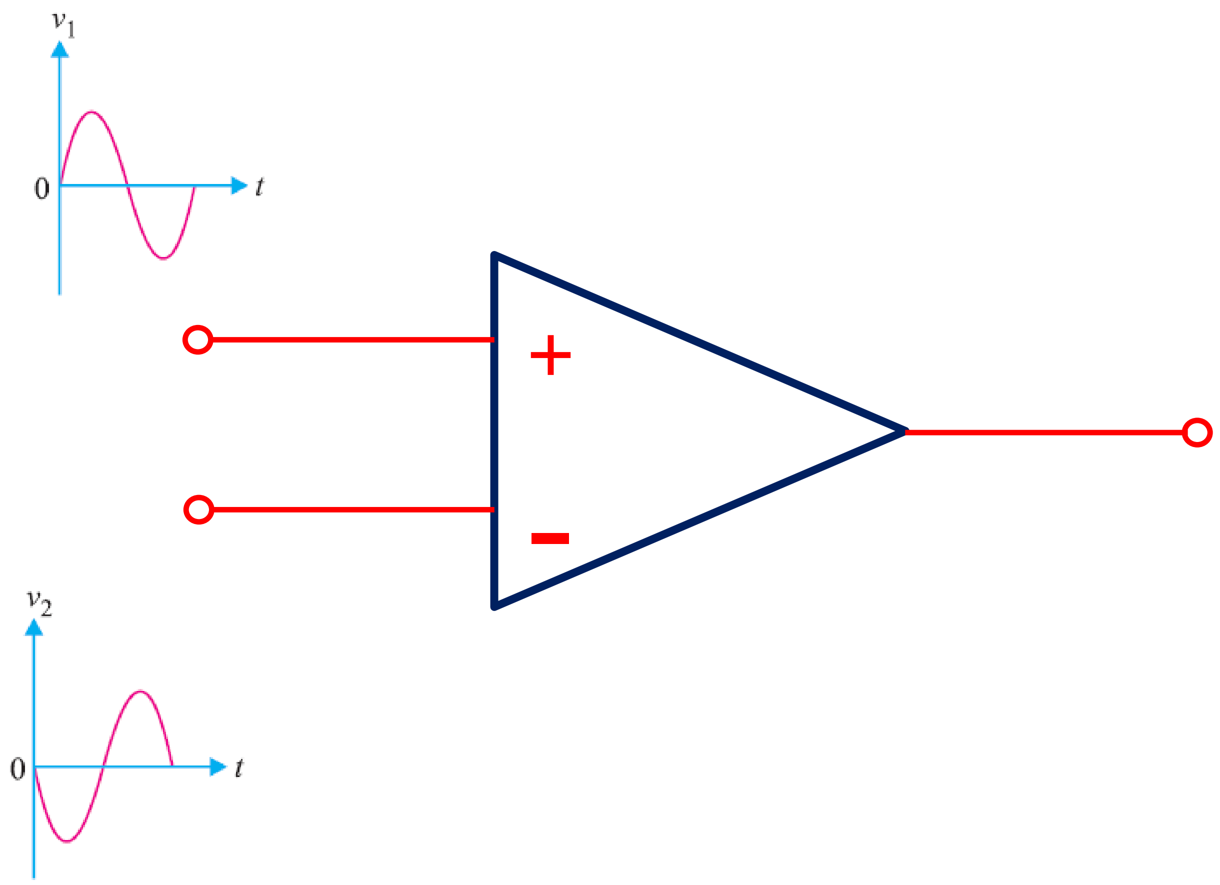

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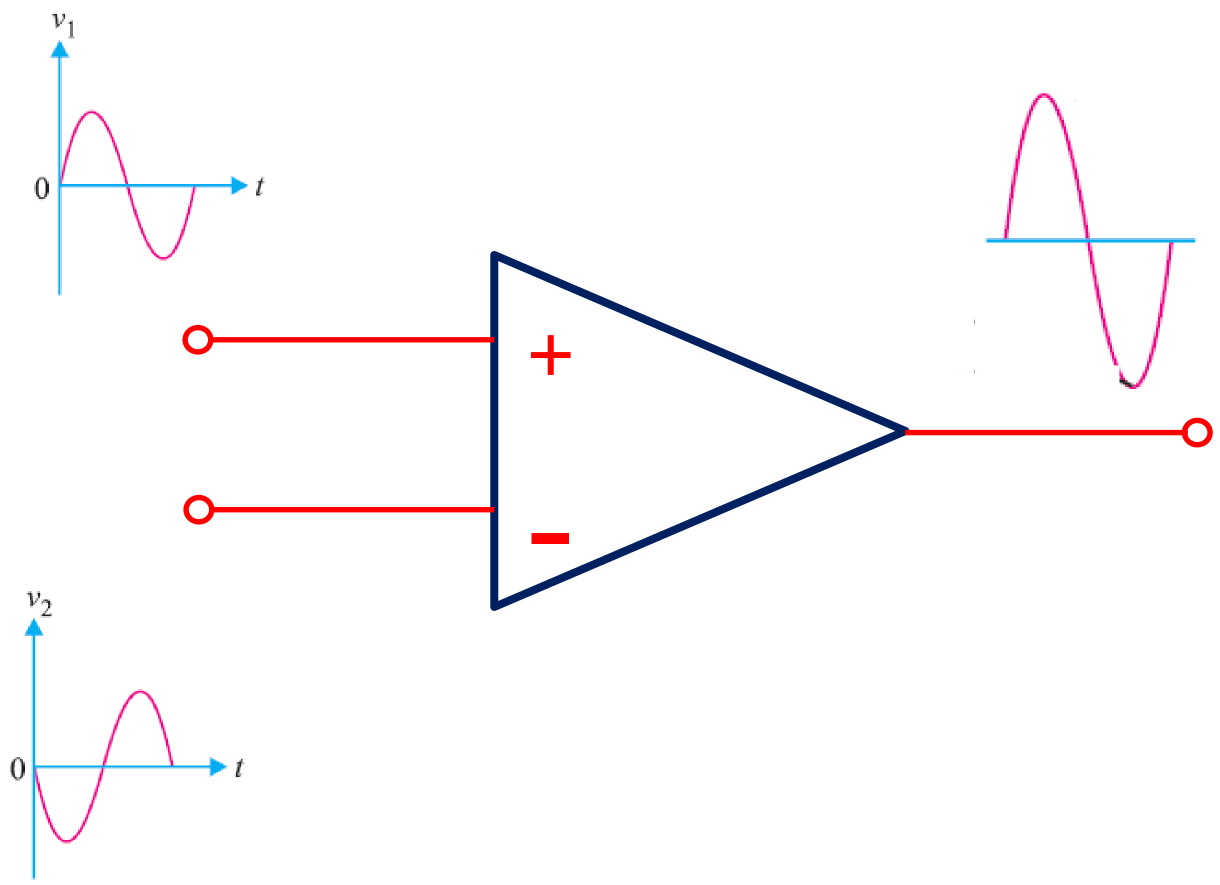

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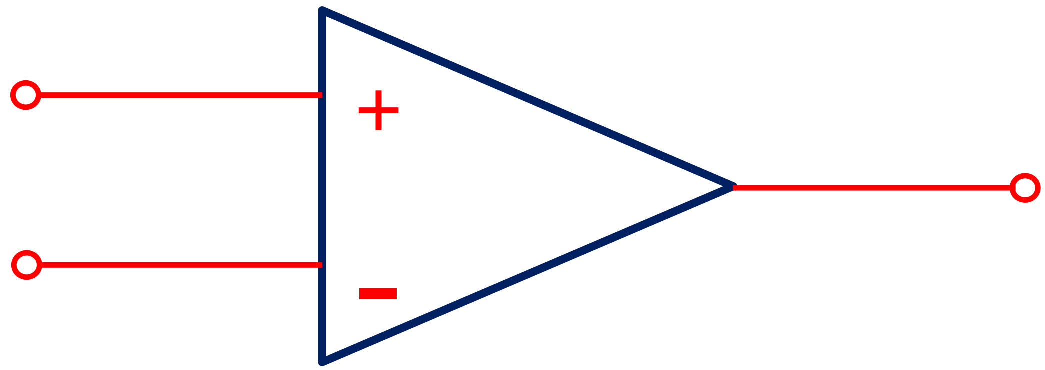

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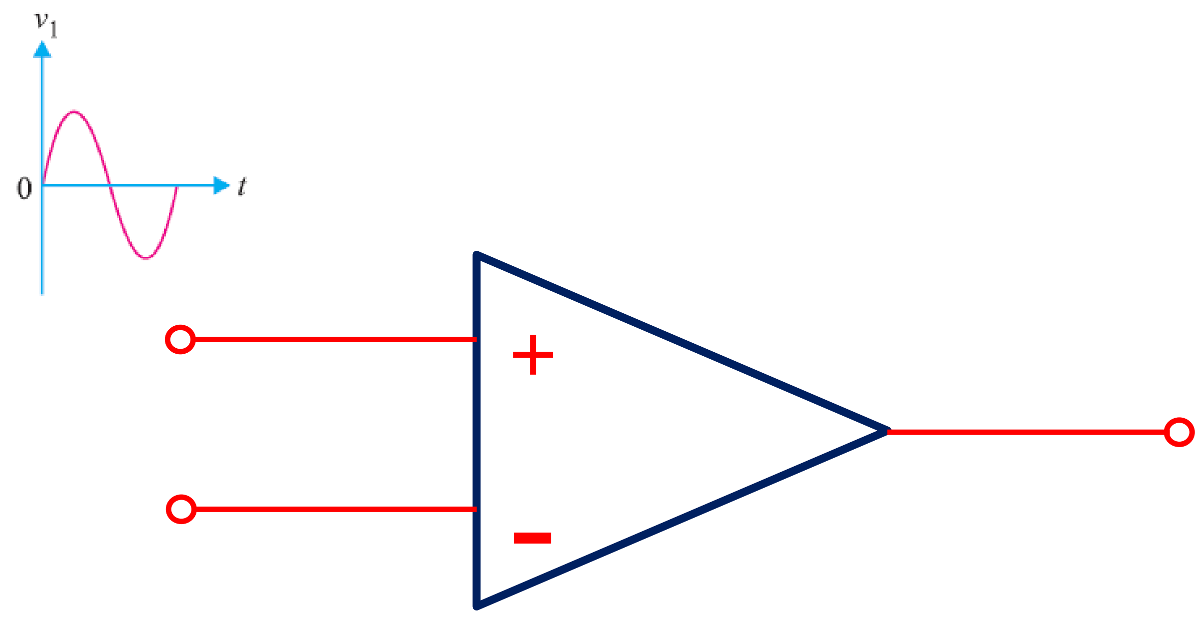

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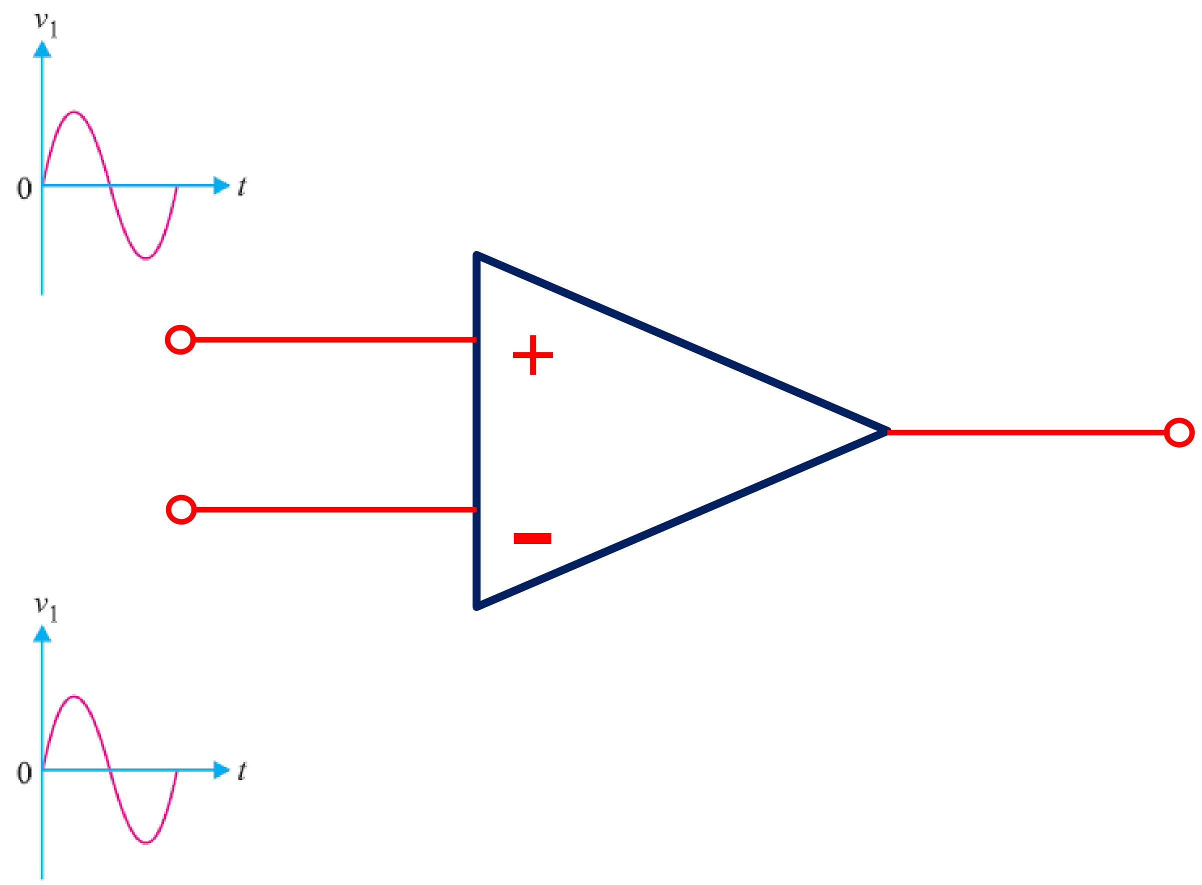

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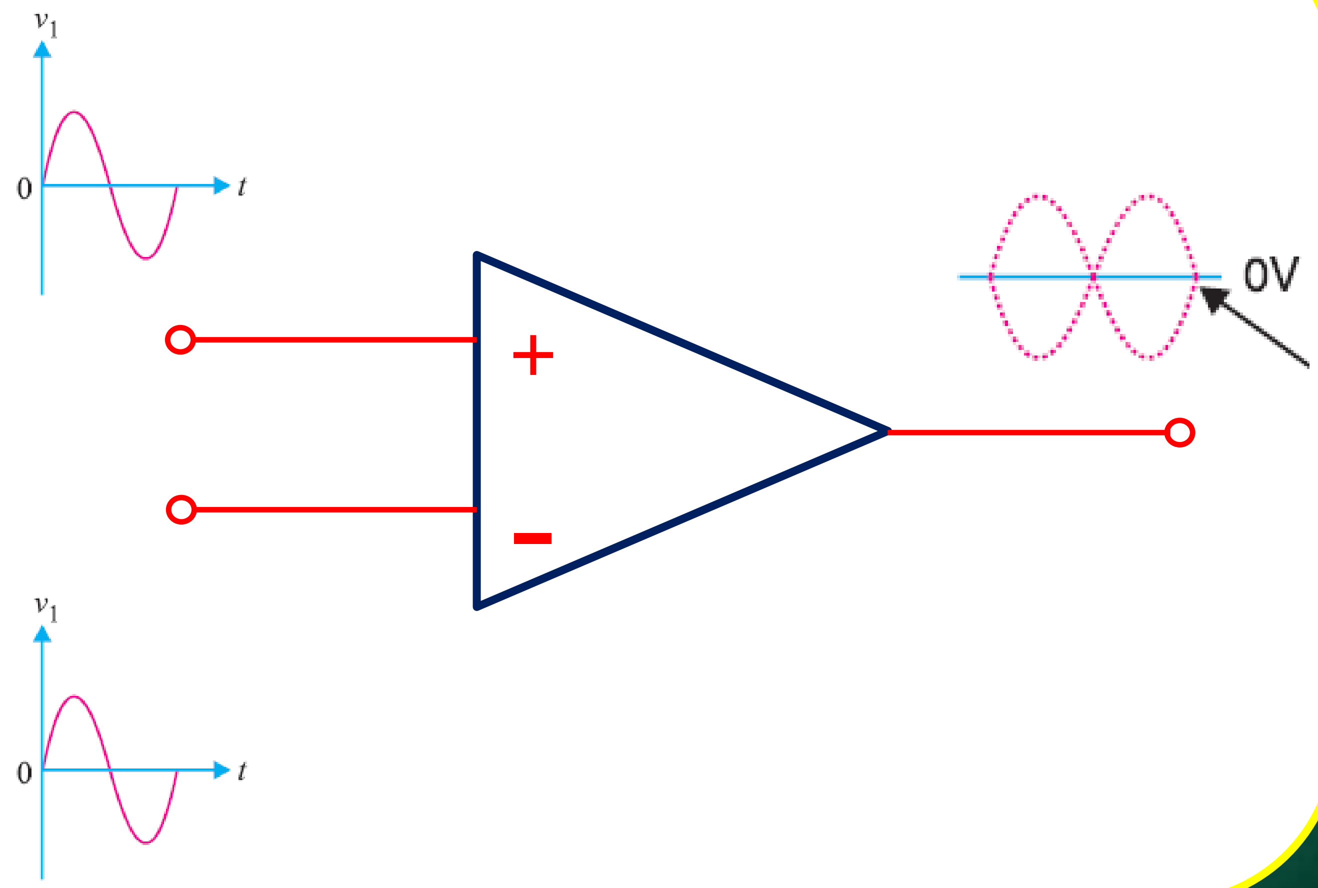

Differential & Common Mode Gain

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- Ideally the voltage gains in differential mode and common mode are infinity and zero, but practical op-amp has very large A_{DM} and very low A_{CM}.

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- Most of the noises & unwanted signals are common mode signals. These unwanted signals appear at the inputs of the op-amp and are virtually eliminated at the output.

- Any RF signal picked up by op-amp inputs would be considered undesirable.

Common Mode Rejection Ratio

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$$CMRR_{dB} = 20\log_{10}\left(\frac{A_{DM}}{A_{CM}}\right)$$

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- The larger the CMRR, better is op-amp at eliminating the common mode signals.

Example

An op-amp has $A_{DM} = 1500$ **and** $A_{CM} = 0.01$**.**
Find CMRR**.**

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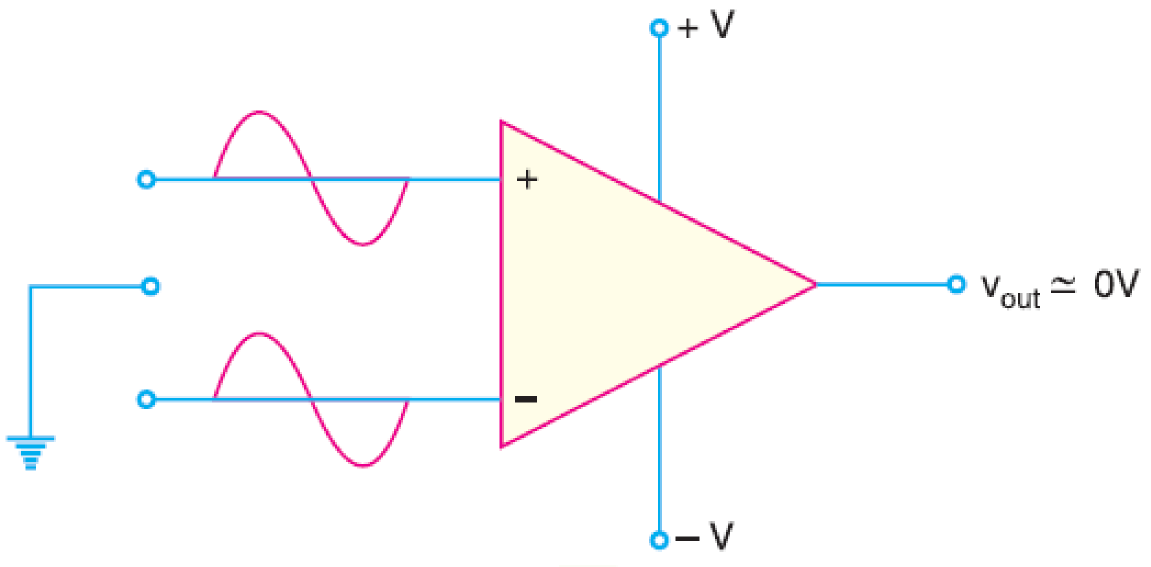

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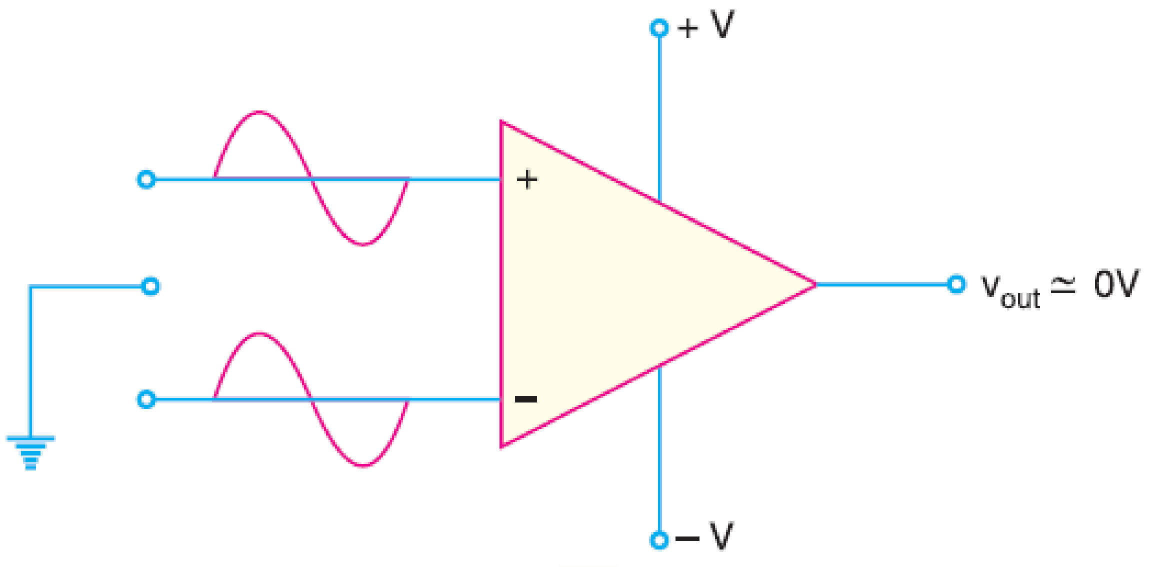
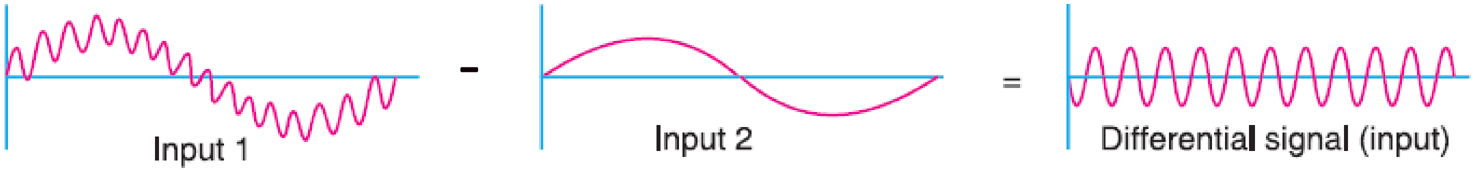


Answer: 150000 or 103.52 dB

Illustration

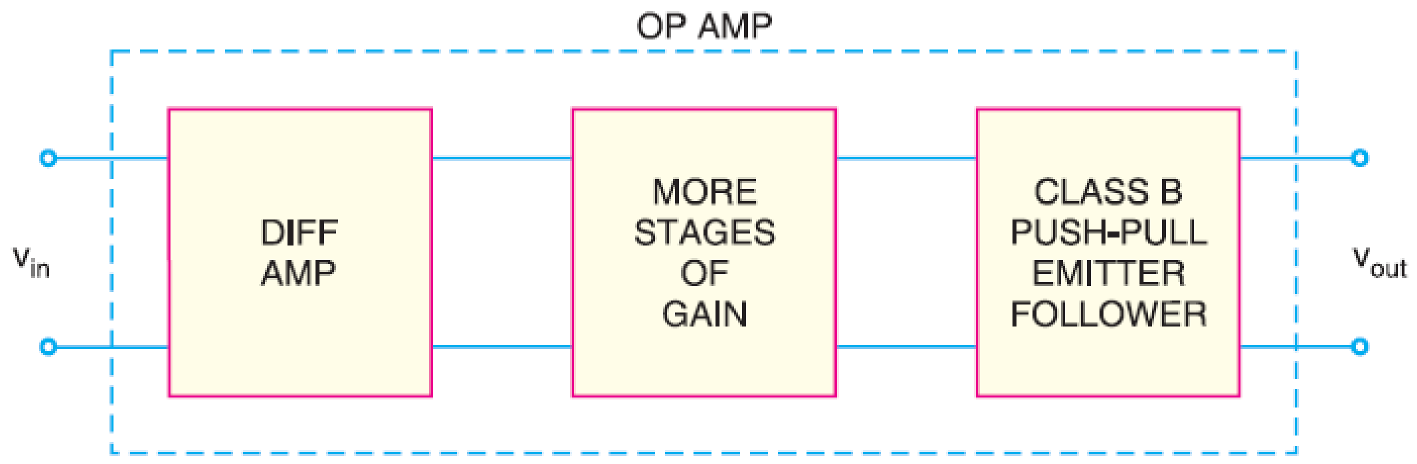
(*i*) Signal input to input 1

(*ii*) Signal input to input 2



(*iii*) Differential input signal

Different Stages in an Op-amp



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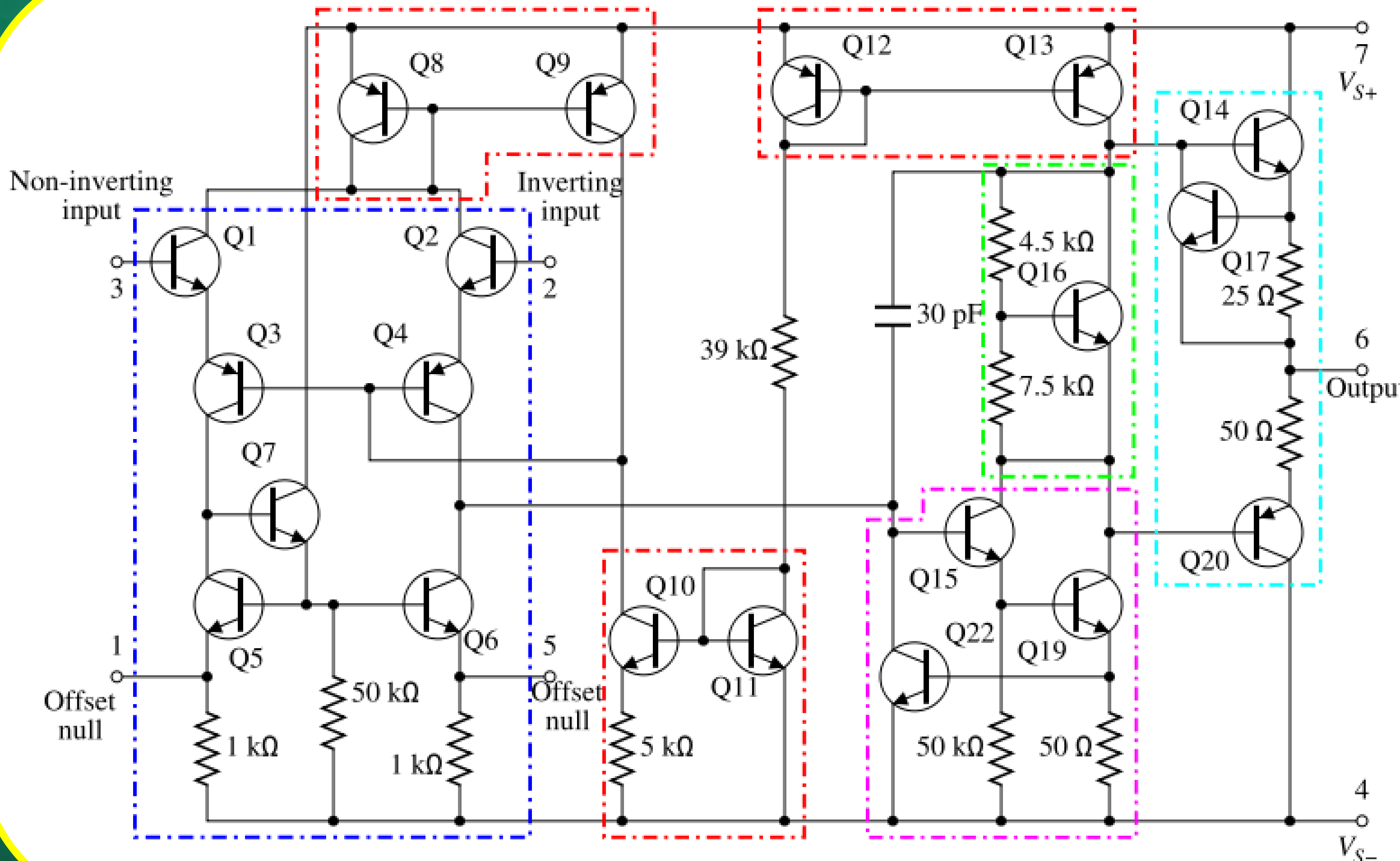

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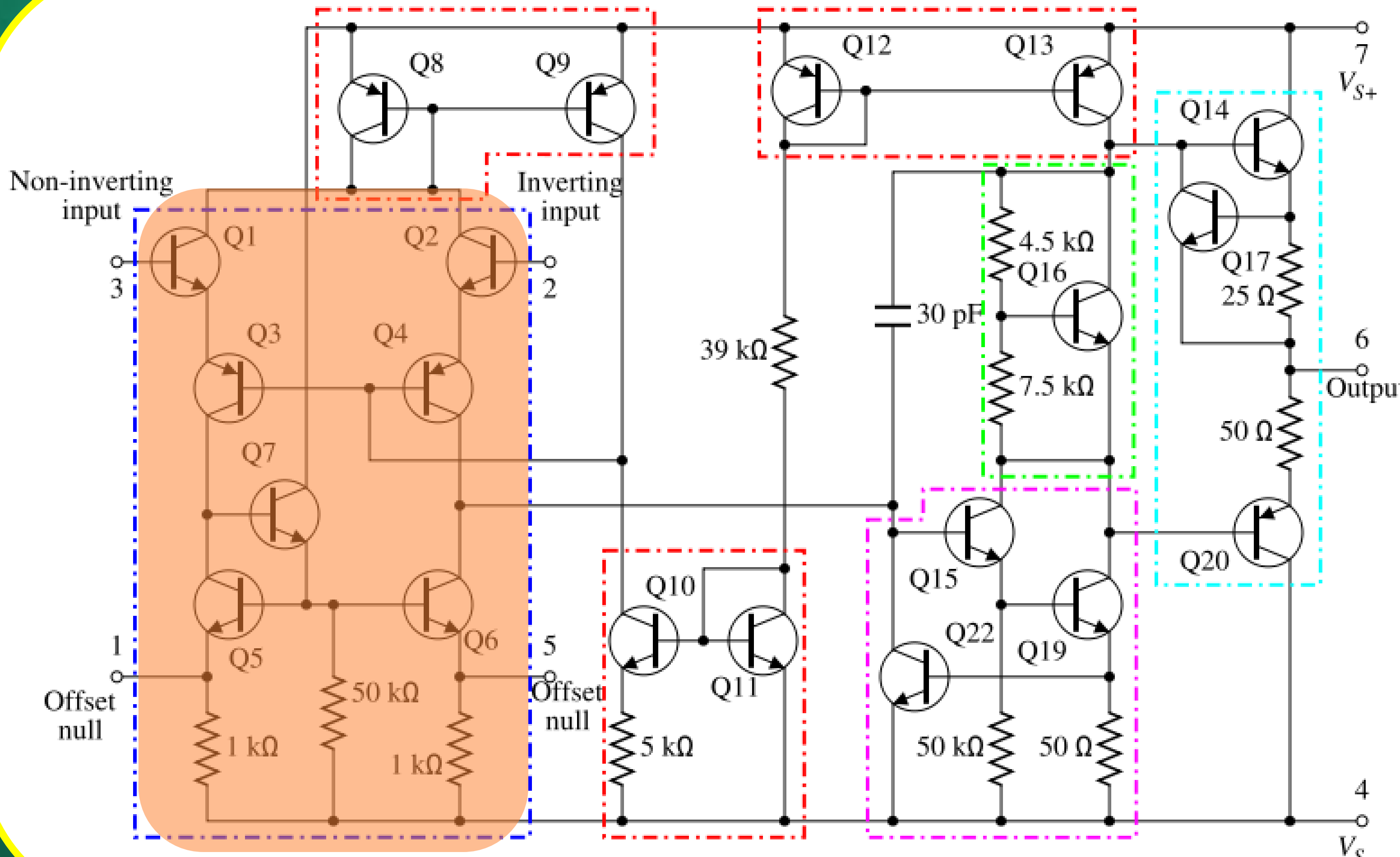

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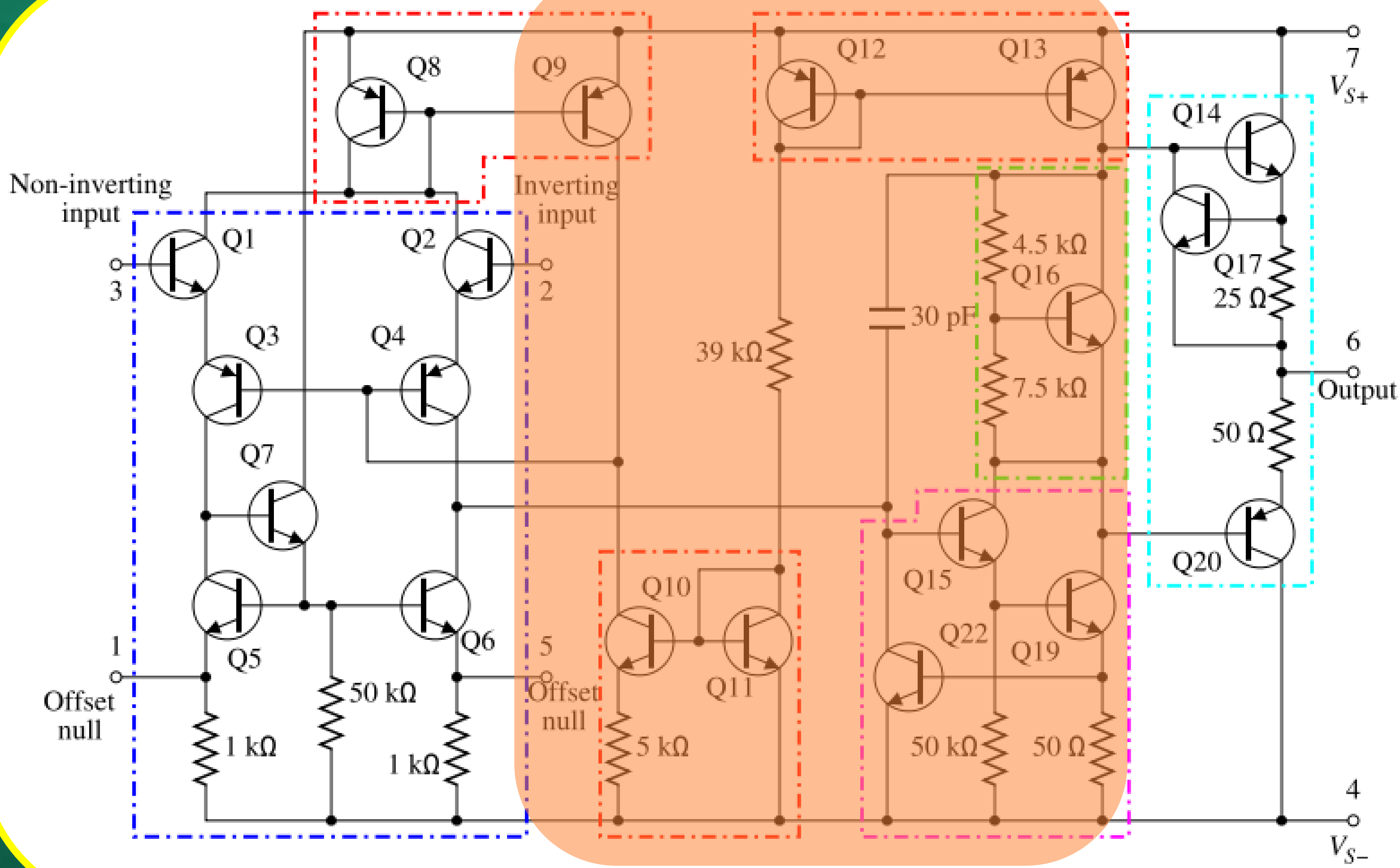

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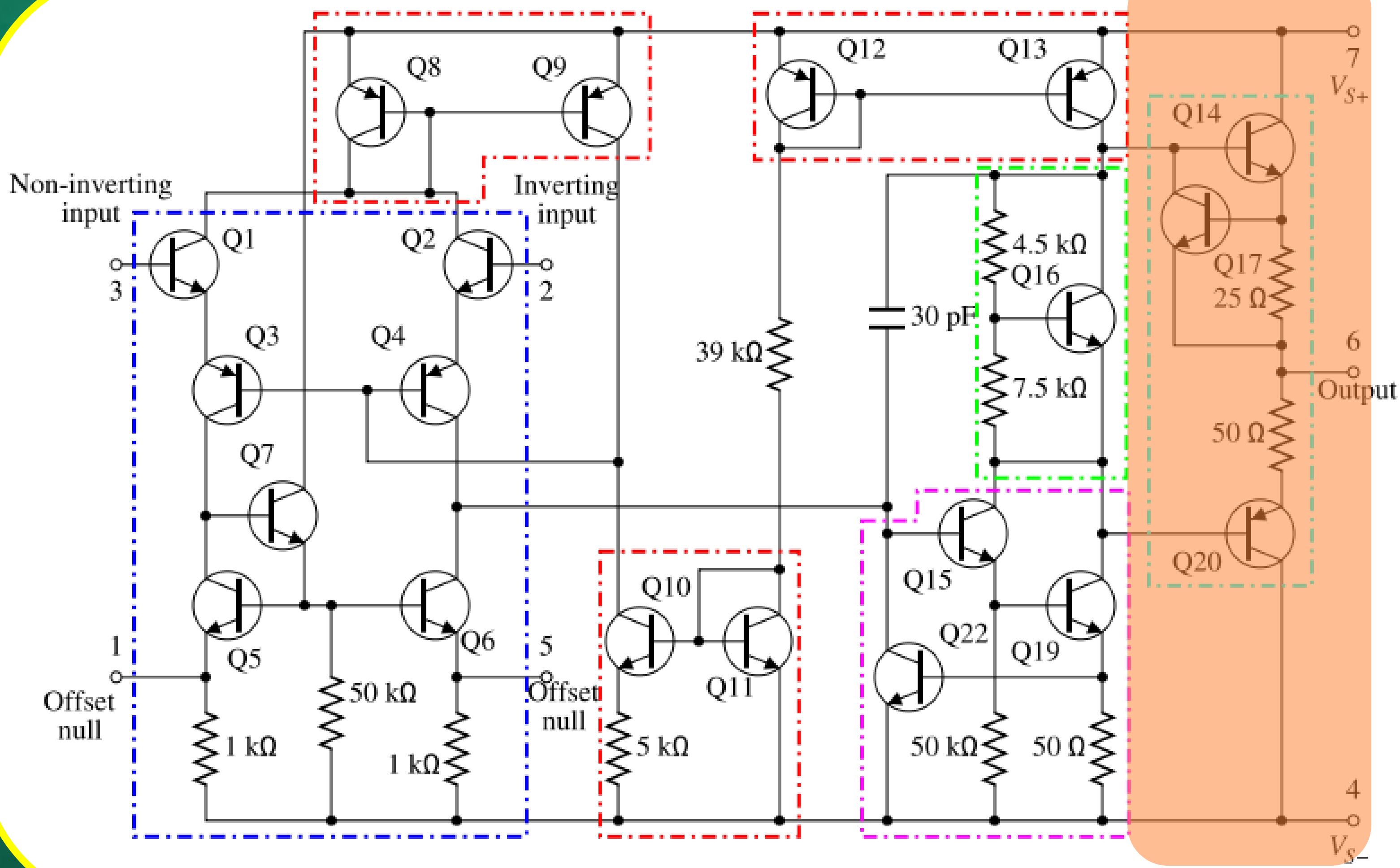

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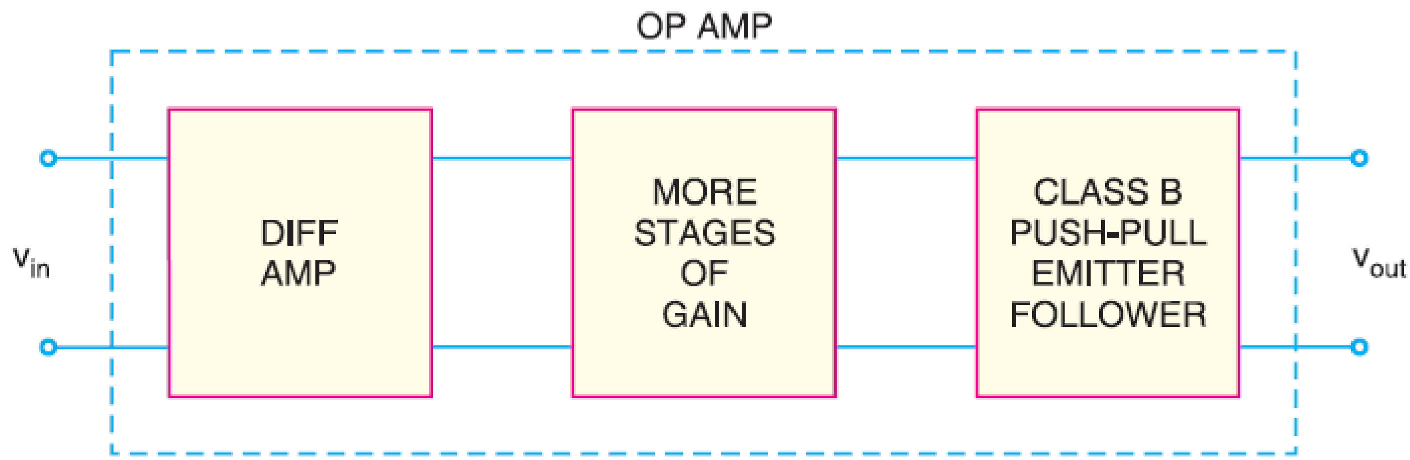

Parameters of Op-amp due to Mismatch of Transistors.

- **Output Offset Voltage**: Small voltage appears at the output terminal of the op-amp even the when voltage applied at both the input terminals are zero. This voltage is termed as output offset voltage. (due to V_{BE} mismatch)

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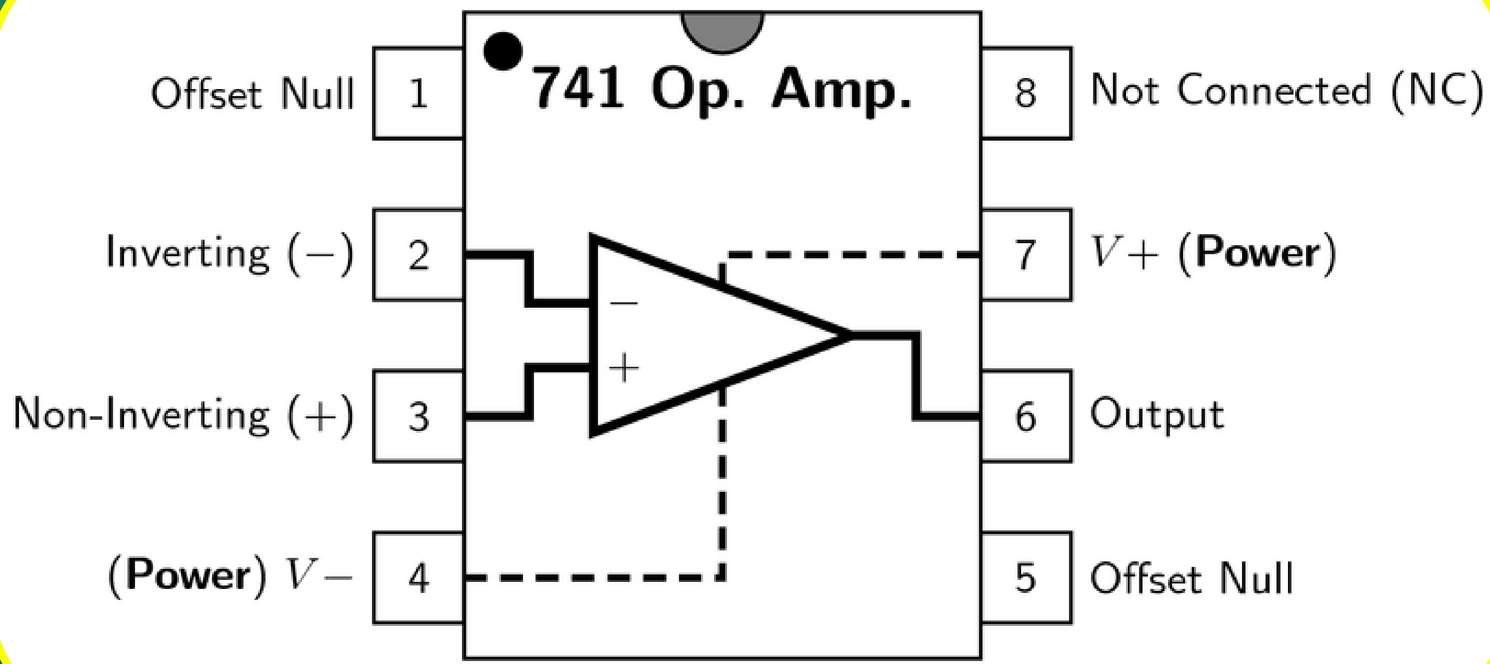
- **Input Offset Current**: When the output offset voltage is eliminated, there will be slight difference between input currents to the non-inverting and inverting terminals of the op-amp. (due to β mismatch)

Offset Pins of an Op-Amp



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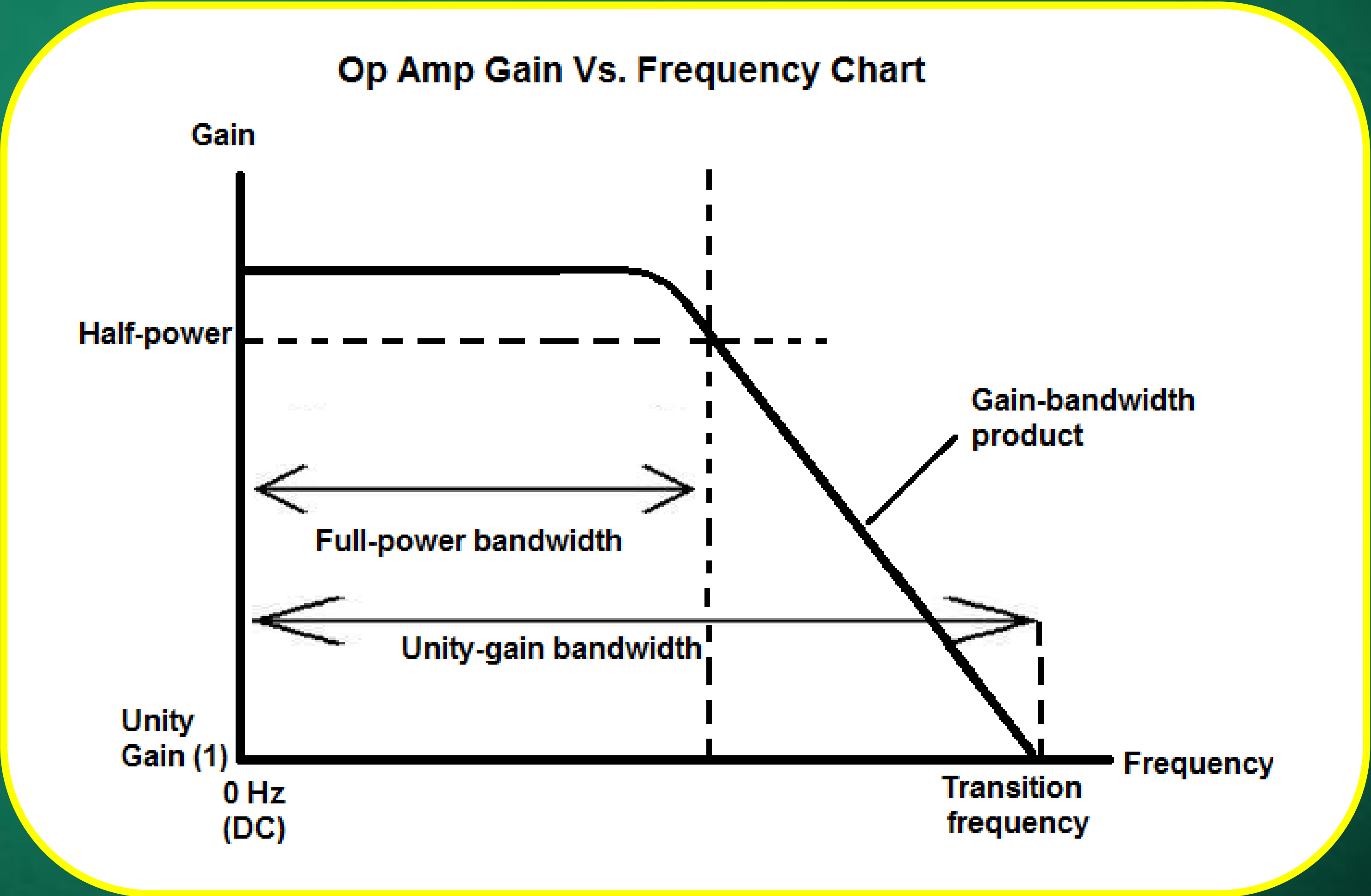
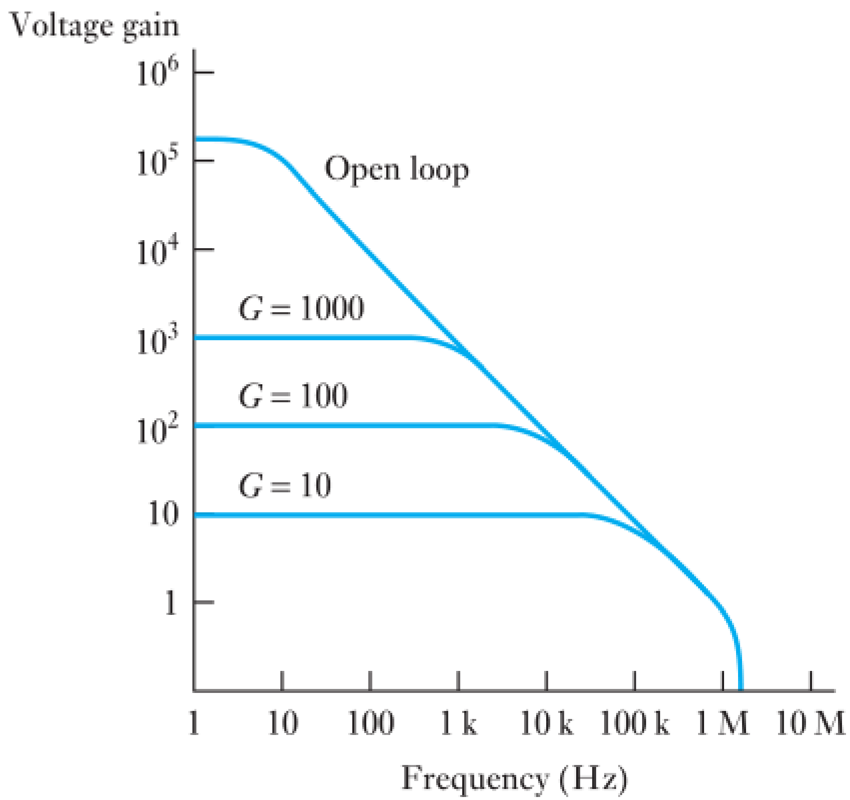
- Op-amp has also limited frequency range of operation.
- The bandwidth of an op-amp depends on the closed-loop gain of the op-amp circuit.

Frequency response (Op-amp)



Frequency Characteristcs (741)



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- It is defined as

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- GBW can be used to find
  - Maximum value of A_{CL} at a given frequency.
  - The value of f_2 for a given A_{CL}.

Gain Bandwidth Product

- Conclusion
  - Higher the value of A_{CL} , narrower is frequency response.
  - Lower the value of A_{CL}, broader is frequency response.

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- The maximum operating frequency (f_{max}) of an op-amp is given by

$$f_{\max} = \frac{\text{slew rate}}{2\pi V_{pk}}$$

V_{pk} is the peak of output voltage

Slew Rate

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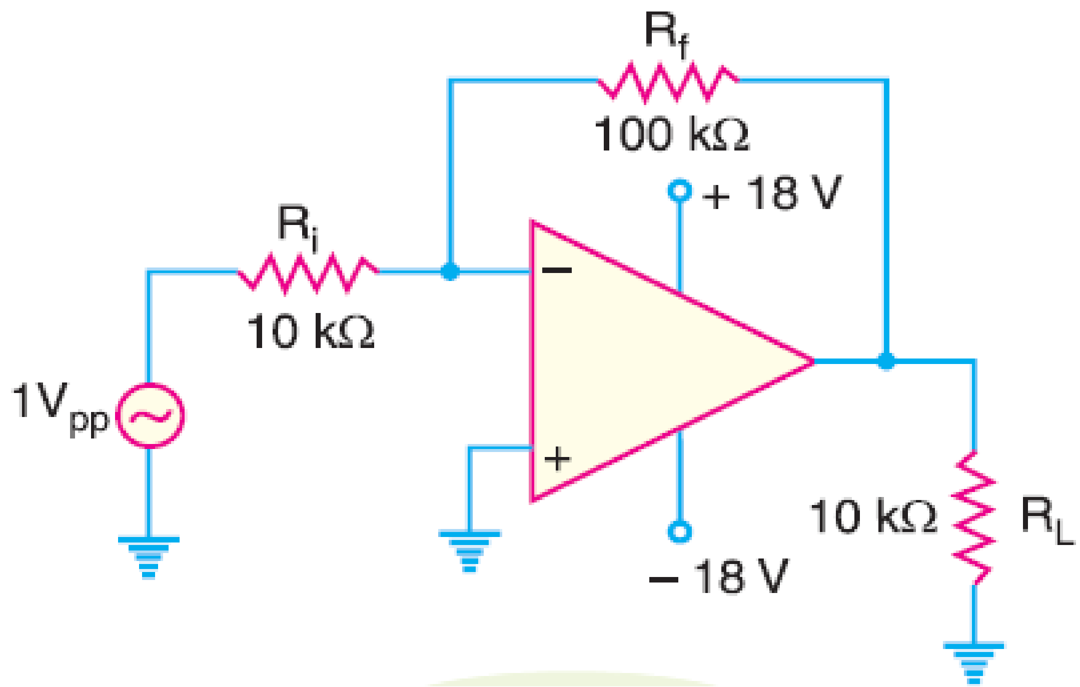
- Exceeding maximum operating frequency results in distortion of the output waveform.

Example

For the circuit shown, find the closed-loop gain, input impedance of the circuit, maximum operating frequency if slew rate is 0.5 V/μs.



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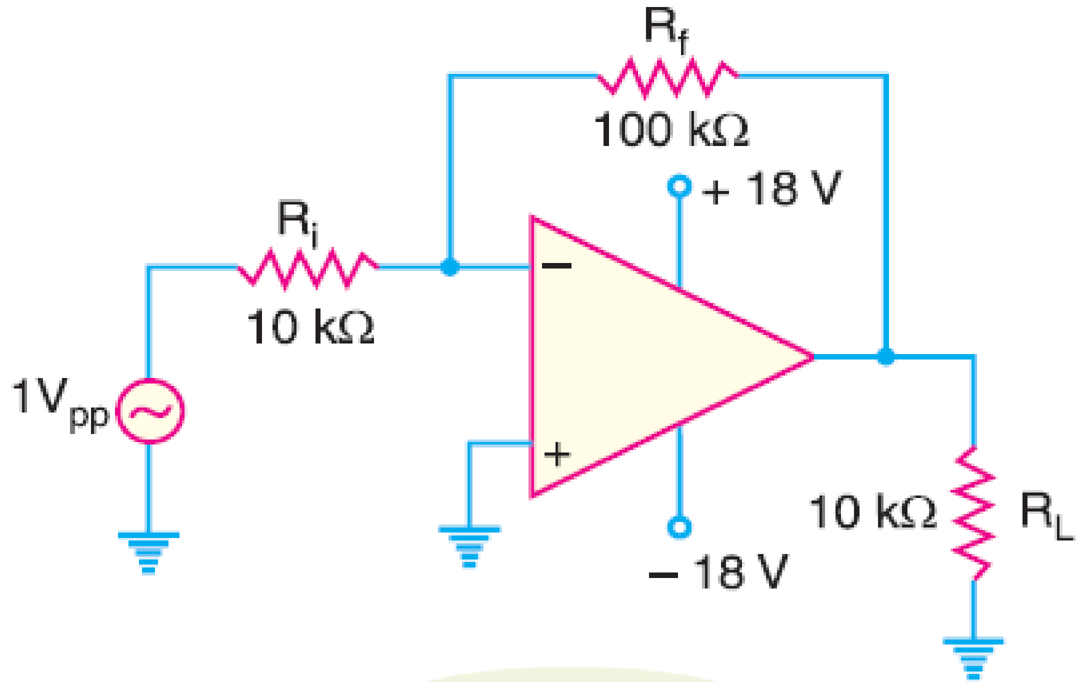
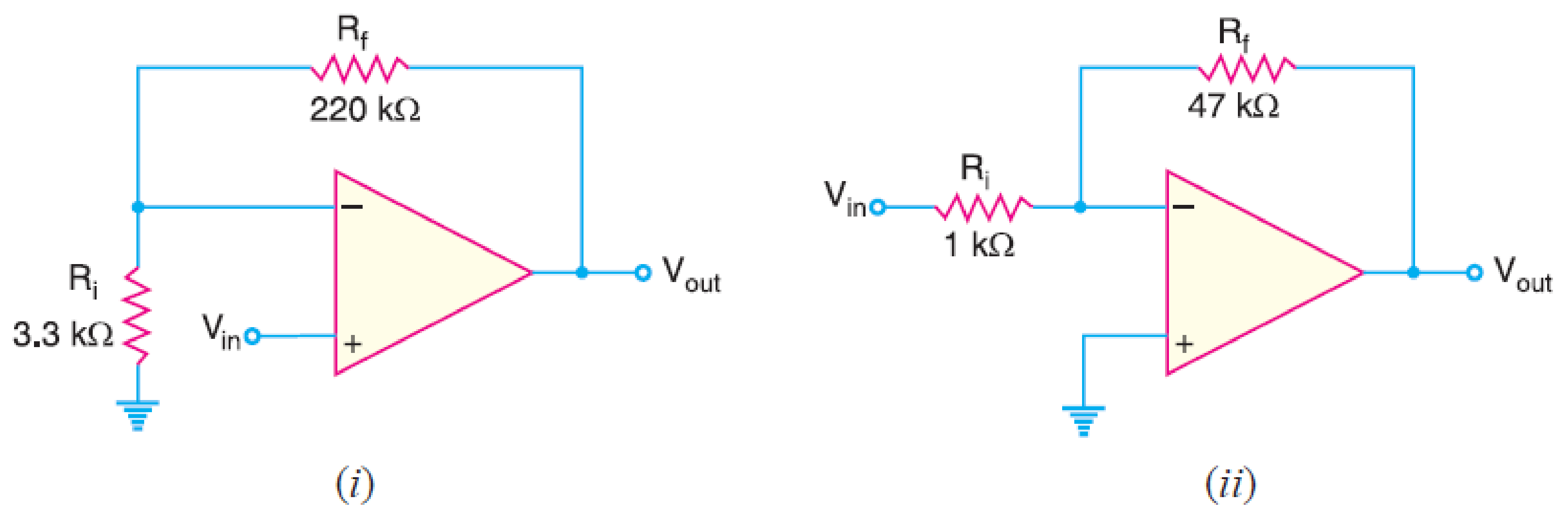


Answer: -10, 10 KΩ, 0.5 V/μs, 15.9 KHz

Example

Determine the bandwidth of each of the amplifier circuits shown below. Both the op-amps have open loop gain of 100 dB and unity gain bandwidth of 3 MHz.



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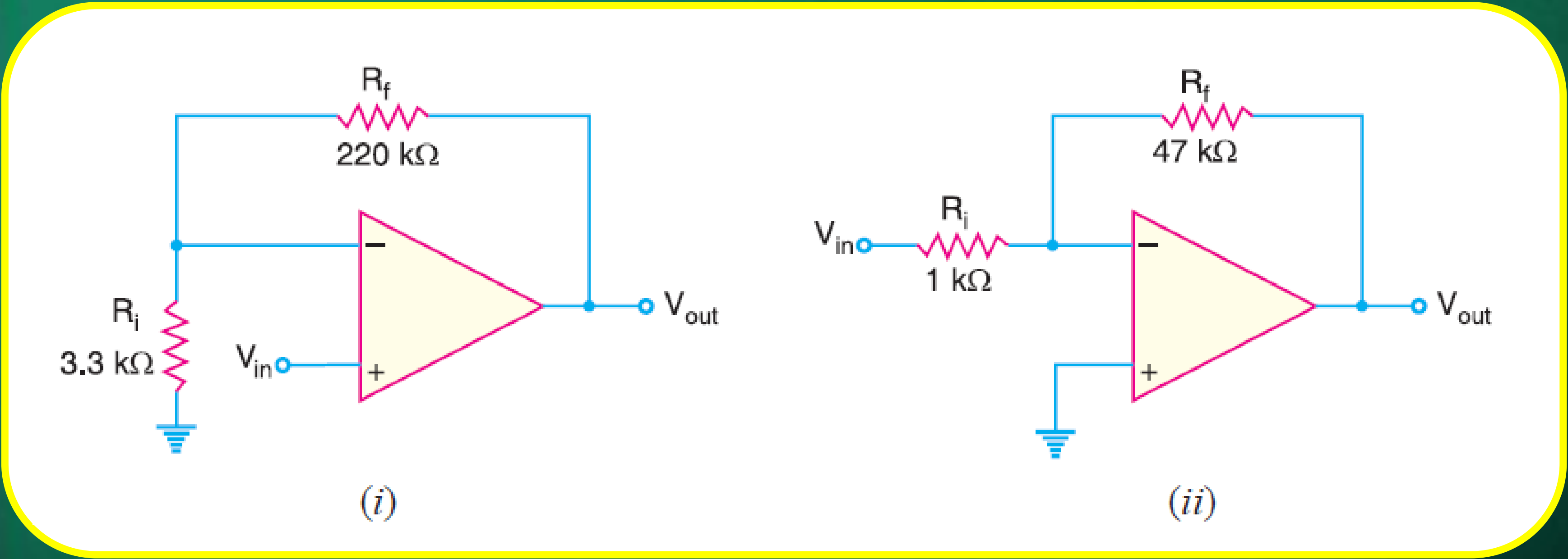
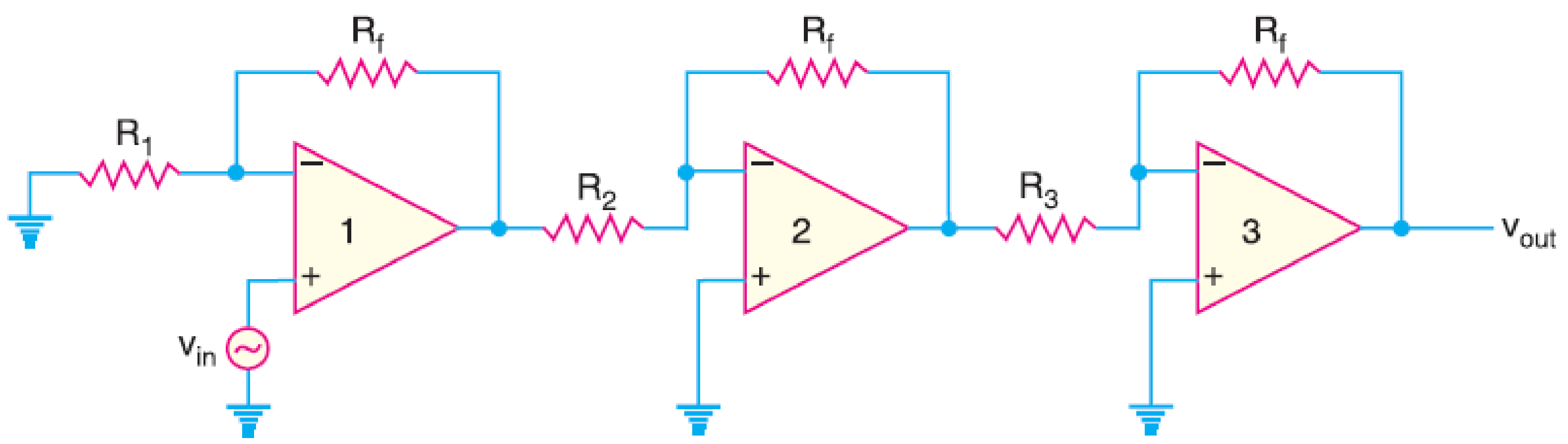


Answer: 44.3 kHz, 63.8 kHz

Multistage Op-amp Circuits

When number of op-amp circuits are connected in cascade, the overall gain is the product individual op-amp circuit gains.



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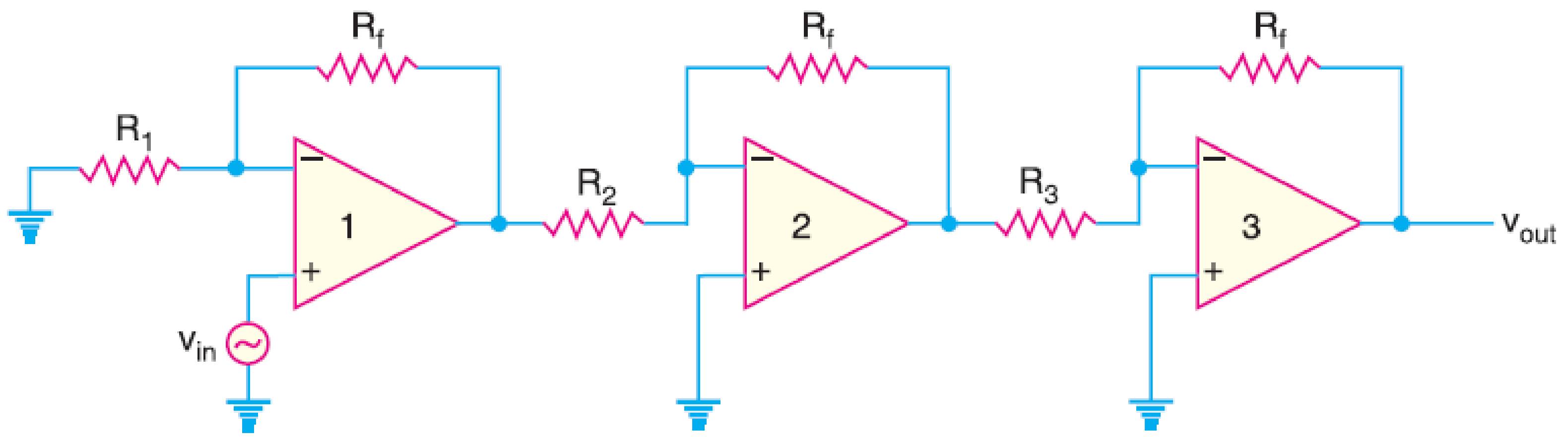
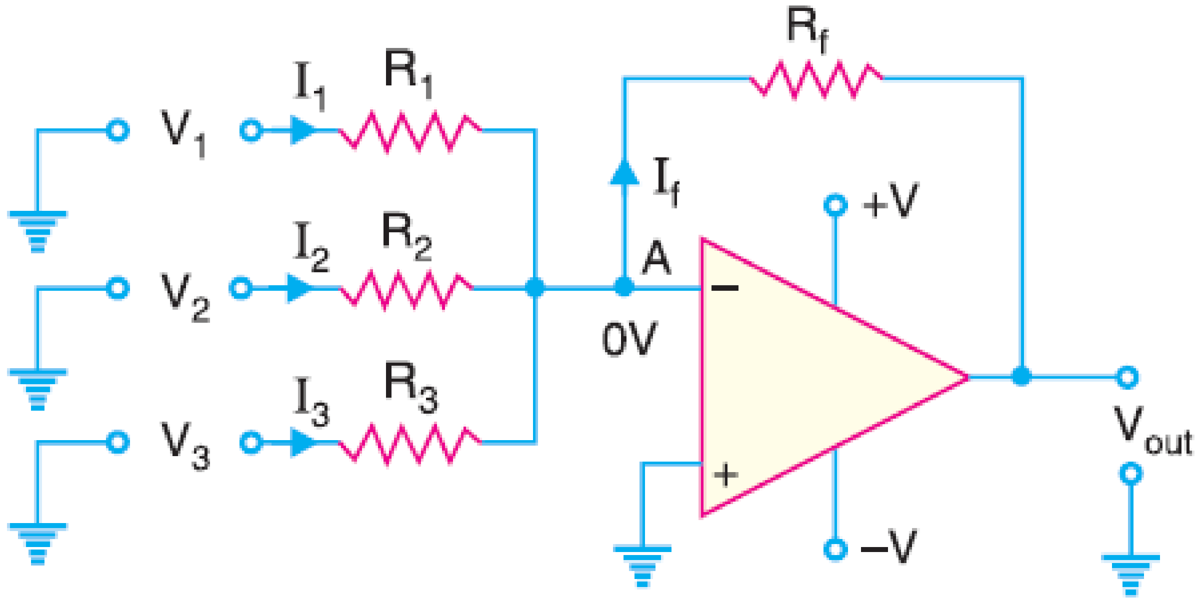


Overall gain is $V_{out}/V_{in} = A = A_1A_2A_3$

where $A_1 = (1+R_f/R_1)$; $A_2 = -(R_f/R_2)$ and $A_3 = (-R_f/R_3)$

Summing Amplifier



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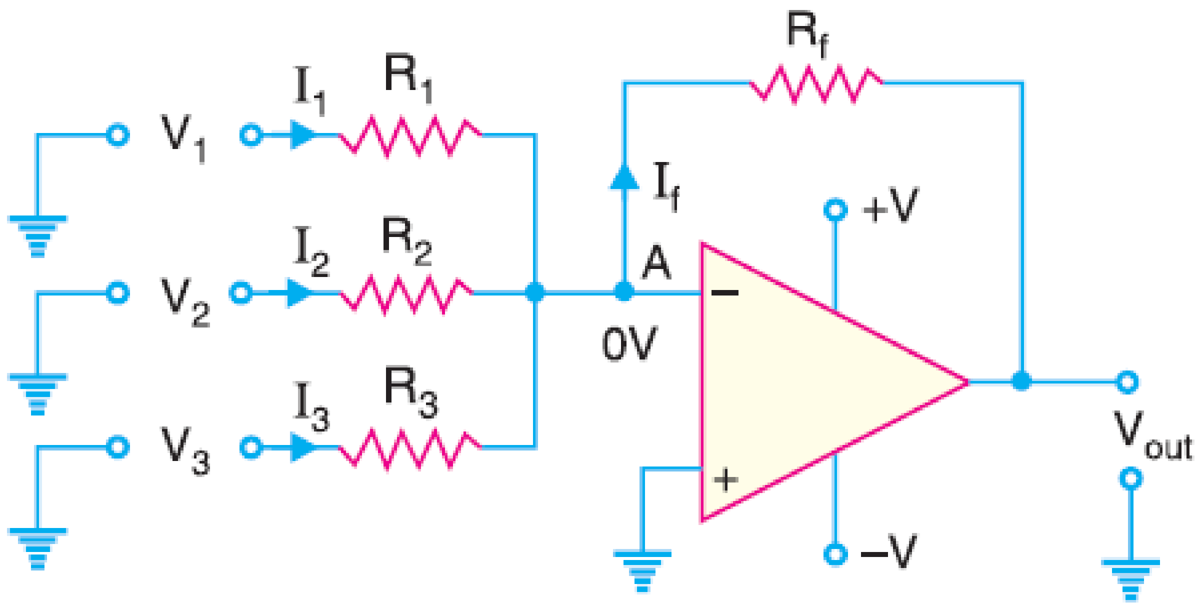

$$V_{out} = -\left(\frac{R_f}{R_1} V_1 + \frac{R_f}{R_2} V_2 + \frac{R_f}{R_3} V_3 \right)$$

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