Penguat Umpan Balik Negatif

Elektronika

(TKE 4012)

Eka Maulana

maulana.lecture.ub.ac.id

Amplifier possibilities

- The input can be a voltage.
- The input can be a current.
- The output can be a voltage.
- The output can be a current.
- The total number of combinations is four.

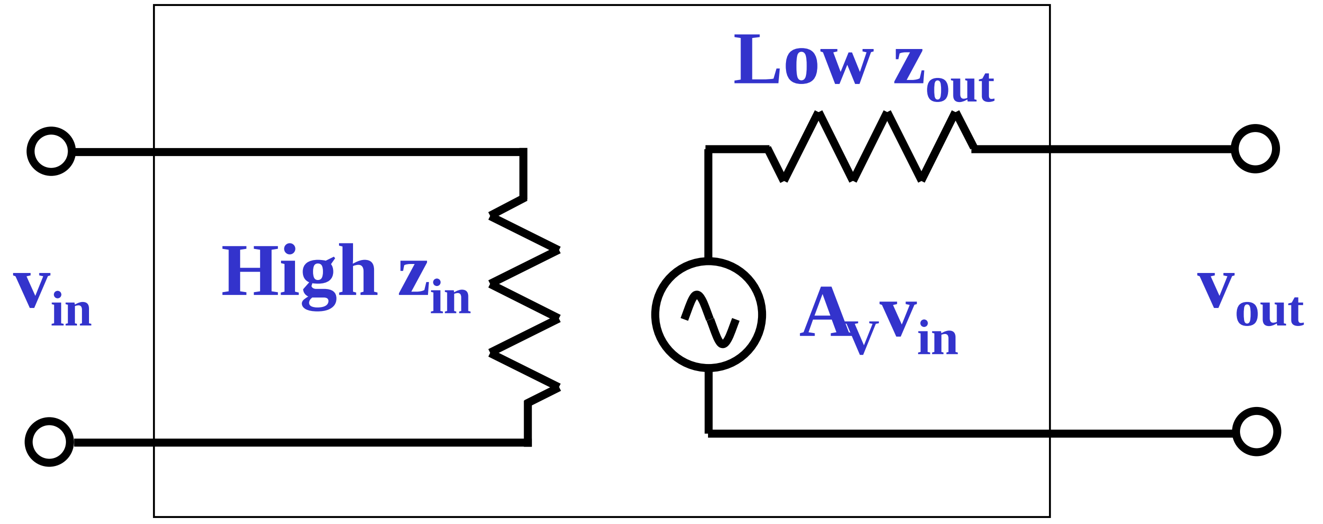
Four types of negative feedback

- Voltage-controlled voltage source (VCVS) (ideal voltage amplifier)
- Current-controlled voltage source (ICVS) (transresistance amplifier)
- Voltage-controlled current source (VCIS) (transconductance amplifier)
- Current-controlled current source (ICIS) (ideal current amplifier)

Converters

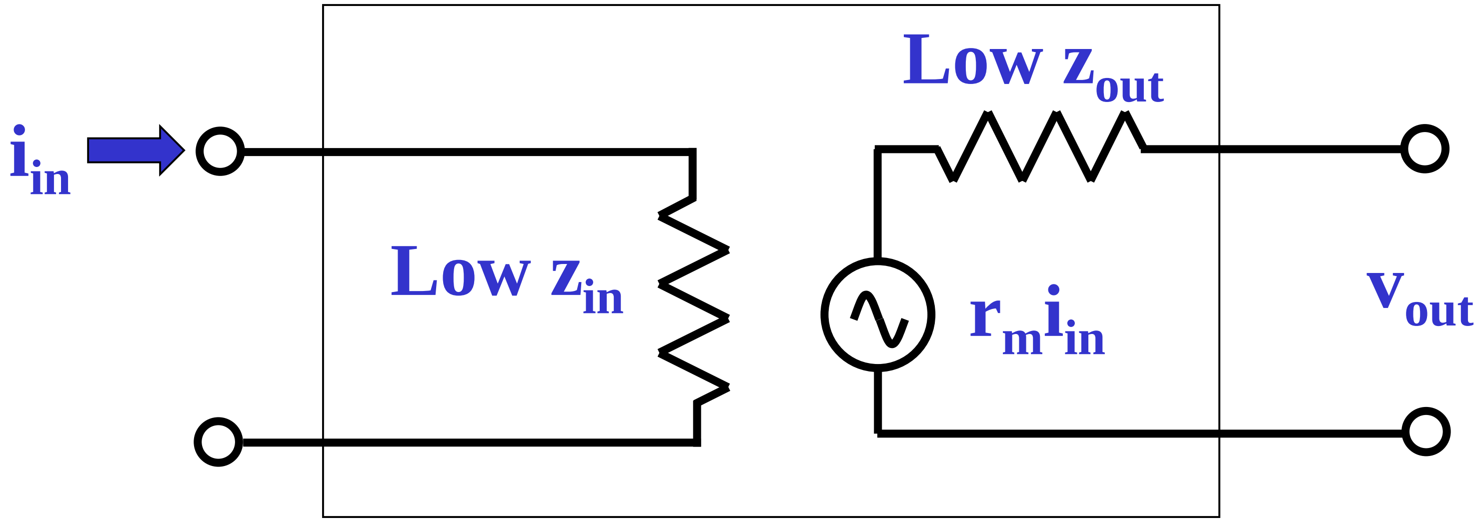
- **VCIS and ICVS amplifiers can be viewed as converters.**
- **The VCIS is often called a voltage-to-current converter.**
- **The ICVS is often called a current-to-voltage converter.**

VCVS equivalent circuit



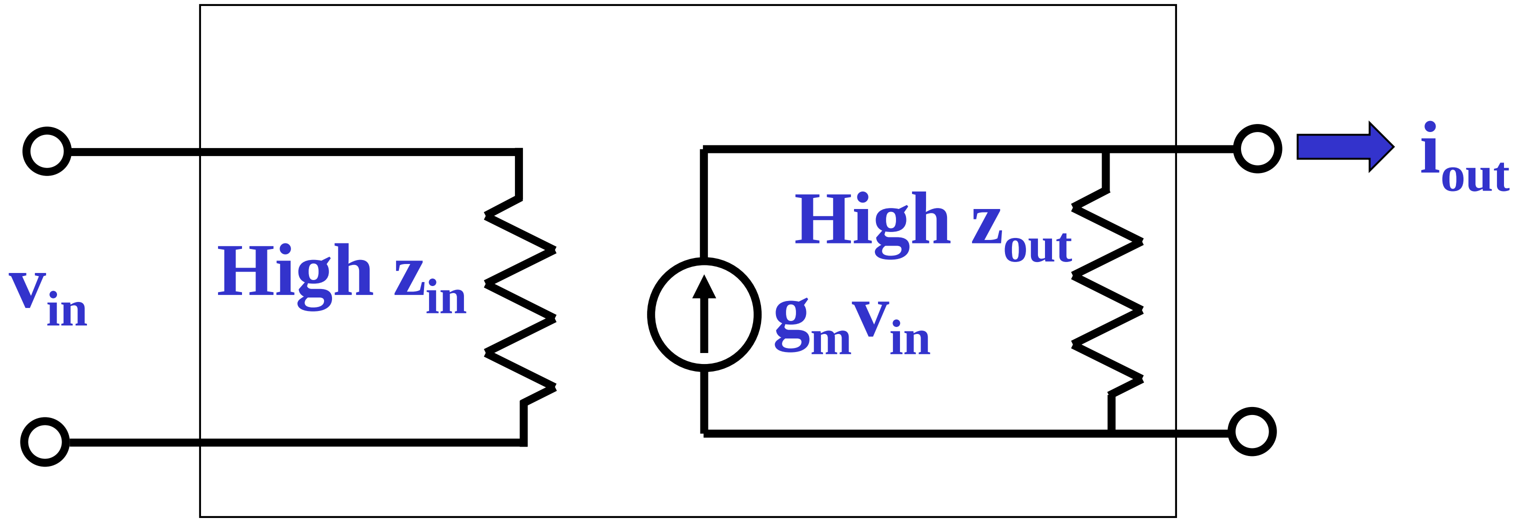
The input impedance is very high and the output impedance is very low. It approaches the ideal voltage amplifier.

ICVS equivalent circuit



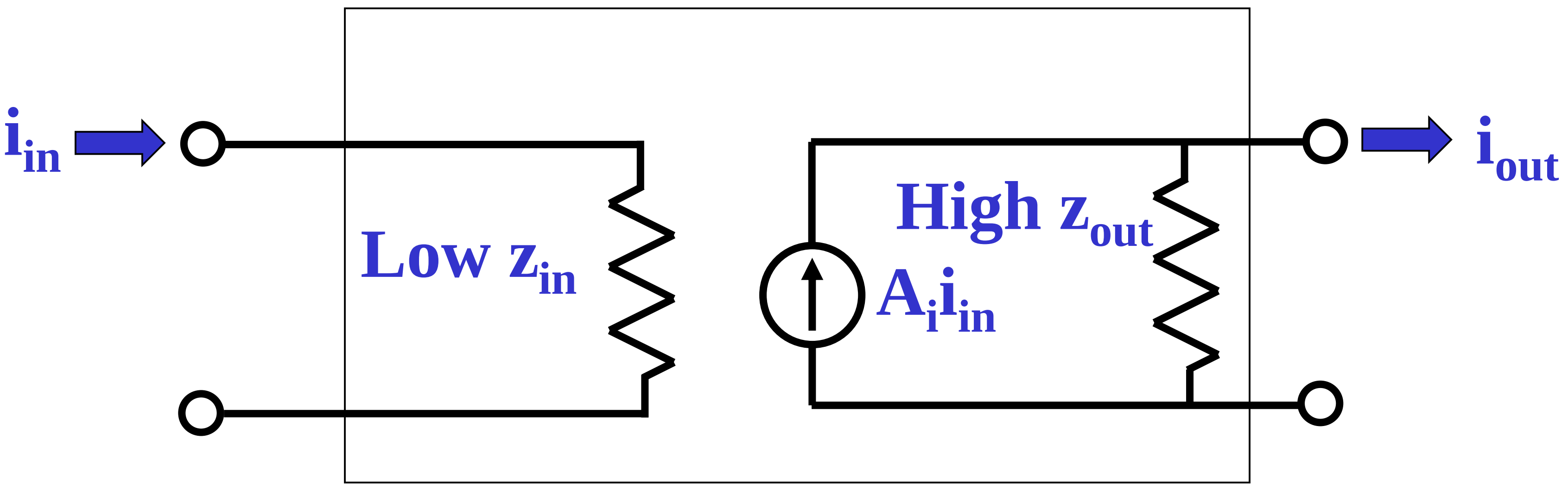
The input impedance is very low and the output impedance is very low.
It is well suited for converting a current into a voltage (r_m is the *transresistance*).

VCIS equivalent circuit



The input impedance is very high and the output impedance is very high. It is well suited for converting a voltage into a current (g_m is the *transconductance*).

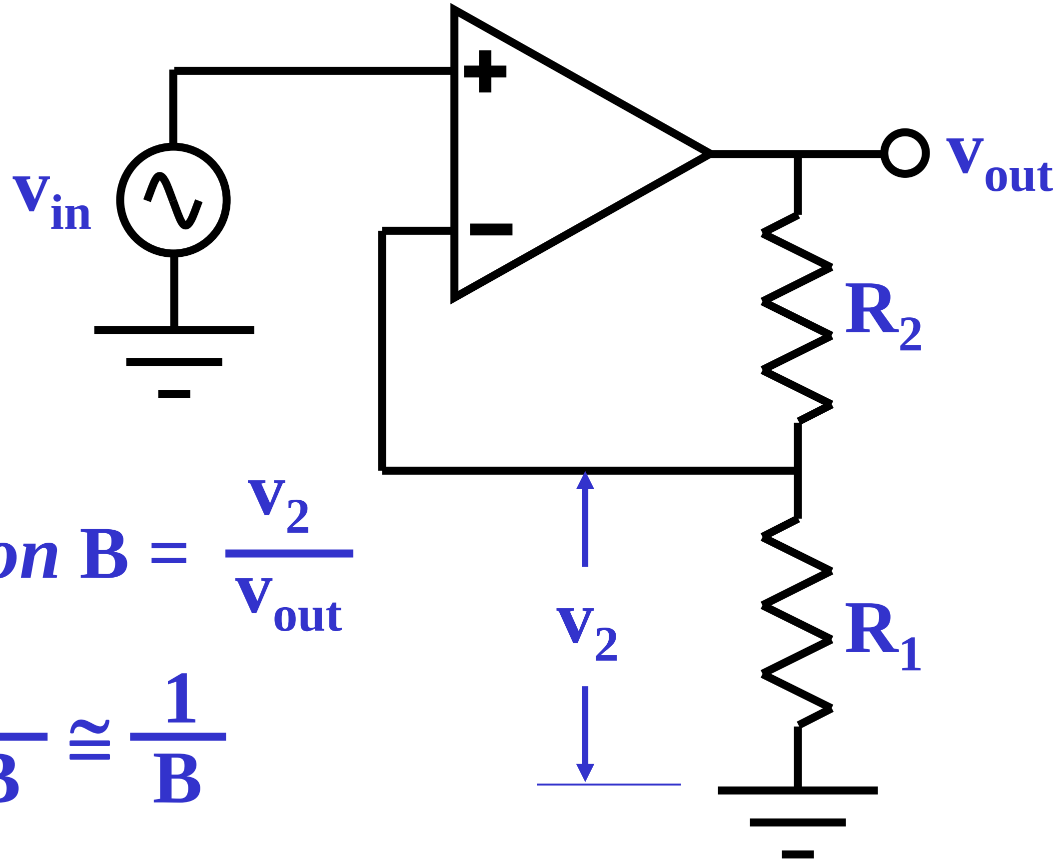
ICIS equivalent circuit



The input impedance is very low and the output impedance is very high. It approaches the ideal current amplifier.

The noninverting circuit is a VCVS amplifier.

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



The *feedback fraction* B = $\frac{v_2}{v_{out}}$

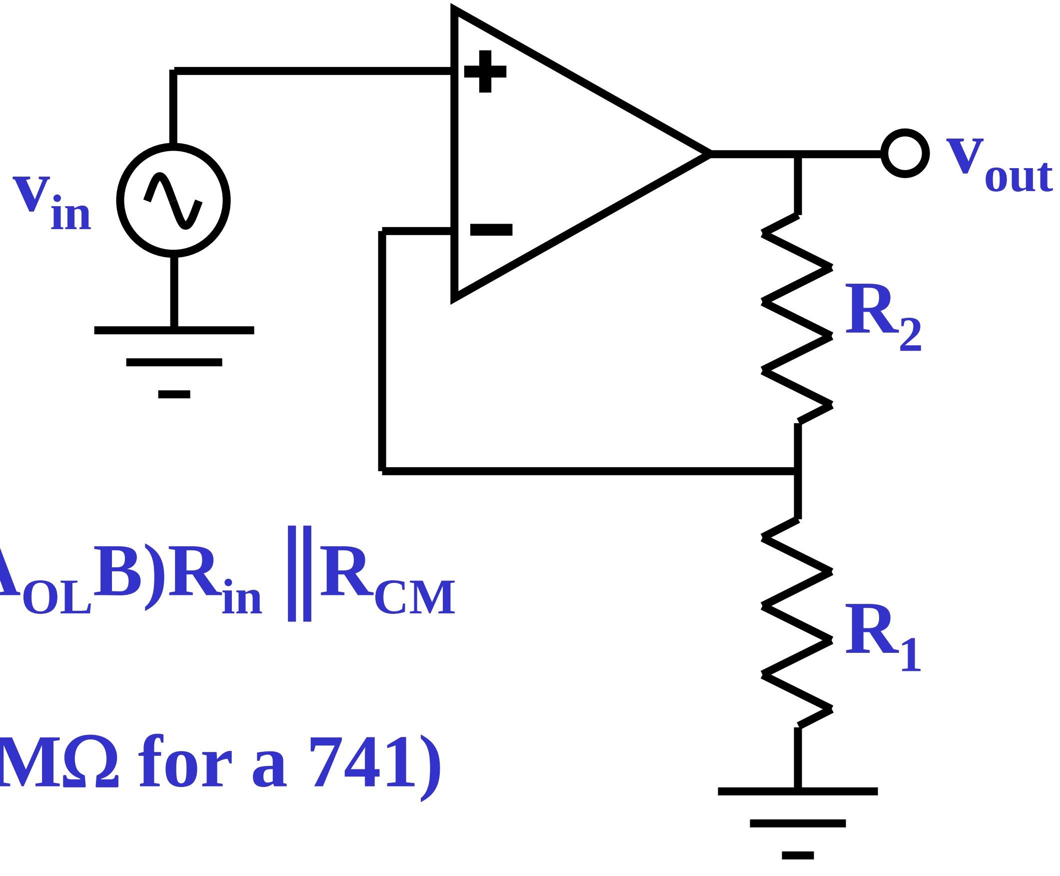
$$A_{CL} = \frac{A_{OL}}{1 + A_{OL}B} \cong \frac{1}{B}$$

The term $A_{OL}B$ is called the *loop gain* and is normally much greater than 1.

The loop gain is usually very large which provides:

- Gain stability
- Low distortion
- Low offsets
- Near ideal input impedance
- Near ideal output impedance

Input impedance of the noninverting amplifier



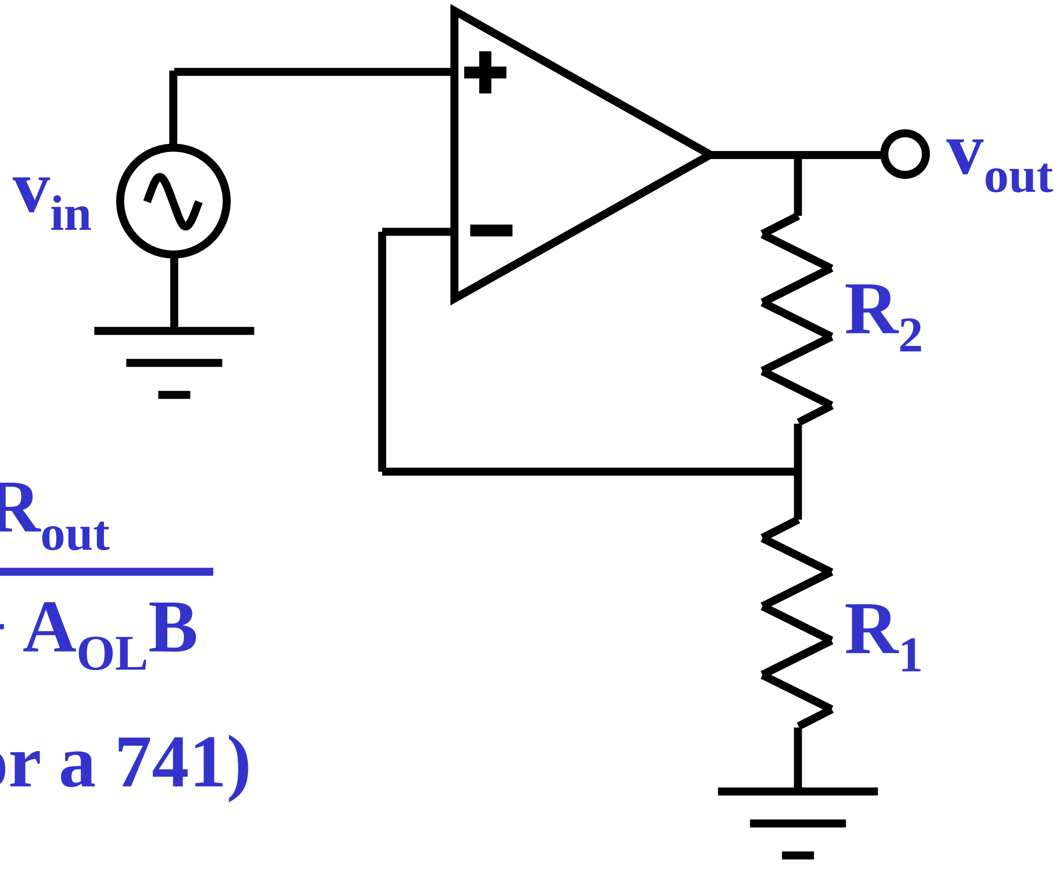
$$z_{in(CL)} = (1+A_{OL}B)R_{in} \parallel R_{CM}$$

(R_{CM} > 100 MΩ for a 741)

R_{in} = the open-loop input resistance of the op amp

R_{CM} = the common-mode input resistance of the op amp

Output impedance of the noninverting amplifier



$$z_{out(CL)} = \frac{R_{out}}{1 + A_{OL}B}$$

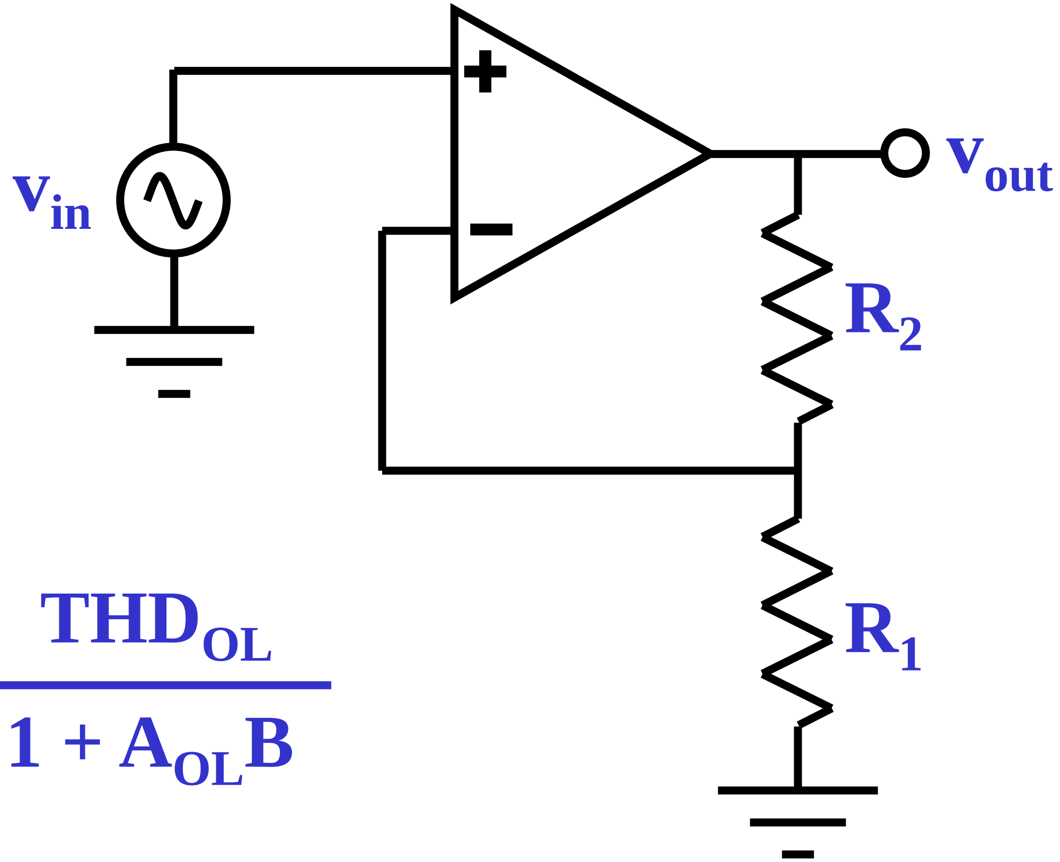
(R_{out} = 75 Ω for a 741)

R_{out} = the open-loop output resistance of the op amp

Distortion

- A sine wave has only one frequency called the fundamental.
- An amplifier with distortion adds energy at new frequencies called harmonics.
- Total harmonic distortion (THD) is the percentage of harmonic voltage in the output signal.
- THD = (Total harmonic voltage/fundamental voltage) x 100%

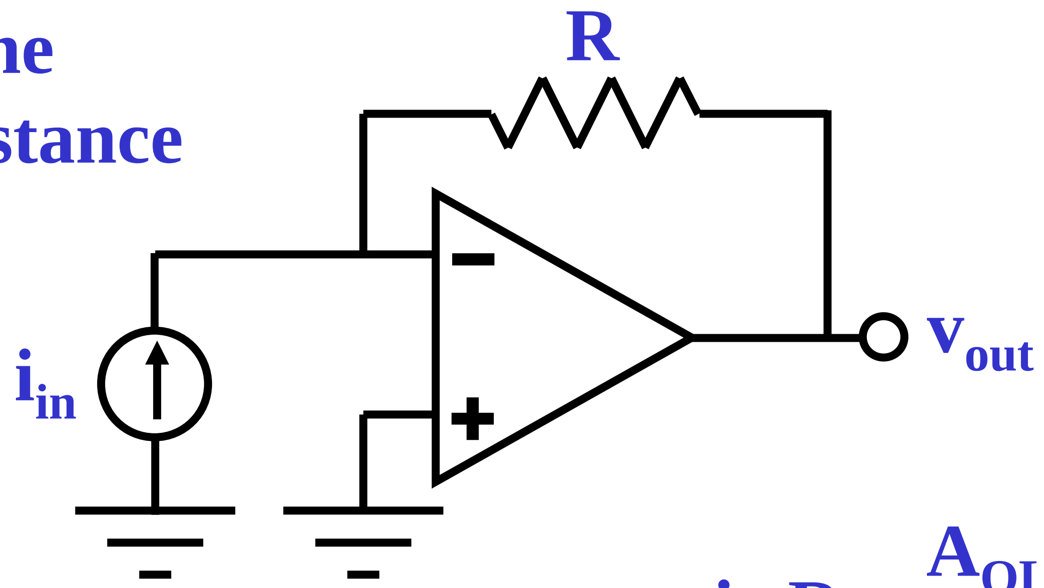
THD of the noninverting amplifier



$$THD_{CL} = \frac{THD_{OL}}{1 + A_{OL}B}$$

The ICVS amplifier

R is the transresistance

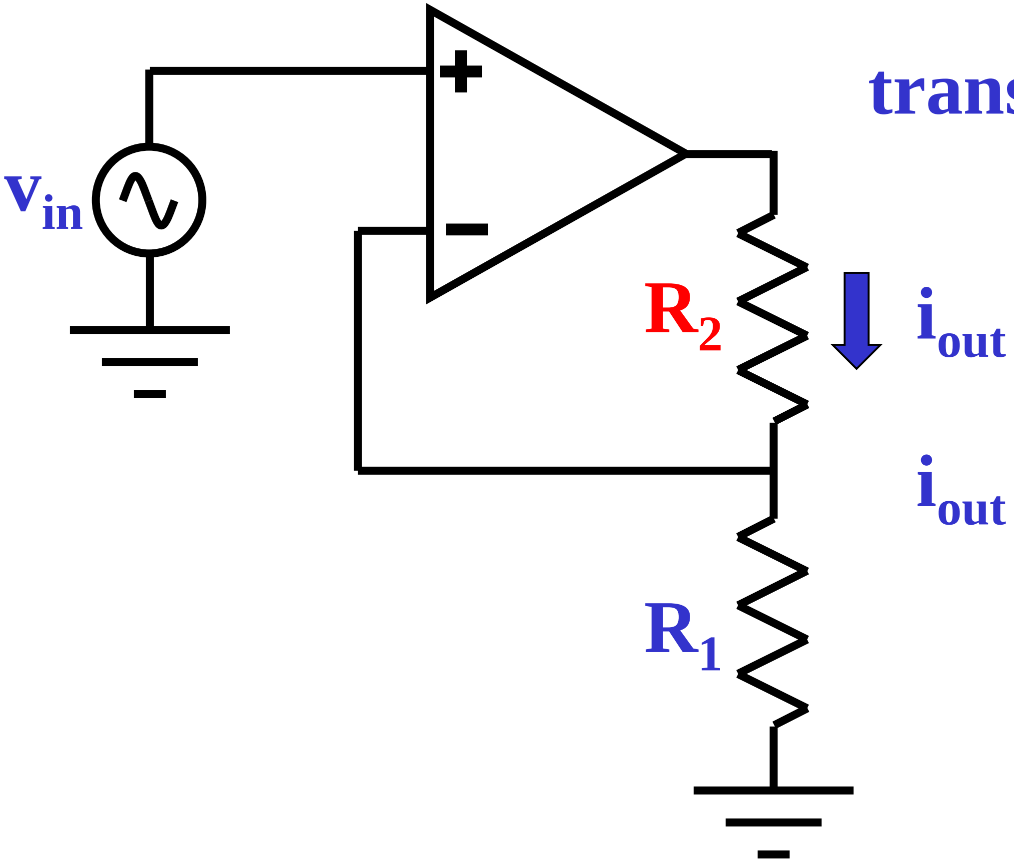


$$v_{out} = i_{in} R \frac{A_{OL}}{1 + A_{OL}} \cong i_{in} R$$

$$z_{in(CL)} = \frac{R}{1 + A_{OL}}$$

$$z_{out(CL)} = \frac{R_{out}}{1 + A_{OL}}$$

The VCIS amplifier



transconductance: $g_m = \dfrac{1}{R_1}$

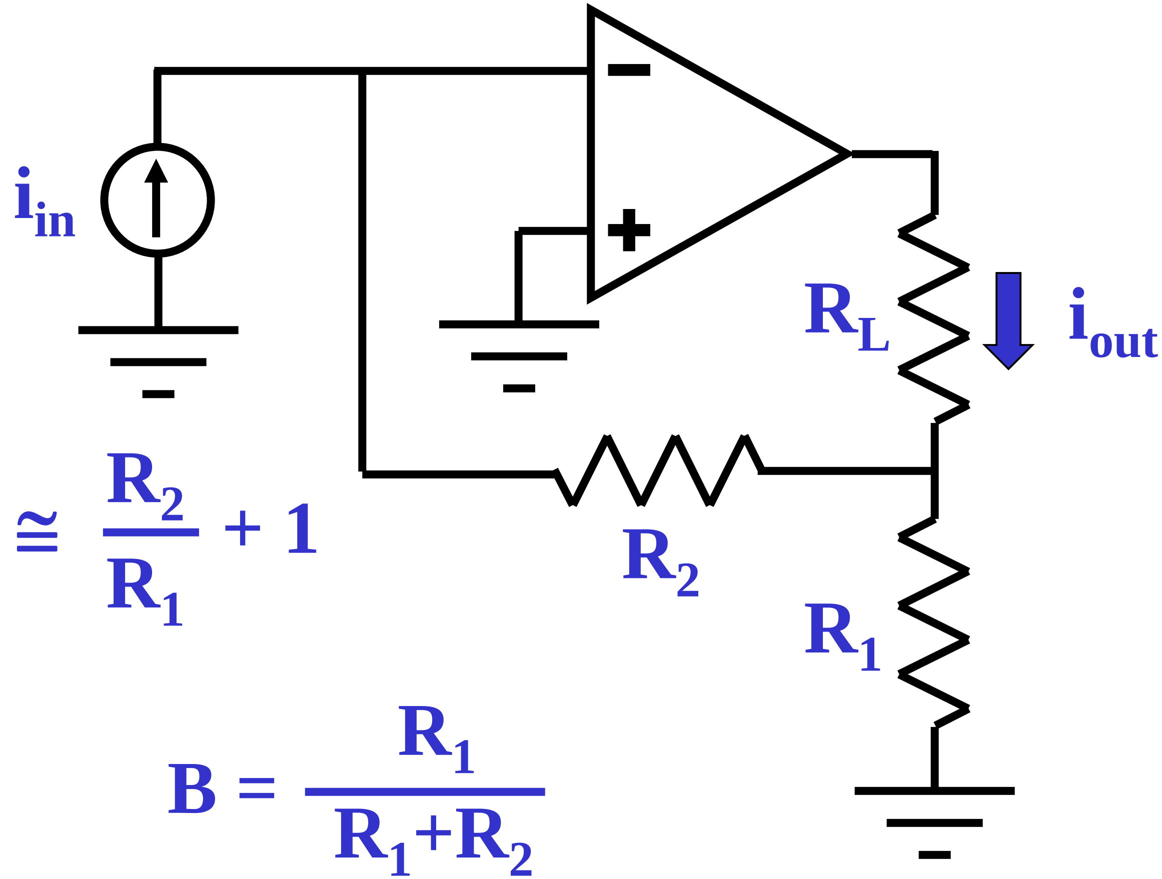
R_2 is the load

$$i_{out} = \frac{v_{in}}{R_1 + \dfrac{R_1 + R_2}{A_{OL}}} \cong \frac{v_{in}}{R_1}$$

$$i_{out} = g_m v_{in}$$

$$z_{in(CL)} = (1 + A_{OL}B)R_{in} \qquad z_{out(CL)} = (1 + A_{OL})R_1$$

The ICIS amplifier



$$A_i = \frac{A_{OL}(R_1+R_2)}{R_L+A_{OL}R_1} \cong \frac{R_2}{R_1} + 1$$

$$z_{in(CL)} = \frac{R_2}{1+A_{OL}B} \qquad B = \frac{R_1}{R_1+R_2}$$

$$z_{out(CL)} = (1+A_{OL})R_1$$

VCVS bandwidth

- Negative feedback increases the bandwidth of an amplifier.
- Less voltage is fed back at the higher frequencies due to rolloff which effectively increases the input signal.
- An equation for closed-loop bandwidth:

$$f_{2(CL)} = (1+A_{OL}B)f_{2(OL)}$$

- The gain-bandwidth product is constant:

$$A_{CL}f_{2(CL)} = f_{unity}$$

Slew-rate distortion

- **Negative feedback has no effect.**
- **The op amp is not acting in the linear mode so the feedback doesn't help.**
- **Even though the small-signal bandwidth might be adequate, the power bandwidth might not.**
- **Independent calculations of both bandwidths are required to ensure adequate performance.**