

LECTURE 4. OPERATIONAL AMPLIFIERS

REVIEW OF SYMBOLS



Power, either positive or negative



Grounds

1. Operational amplifiers (op-amps) are active devices. This means you must connect them to a power supply in order for them to work. Usually a dual supply, positive and negative supply.
2. Op-amps come in many packages. They can be purchased in single, dual, and four op-amps per unit. They can be mounted in a metal case or encapsulated in plastic.
3. Op-amps come in many varieties

Low power	Comparators	Power Amplifiers
Precision	Audio amps	Low Noise
Video amps	Differential	Instrumentation
4. You should be able to work with an op-amp without knowing what is inside.

BASIC CHARACTERISTICS

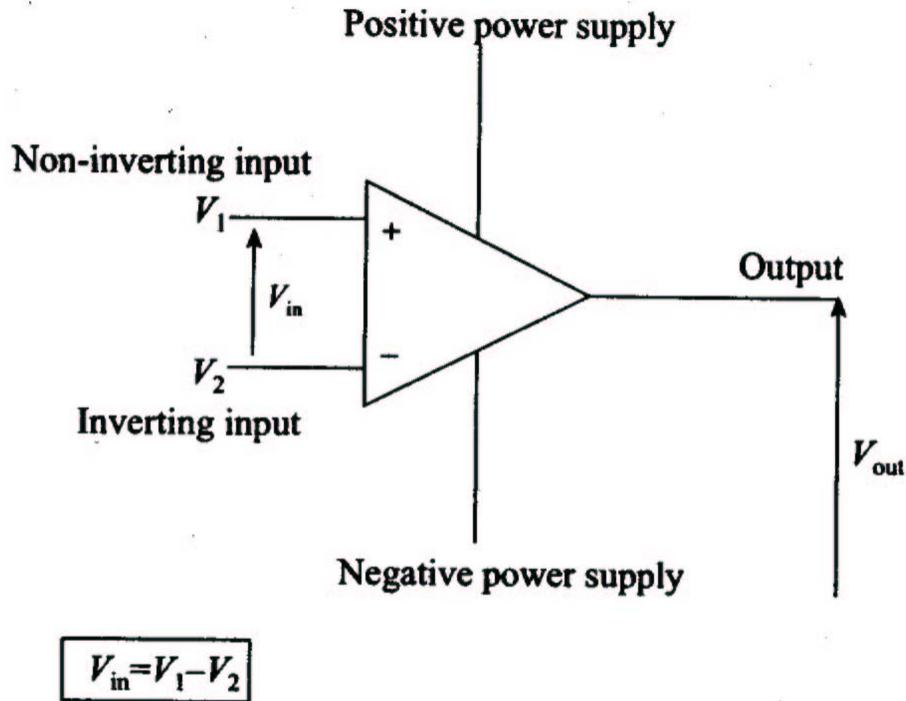


Figure 3.1

BASIC OP-AMP CIRCUIT DIAGRAM, OPEN LOOP

The following concepts pertain to ideal op-amps, which are used to make circuit analyses easier.

1. The open loop gain of the op-amp is considered to be infinity.
($A_{VOL} \approx \infty$)
2. The input resistance is considered to be infinity. The resistance between the + and - terminals.
($R_{IN} \approx \infty$)
3. The output resistance is considered to be zero ohms.
($R_{OUT} \approx 0$ ohms)
4. The potential difference between the two input pins is considered to be zero volts.
($V_{IN} = V_2 - V_1 \approx 0$ volts)
5. No current flows into the op-amp.

In lab you will be using the LM741C op-amp. It is one of the most popular because of its high voltage gain and is relatively inexpensive.



August 2000

LM741 Operational Amplifier

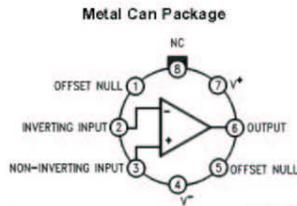
General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications. The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0°C to +70°C temperature range, instead of -55°C to +125°C.

LM741 Operational Amplifier

Connection Diagrams

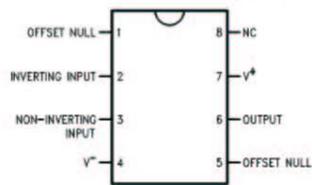


DS009341-2

Note 1: LM741H is available per JM38510/10101

Order Number LM741H, LM741H/883 (Note 1),
LM741AH/883 or LM741CH
See NS Package Number H08C

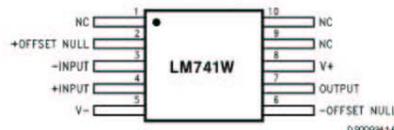
Dual-In-Line or S.O. Package



DS009341-3

Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

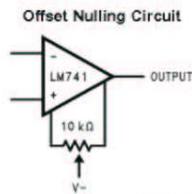
Ceramic Flatpak



DS009341-6

Order Number LM741W/883
See NS Package Number W10A

Typical Application



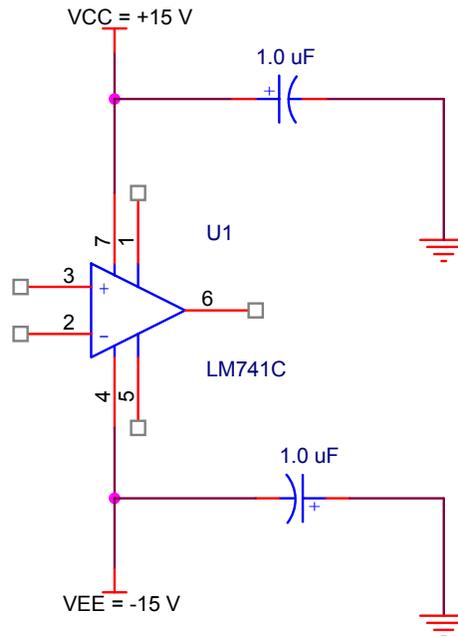
DS009341-7

The main items of interest in an op-amp is that there are two input terminals, one labeled + and one labeled -. The plus sign indicates the non-inverting input pin. Non-inverting input means that if you measure the output signal and compare it

to the input signal, the two signals would be in phase with one another. The minus sign indicates the inverting input. Comparing the input at the inverting terminal with the output you would see that the output is 180 degrees out of phase. If there was an input at both the + and – terminals, the voltage difference measured between them would be zero volts.

There is one output terminal. There are two power supply connections, one for positive voltage and one for negative. Typically, op-amps are powered with a dual supply.

One word of caution, due to the device physics of the construction of an op-amp, it is possible to have a high frequency (>10MHz) at the output without you having done anything wrong. This is caused by the power supply connections to the op-amp. How you fix this is to connect shunt bypass capacitors at each power connection and ground. See the figure below.



OP-AMP WITH BY PASSED POWER CONNECTIONS

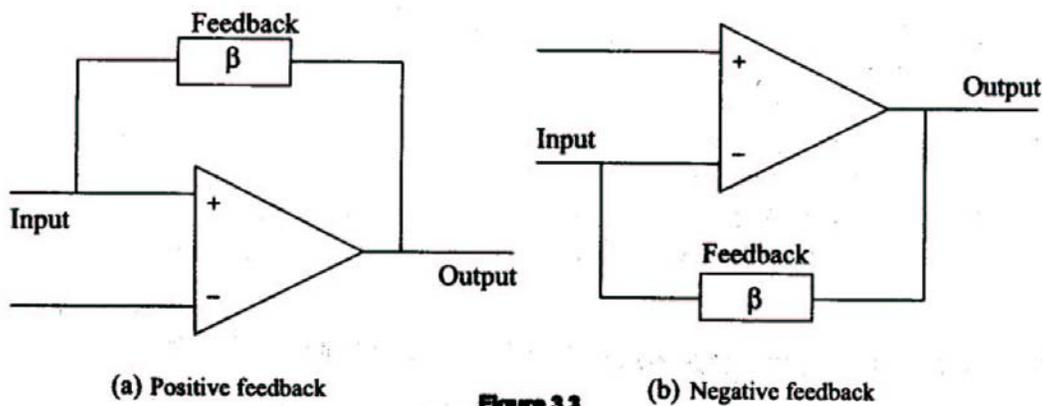
Take note that the capacitors are polarized. The plus terminal must be connected to the higher potential. These capacitors are usually made from tantalum and are ideal for noise bypass situations. While it is intuitive to connect the plus terminal to pin 7 and the other pin to ground, it is not so with the negative supply. If you look at a number line you would agree that -15 is smaller than 0. Likewise, from a potential perspective, -15 volts is less than 0 volts. Since a polarized capacitor must have the positive lead connected to the higher potential source, on the negative supply connection the positive capacitor lead is connected to ground and the negative capacitor lead is connected to pin 4.

FEEDBACK

Feedback occurs when the output of the op-amp is connected to the input. There are two different types of feedback, positive and negative. Circuits using positive feedback generally have unstable states, unpredictable parameters, and are usually oscillators or electronic switches. Positive feedback adds to the input signal and usually results in an output signal that is larger than it would have been without the feedback connection.

Circuits using negative feedback are usually stable, predictable, linear circuits with a well defined parameters and characteristics. Negative feedback subtracts from the input signal and results in an output signal that is smaller than it would have been without the feedback connection.

Below is an example of both positive and negative feedback.

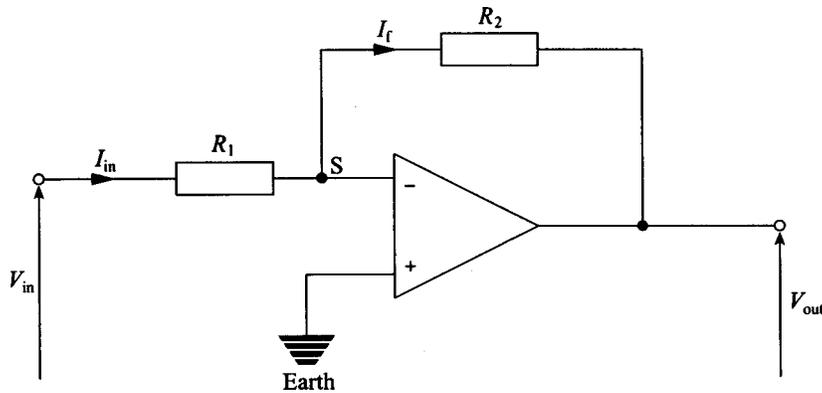


POSITIVE AND NEGATIVE FEEDBACK

OP-AMP CIRCUITS

- Inverting Amplifier
- Non-Inverting Amplifier
- Buffer or Voltage Follower Amplifier
- Summing Inverting Amplifier
- Differentiator
- Integrator
- Filter

INVERTING AMPLIFIER, IDEAL



Since $R_{INT} \approx \infty$, no current flows between the non-inverting and inverting terminals. If no current flows, there is no voltage drop, $V=IR$. Since the non-inverting terminal is connected to ground, 0V, we can say the inverting terminal, point S, is at 0V due to a virtual ground effect.

No current flows into the op-amp, therefore

$$I_{IN} = I_F$$

$$\begin{aligned} I_{IN} &= \frac{V_{IN} - 0}{R_1} \\ &= \frac{V_{IN}}{R_1} \end{aligned}$$

$$\begin{aligned} I_F &= \frac{0 - V_{OUT}}{R_2} \\ &= -\frac{V_{OUT}}{R_2} \end{aligned}$$

Equating these two expressions we get

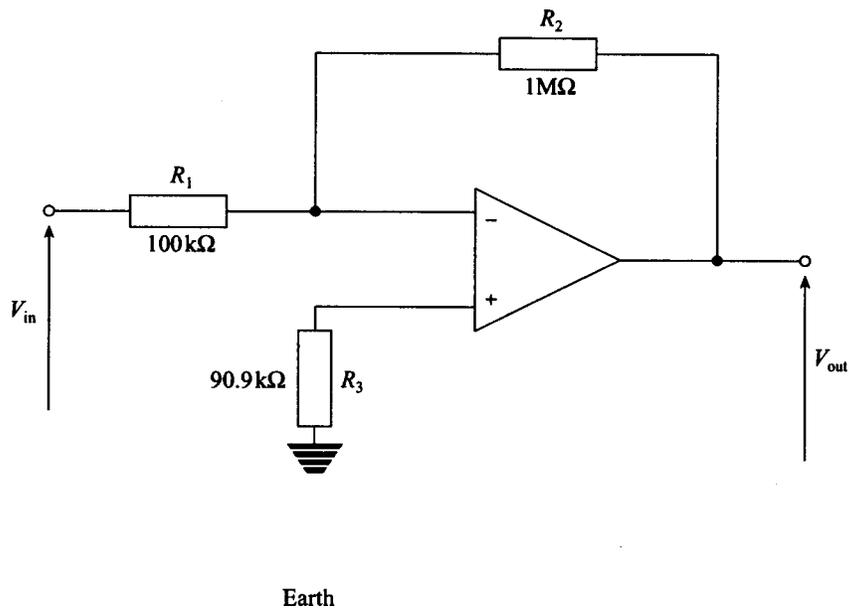
$$\frac{V_{IN}}{R_1} = -\frac{V_{OUT}}{R_2}$$

$$\frac{V_{OUT}}{V_{IN}} = -\frac{R_2}{R_1}$$

Transfer Function

$$A_V = -\frac{R_2}{R_1}$$

INVERTING OP-AMP, PRACTICAL

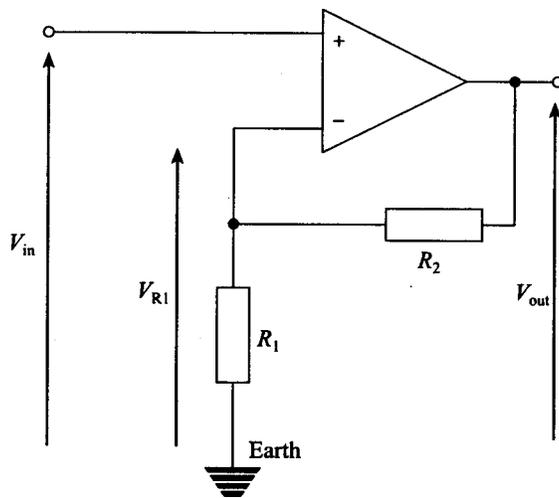


In this circuit notice a resistor, R_3 , is connected between the non-inverting terminal and ground. This is because, despite the ideal characteristics we use for analysis, there is indeed a small current flowing between the non-inverting and inverting terminals. In order to negate this voltage, a resistor is chosen to connect the non-inverting terminal to ground, producing a voltage at the non-inverting terminal equal to the one at the inverting terminal. If there is no

potential difference between these two points then no current can flow. If no current flows then the potential at the inverting terminal is considered to be zero volts, as in our original analysis. The value of R_3 is equal to the parallel value of R_1 and R_2 .

$$R_3 = \frac{R_1 R_2}{R_1 + R_2}$$

NON-INVERTING AMPLIFIER



By virtue of the fact no current flows between the non-inverting and inverting terminals, there is almost no potential difference, we can say

$$V_{IN} = V_{R1}$$

V_{R1} is the output of the potential divider formed by R_2 , R_1 , V_{OUT} , and ground.

$$V_{R1} = V_{OUT} \left(\frac{R_1}{R_1 + R_2} \right)$$

Equating the two expressions gives

$$V_{IN} = V_{OUT} \left(\frac{R_1}{R_1 + R_2} \right)$$

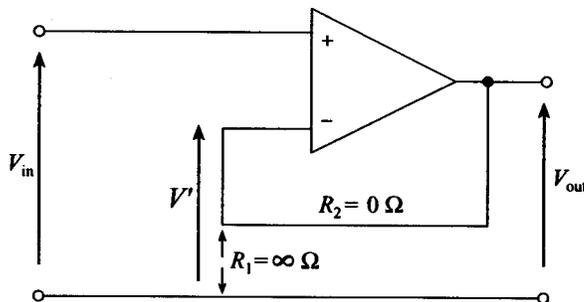
$$\frac{V_{OUT}}{V_{IN}} = \frac{R_1 + R_2}{R_1}$$

$$A_v = \frac{R_1 + R_2}{R_1} = \frac{R_1}{R_1} + \frac{R_2}{R_1}$$

$$= 1 + \frac{R_2}{R_1}$$

If we wanted a voltage gain of 1 we would reduce R_2 to zero and increase R_1 to ∞ . R_2 becomes a short circuit and R_1 is an open circuit.

VOLTAGE FOLLOWER OR BUFFER AMPLIFIER



$$V_{IN} = V' = V_{OUT}$$

$$V_{IN} = V_{OUT}$$

$$A_v = 1$$

Buffers are used where circuits need to be connected together and the output resistance of one circuit does not equal the input resistance of another circuit.