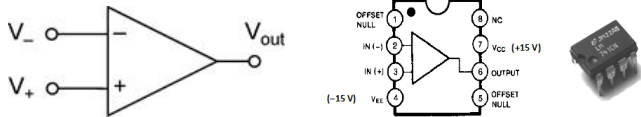


## BASICS OF OP-AMP (OPERATIONAL AMPLIFIER)

An operational amplifier (op-amp) is a type of electronic direct-coupled amplifier (also, an analog-linear integrated circuit or IC) that amplifies the difference between two input voltages. It is a high-gain voltage amplifier with a differential input, level shifter and a single-ended output. Initially, these amplifiers were used in mathematical operations, thus the term 'operational' is used. The  $\mu A741$  (in an 8-pin dual-in-line plastic package) is a popular general-purpose operational amplifier featuring offset-voltage null capability that has been widely used for over four decades.



### PROPERTIES AND CHARACTERISTICS —

Op-amps have

- High gain: very high voltage gain, typically in the range of  $10^5$  to  $10^8$ .
- High input impedance: very high input impedance, typically in the range of  $10^6$  to  $10^{12}$  ohms.
- Low output impedance: very low output impedance, typically in the range of 10 to 100 ohms.
- Differential input: two input terminals, one inverting and one non-inverting, that amplify the difference between the two input voltages.
- Single-ended output: single output terminal that produces an amplified version of the input voltage difference.
- Linear operation: operate linearly over a wide range of input voltages.
- High bandwidth: high bandwidth, typically in the range of 1 MHz to 100 MHz.

### IDEAL OP-AMP —

The ideal op-amp is a theoretical model that exhibits seven key characteristics: infinite open-loop voltage gain, infinite input impedance, zero output impedance, zero noise contribution, zero DC output offset, infinite bandwidth, and differential inputs that remain at the same potential. Understanding these properties is essential for the design and analysis of a wide range of practical circuits..

### OP-AMP CIRCUIT TYPES —

**INVERTING** amplifiers are commonly used for voltage amplification and signal inversion. They amplify the input signal and invert its phase.

**NON-INVERTING** amplifiers are used for voltage amplification and maintaining the phase of the input signal. They amplify the input signal and maintain its phase.

**SUMMING** amplifiers are used to add multiple input signals and amplify the result. They add the input signals and amplify the result.

**DIFFERENCE** amplifiers are used to amplify the difference between two input signals. They amplify the difference between the input signals.

Integrators and differentiators are used for time-domain signal processing, such as low-pass filtering and differentiation. **INTEGRATORS** convert a voltage input to a current output over time. **DIFFERENTIATORS** convert a current input to a voltage output over time.

An instrumentation amplifier is a differential voltage-gain amplifier that has a primary function of amplifying small signals. It is composed of three internal op-amps and a few internal components. An op-amp can also be configured to be a constant-current source or a current-to-voltage converter. A log amplifier is an op-amp configuration in which its output voltage is proportional to the logarithm of

its input current. It is usually used for signal compression applications.

### SCHMATIC DIAGRAMS AND FORMULAE –

Amplifier	Schematic Diagram	Formula
Inverting		$V_{out} = -\frac{R_f}{R_{in}} V_{in}$ $A_V = \frac{V_{out}}{V_{in}} = -\frac{R_f}{R_{in}}$ $\frac{dV_{in}}{dI_{in}} = R_{in}$
Non-inverting		$V_{out} = \left(1 + \frac{R_f}{R_{in}}\right) V_{in}$ $A_V = \frac{V_{out}}{V_{in}} = 1 + \frac{R_f}{R_{in}}$ $\frac{dV_{in}}{dI_{in}} \rightarrow \infty$
Summing		$V_{out} = A_1 V_{in1} + A_2 V_{in2} + A_3 V_{in3} + \dots$ <p style="font-size: small;">the gain of the nth input : <math>A_n = \frac{dV_{out}}{dV_{in}} = -\frac{R_f}{R_{in}}</math>                      the impedance of the nth input : <math>Z_{in} = \frac{dV_{in}}{dI_{in}} = R_{in}</math></p>
Difference		$V_{out} = \frac{R_2}{R_1} (V_{in1} - V_{in2})$ <p style="font-size: small;">the gain for <math>V_{in1}</math> : <math>A_{V1} = \frac{dV_{out}}{dV_{in1}} = +\frac{R_2}{R_1}</math>                      the gain for <math>V_{in2}</math> : <math>A_{V2} = \frac{dV_{out}}{dV_{in2}} = -\frac{R_2}{R_1}</math></p>
Integrator		$V_{out}(\omega) = \frac{j}{\omega R_{in} C_f} V_{in}(\omega)$ $ V_{out}(\omega)  = \frac{1}{\omega R_{in} C_f}  V_{in}(\omega) $ $V_{out}(t) = -\frac{1}{R_{in} C_f} \int V_{in}(t) dt$ $A_V(\omega) = \frac{V_{out}}{V_{in}} = \frac{j}{\omega R_{in} C_f}$ $ A_V(\omega)  = \left  \frac{V_{out}}{V_{in}} \right  = \frac{1}{\omega R_{in} C_f}$ $\frac{dV_{in}}{dI_{in}} = R_{in}$
Differentiator		$V_{out}(\omega) = -j\omega R_f C_{in} V_{in}(\omega)$ $ V_{out}(\omega)  = -\omega R_f C_{in}  V_{in}(\omega) $ $V_{out}(t) = -R_f C_{in} \frac{dV_{in}(t)}{dt}$ $A_V(\omega) = \frac{V_{out}}{V_{in}} = -j\omega R_f C_{in}$ $ A_V(\omega)  = \left  \frac{V_{out}}{V_{in}} \right  = -\omega R_f C_{in}$ $\frac{dV_{in}}{dI_{in}} = \frac{1}{j\omega C_{in}}$

### OP-AMP APPLICATIONS —

Op-amps are used in a wide range of applications, including amplifiers, filters, signal conditioning, mathematical operations, and oscillators.

### CONCLUSION —

The ideal op-amp model is used as a reference for analyzing and designing op-amp circuits, but real op-amps have limitations and imperfections that must be taken into account in practical circuit design.