20 Formulas for Operational Amplifier Circuit Design

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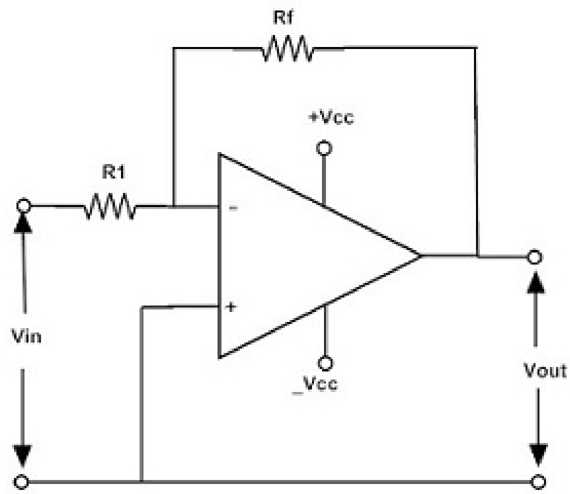


I Introduction

Although there are many **types of operational amplifiers,** different **amplifier circuits** are suitable for interfacing with different types of sensors, but most complex amplifiers are built by combining operational amplifiers. In order to get good amplication effect, it is necessary to design the circuit of the amplifier. This paper will introduce 20 **opamp formulas** as a design reference.

Op Amp Formulas For Voltage Calculation

Catalog

II Operational Amplifier Formulas

In almost cases today, op amps are configured in different ways using a feedback network to "calculate" the input signal. There are 20 formulas used to calculate.

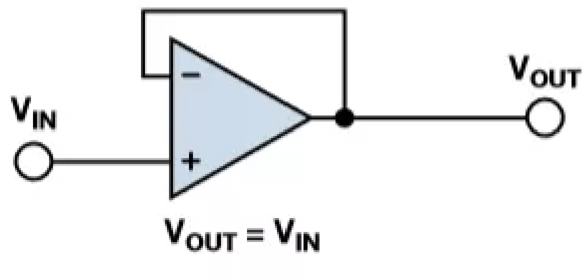


Figure 1. Voltage Follower

Note: Buffer High Impedance Signal and Low Impedance Load

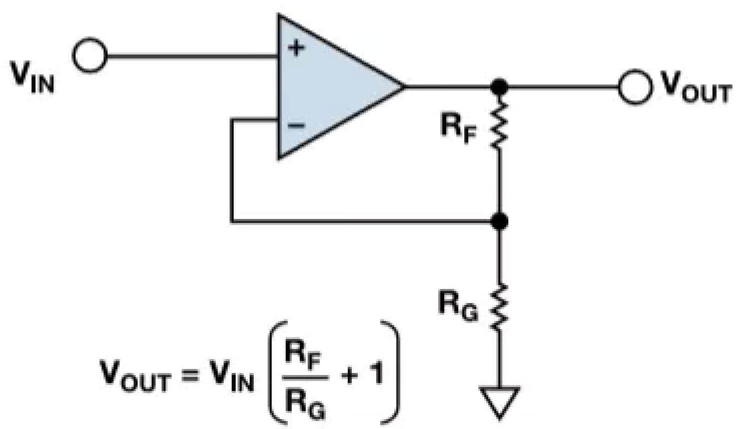


Figure 2. In-phase Op Amp

Note: In-phase Signal Amplification

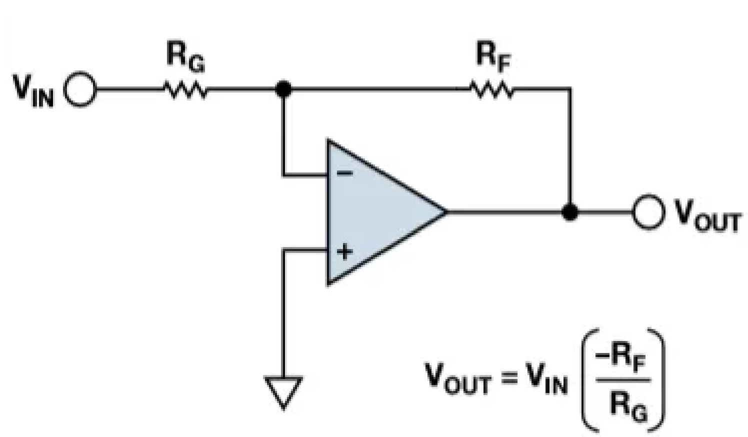


Figure 3. Reversed-phase Op Amp

Note: Amplify and Invert Input

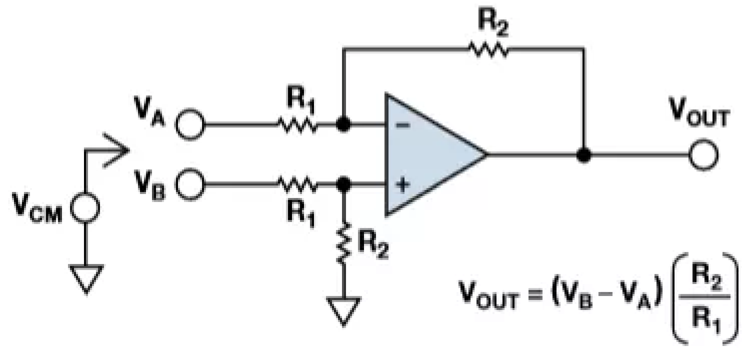


Figure 4. Voltage Subtractor, Differential Amplifier

Note: Amplify the voltage difference and suppress the common - mode voltage

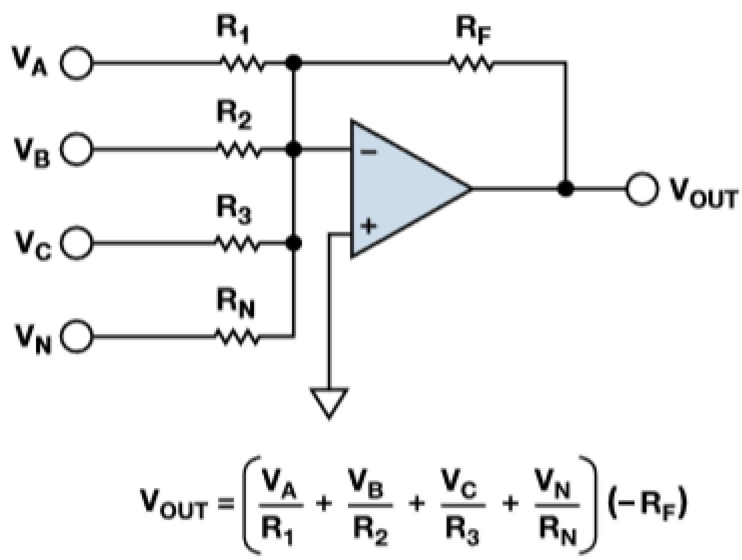


Figure 5. Voltage Adder

Note: Summation of Adding Voltage Values

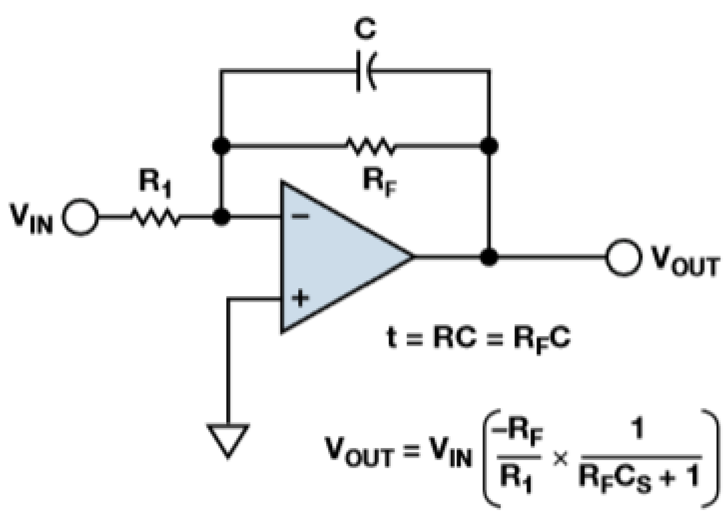
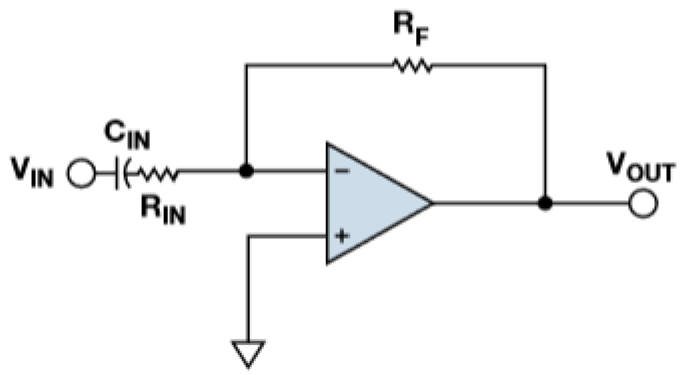


Figure 6. Low-pass Filter, Integrator

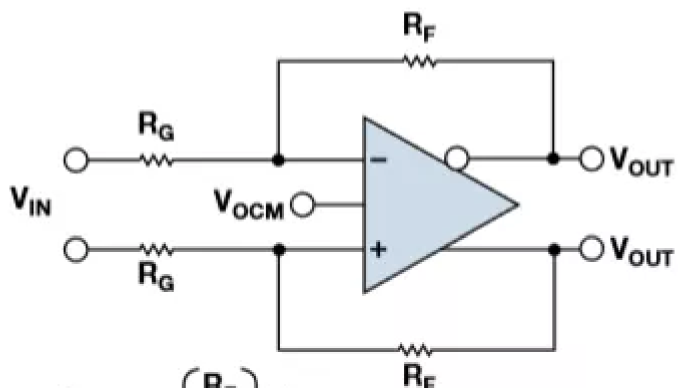
Note: Limit Signal Bandwidth



$$V_{OUT} = V_{IN}\left(\frac{-R_F}{R_{IN}} \times \frac{R_{IN}C_S}{R_{IN}C_S + 1}\right)$$

Figure 7. High-pass Filter, Differentiator

Note: Eliminate DC, Amplify AC Signal



$$V_{OUT_{diff}} = \left(\frac{R_F}{R_G}\right) V_{IN}$$

Figure 8. Differential Amplifier

Note: Drive Differential Signal to Analog-to-Digital Converter From A Differential or Single-ended Signal Source

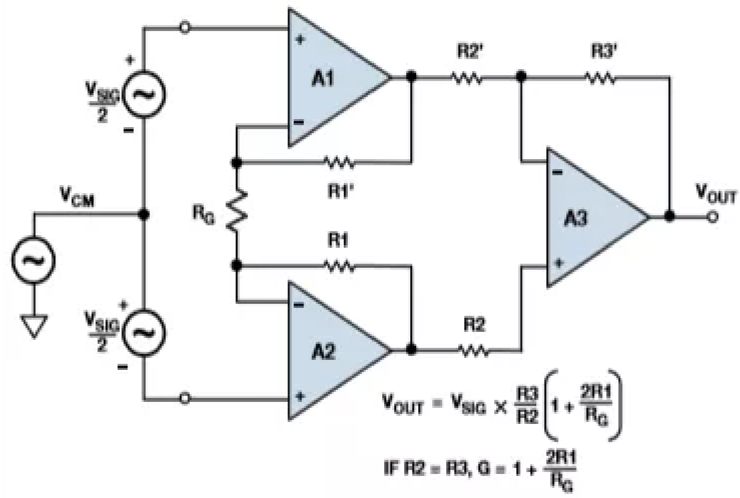


Figure 9. Instrumentation Amplifier

Note: Amplify the Low Level Difference Signal and Suppress the Common Mode Signal

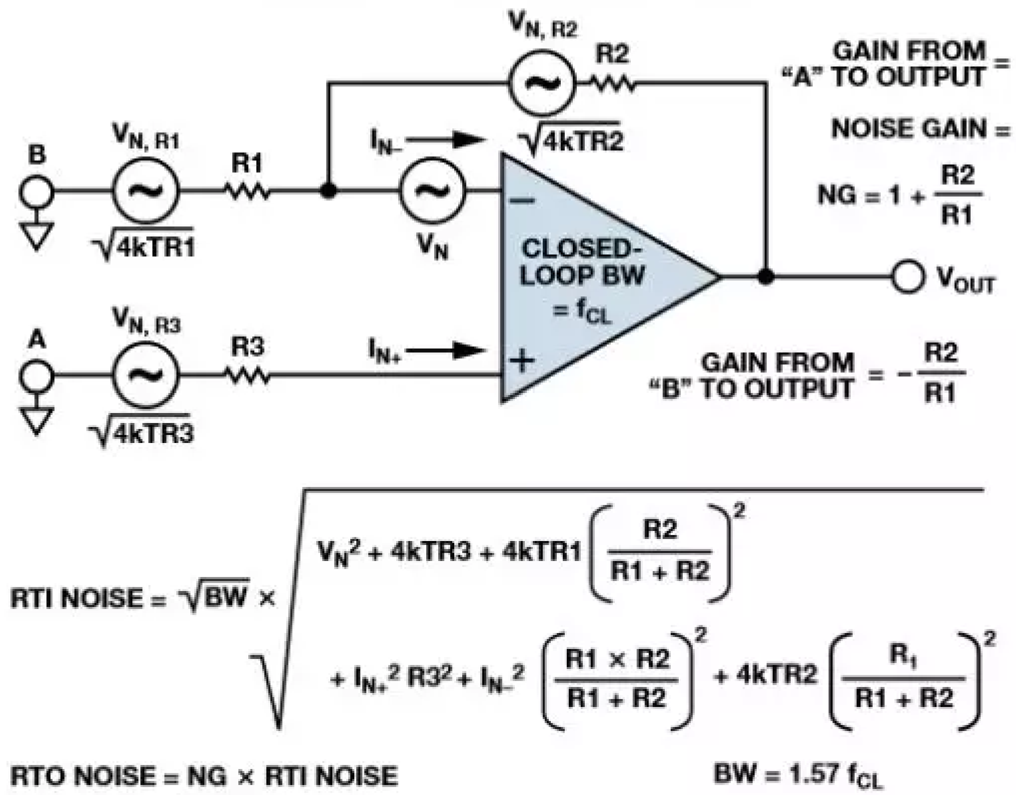


Figure 10. Single State Op Amp Noise

Note: RTO NOISE=NG×RTI NOISE

RTI=Converted to the Input

RTO=Converted to the Output

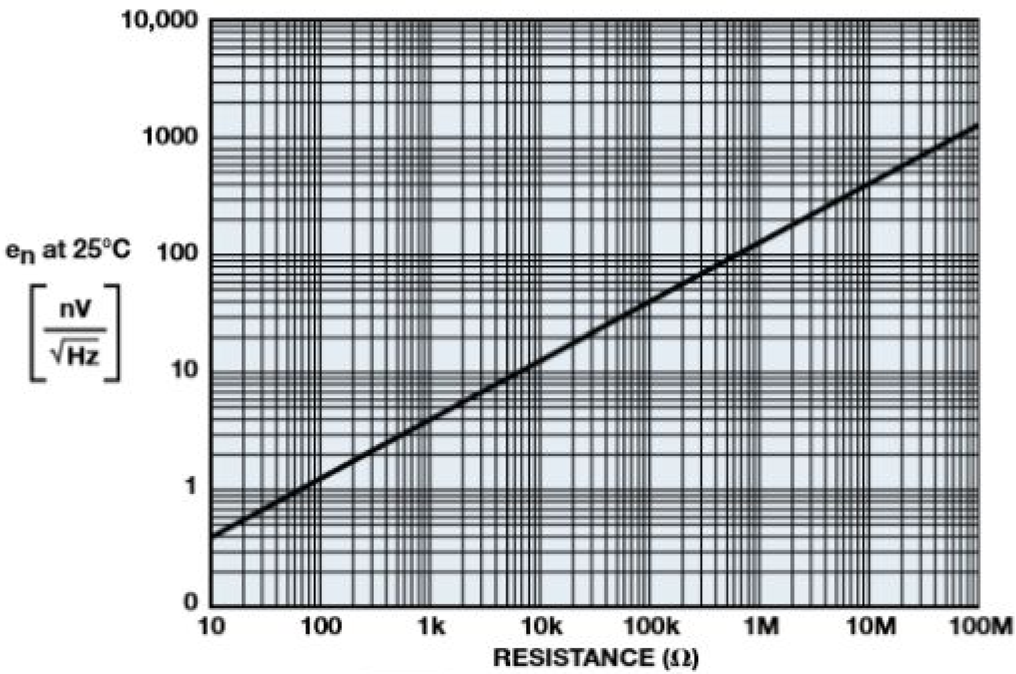
$$db = 10\ Log\ \frac{P_{OUT}}{P_{IN}} = 20\ Log\ \frac{V_{OUT}}{V_{IN}}$$

$$= 20\ Log\ \frac{I_{OUT}}{I_{IN}}\quad \text{(Gain)}$$

$$db = 10\ Log\ \frac{P_{IN}}{P_{OUT}} = 20\ Log\ \frac{V_{IN}}{V_{OUT}}$$

$$= 20\ Log\ \frac{I_{IN}}{I_{OUT}}\quad \text{(Gain)}$$

Decibel Formula (equivalent impedance)



$V_R = \sqrt{4kTRB}$

V_R = Johnson–Nyquist Noise Spectral Density

k = Boltzmann's constant $(1.38 \times 10^{-23} J/K)$

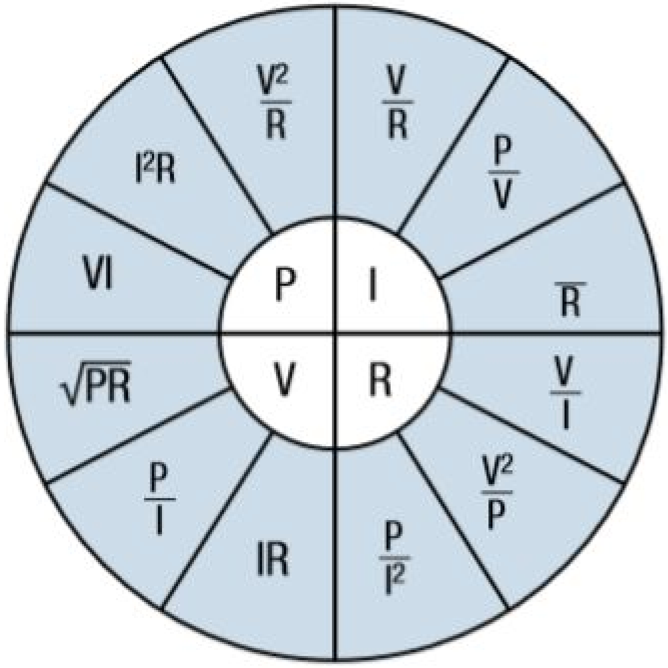
T =Kelvin Absolute Temperature

R =Resistance(OHms)

B =Bandwidth(Hz)

T=25°C， $4kT = 1.65 \times 10^{-20} W/Hz$,where, $V_R = \sqrt{1.65 \times 10^{-20} RB}$

Johnson-Nyquist Noise Formula



Ohm's Law (DC circuit)

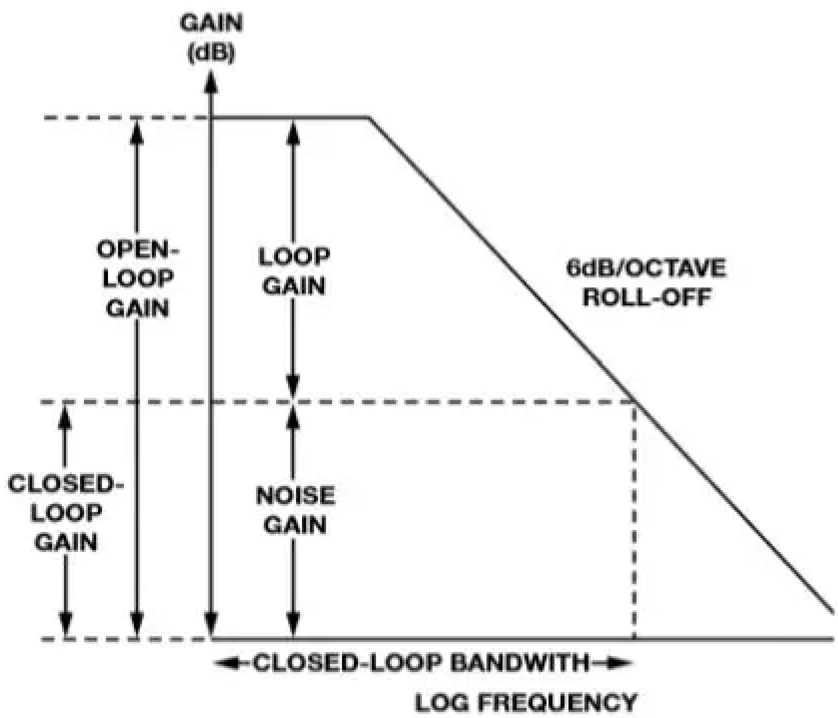


Figure 11. Closed-loop Frequency Response (voltage feedback amplifier)

Series Resistor

$$R_{TOTAL} = R_1 + R_2 + R_3 + \ldots$$

Parallel Resistance

$$R_{TOTAL} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots}$$

Two Resistance in Parallel

$$R_{TOTAL} = \frac{R_1 R_2}{R_1 + R_2}$$

Equivalent Resistors in Parallel Connection

$$R_{TOTAL} = \frac{R}{N}$$

R is the resistance of one of the equivalent resistors and N is the number of equivalent resistors.

Resistance Formulas

$$X_C = \frac{1}{2\pi fC}$$

$$X_L = 2\pi fL$$

Reactance Formulas

$$\frac{N_P}{N_S} = \frac{E_P}{E_S} = \frac{I_S}{I_P} = \sqrt{\frac{Z_P}{Z_S}}$$

Transformer (step-up or step-down ratio)

$$Z = \sqrt{R^2 + X_L^2}$$

$$Z = \sqrt{R^2 + X_C^2}$$

$$Z = X_L - X_C$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \frac{V_A}{I}$$

Impedance Formulas (in series)

Note: RL in series

RC in series

LC in series

RLC in series

$$Z = \frac{RX_L}{\sqrt{R^2 + X_L^2}} \text{ (RL)} \qquad Z = \frac{V_A}{I_{LINE}}$$

$$Z = \frac{RX_C}{\sqrt{R^2 + X_C^2}} \text{ (RC)} \qquad V_A = V_L = V_C = V_R$$

$$Z = \frac{X_L X_C}{X_L - X_C} \text{ (LC)} \qquad V_A = I_{LINE} Z$$

$$Z = \frac{RX}{\sqrt{R^2 + X^2}} \text{ (RLC)}$$

Voltage and Impedance Formulas (parallel connection)

Frequently Asked Questions about Operational Amplifier Circuit

1. How do you make an op amp circuit?

2. What is amplifier with example?
Amplifiers are usually designed to function well in a specific application, for example: radio and television transmitters and receivers, high-fidelity ("hi-fi") stereo equipment, microcomputers and other digital equipment, and guitar and other instrument amplifiers.

3. Why do op amps have two inputs?
Operational amplifiers have two power supply rails because they usually need to swing bipolar - output voltages that go either positive or negative in response to the normal range of input signals. ... Without the dual supplies the output signal would clip at the ground potential.

4. Which type of amplifier is best?
Class “A” amplifiers are considered the best class of amplifier design due mainly to their excellent linearity, high gain and low signal distortion levels when designed correctly.

5. Are op amps AC or DC?
The basic Op-amp construction is of a 3-terminal device, with 2-inputs and 1-output, (excluding power connections). An Operational Amplifier operates from either a dual positive (+V) and an corresponding negative (-V) supply, or they can operate from a single DC supply voltage.

6. Can op amp amplify both AC and DC?
Infinite – An ideal operational amplifier has an infinite frequency response and can amplify any frequency signal from DC to the highest AC frequencies so it is therefore assumed to have an infinite bandwidth.

7. Do op amps work with DC?
In principle, yes, you can amplify DC with an op-amp, subject to the constraints of the amplifier. Mainly, the amplified output voltage must be between the output limits of the op-amp. ... (A fraction of the final output of the power supply is fed back to the op-amp's negative input to regulate the overall circuit.)

8. How do you amplify DC current?
A transistor can be used to increase current. You'll have a low current path, from base to emitter in an NPN,

and a higher current path from collector to emitter. The collector current will be a multiple of the base current if the circuit allows it.

9. What are the ideal characteristics of op amp?
Ideal op amps use no power, have infinite input impedance, unlimited gain-bandwidth and slew rate, no input bias current, and no input offset. They have unlimited voltage compliance.

10. What is slew rate of op amp?
Slew rate is defined as the maximum rate of change of an op amp's output voltage and is given units of volts per microsecond. Slew rate is measured by applying a large signal step, such as 1V, to the input of the op amp, and measuring the rate of change from 10% to 90% of the output signal's amplitude.