
Unit 2: Introduction to Operational Amplifiers

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based on Operational
Amplifiers and Linear
Integrated Circuits by
Coughlin & Driscoll

Analog and Digital Systems

The first op-amps were used for performing operations in an analog environment:

- addition and subtraction
- multiplication and division
- integration and differentiation.

These operations are now performed with greater speed, accuracy, and versatility within a digital environment.

Did this do the op-amp in?

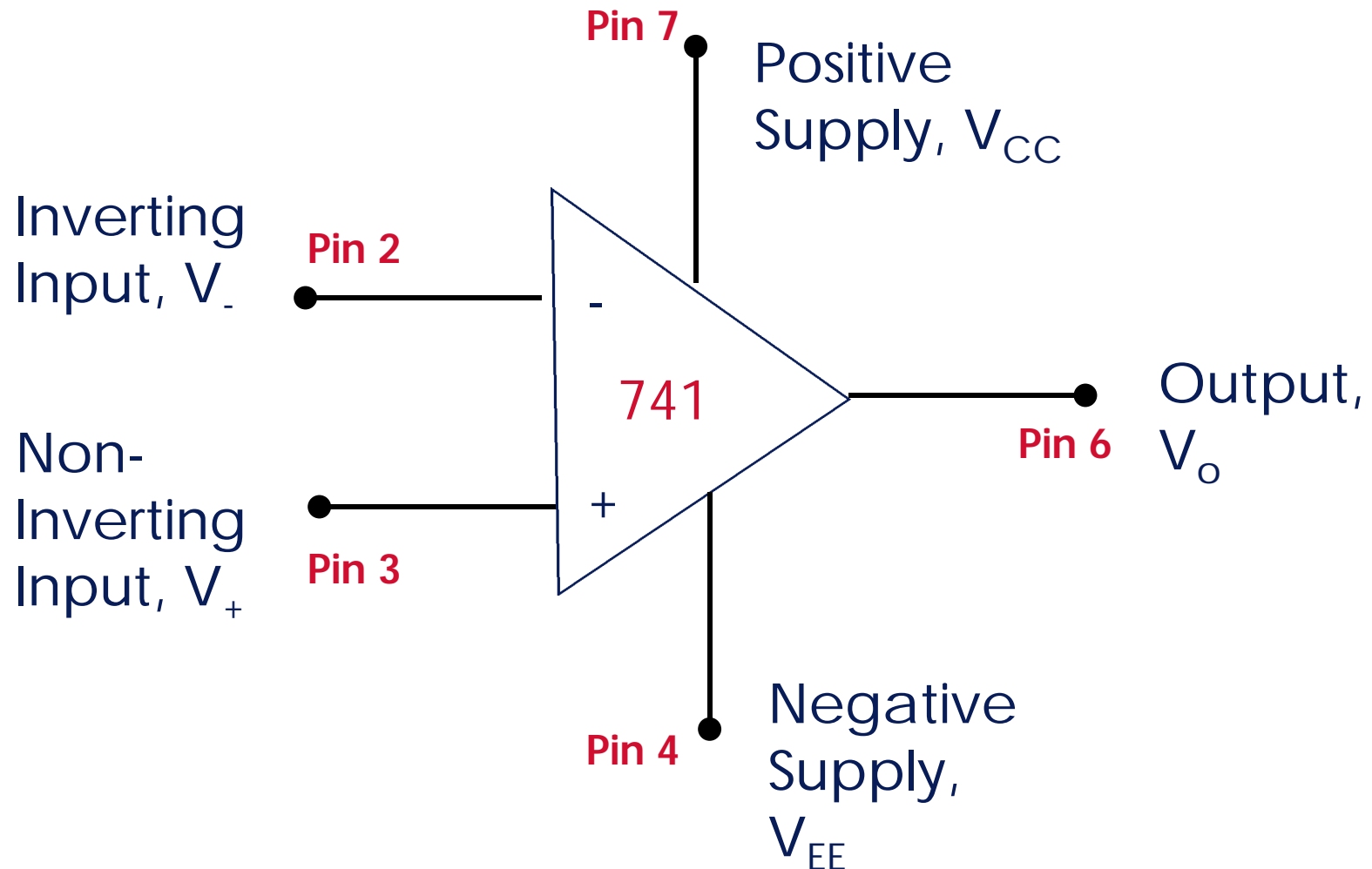
Current Op-Amp Applications

“As more digital systems are created for data acquisition and process control, more interface circuits using op-amps and other linear integrated circuits are also required.” C&D, p. 2.

Op-Amp Applications

- signal conditioning**
- A/D and D/A conversion**
- filters**
- oscillators And much more.**

Circuit Symbol and Terminals



Internal Op-Amp Circuitry (see figure 1-3 or handout)

Input Stage - Differential Amplifier

→ Its characteristics are very high input impedance and large voltage gain.

Intermediate Stage - Level Shifter

→ Output of the differential amplifier is directly coupled to the intermediate stage. Its function is to pass the signal unaltered while shifting its dc voltage level to a value required to bias the output stage.

Internal Op-Amp Circuitry (cont.)

Output Stage - Push-Pull Amplifier

- A pnp-npn push-pull amplifier configuration is used as the output stage. This gives the op-amp its characteristic low output impedance.

Packaging and Pinouts

- Packaging: see figure 1-4
- Pinouts: see figure 1-5

Breadboarding Suggestions : read 1-6.2

Op-Amp Terminals

(see figure 2-1 or handout)

power supply terminals: $+V$ and $-V$

output terminal: V_o

input terminals: V_+ and V_-

input resistance: R_{in}

output resistance: R_o

input bias currents: I_+ and I_-

differential voltage: $E_d = V_+ - V_-$

Open Loop Voltage Gain

A_{ol} , the open loop voltage gain, is the voltage gain supplied when there is no negative feedback from output back to input.

General Amplifier Equation: $V_o = A_v V_{in}$

Operational Amplifier Equation:
 $V_o = A_{ol} E_d$

Typical vs. Ideal Values

The table below compares some typical values for an operational amplifier along with the ideal values.

Description	Typical Value	Ideal Value
Open loop gain	200,000	Infinite
Input resistance	2 MΩ	Infinite, open circuit
Input bias currents	80 nA	0 A
Input offset voltage	1 mV	0 V

Significance of Real versus Ideal Value

The input offset voltage, V_{os} , is a characteristic of the real op-amp.

Input offset does not occur in the ideal device because the differential amplifier in the input stage is made from perfectly matched transistors.

Any mismatch in the differential amplifier results in an input offset.

Effect of Offset Voltage

Consider that both inputs are equal, so that $E_d=0$.

→ Ideally, $V_o = A_{ol} E_d = 0$.

→ In reality, the input offset voltage is also amplified so that

$$V_o = A_{ol} V_{os} = 200,000 (1\text{mV}) = 200\text{V} !$$

Even with no input, the output is driven to its highest possible value as limited by the power supply of the circuit.

The Limits

The output voltage can never exceed the power supply voltages. See fig. 2-3.

→ In a real op amp, the output is usually limited to a value slightly less than the power supply voltage due to internal voltage drops. See internal circuitry.

→ Saturation voltages are specified on the manufacturer's data sheet.

→ For a 741 Op-Amp using +/- 15V supplies:

$$\gg +V_{\text{sat}} = 14\text{V} \quad \text{and} \quad -V_{\text{sat}} = -13\text{V}$$

Open Loop Applications

Zero-Crossing Detector - fig. 2-4

Positive Voltage Level Detector - fig. 2-5

Negative Voltage Level Detector - fig. 2-6

Typical Applications of Voltage-Level Detectors

→see sections 2-5, 2-7, and 2-8

→discuss

The End

Read

→chapter 3, C & D

HW

→Consider figures 2-4, 2-5, and 2-6 and how you would implement them on Multisim.

Lab Activity

→Test for existence of offset.

→Construct variety of op amp level detectors.