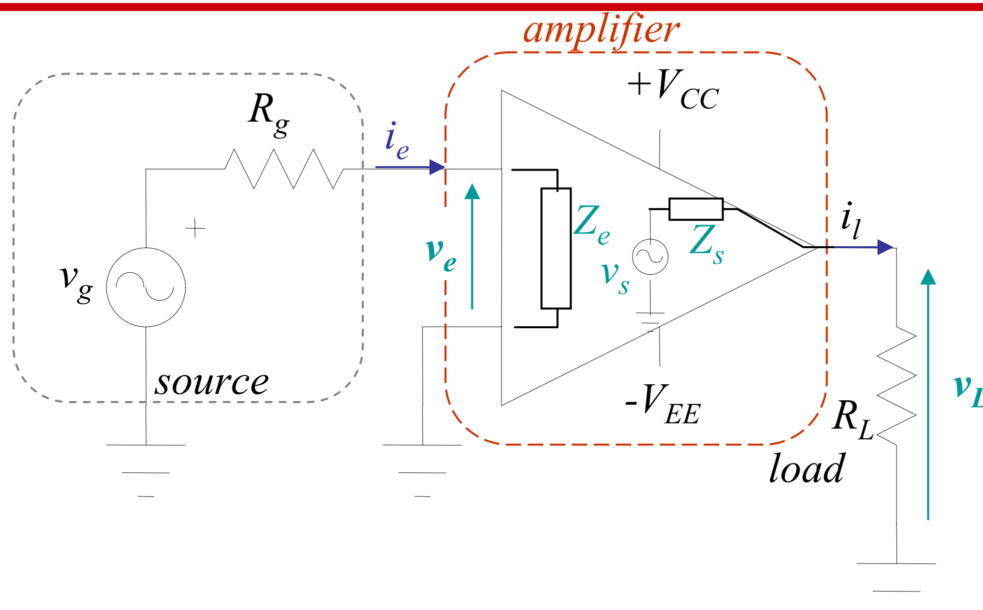
# Amplifier and feedback systems

- **Amplifier system**
- **Feedback system**

# Amplifier




- **Function:** amplify the "signal" power
  → amplifiers are powered by an external source [here: $V_{CC}$ ***and (or)*** $V_{EE}$]

- **Input** of amplifier characterized by the **input impedance** $Z_e = \dfrac{v_e}{i_e}$

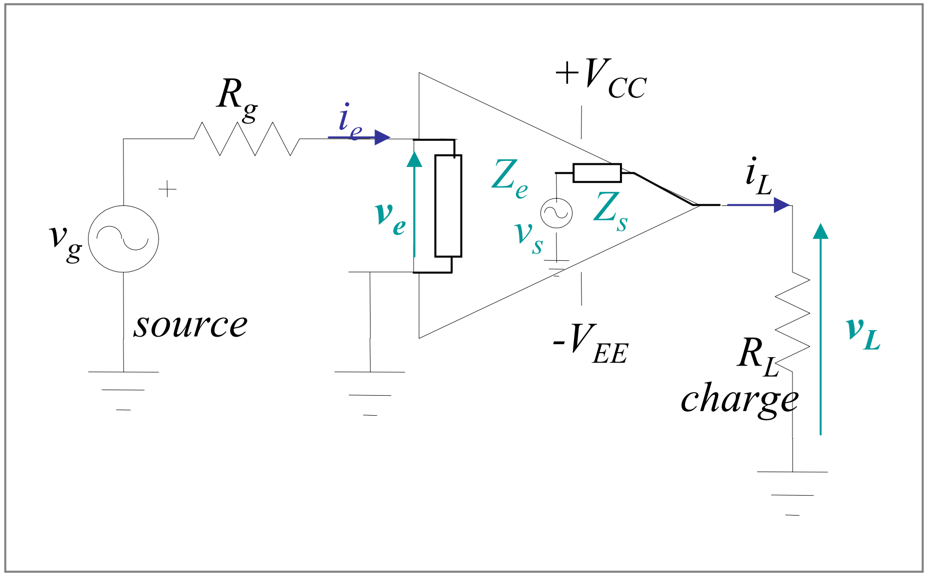
- The amplifier **output** acts as a voltage **source** characterized by its **output impedance $Z_s$**

  **!** $\boldsymbol{Z_s}$ **= Thévenin** equivalent resistance of the circuit "seen" by $\boldsymbol{R_L}$

# Gain(s) definition

- **Voltage gain:**

Since $\mathbf{Z_s \neq 0}$, voltage gain **depends** on load




*Gain "in open circuit" :* $$A_v = \left.\frac{v_L}{v_e}\right|_{R_L=\infty} = \frac{v_s}{v_e}$$

*Gain "on load" :* $$A_{vL} = \frac{v_L}{v_e} = \frac{R_L}{R_L + Z_s} A_v$$

*"composite" gain:*
*(take into account*
*the output impedance)*

$$A_{vc} = \frac{v_L}{v_g} = \frac{Z_e}{R_i + Z_e} A_{vL}$$

Since $\mathbf{Z_e \neq \infty}$, $A_{vc}$ *different from* $A_{vL}$

- **Current gain**

$$A_i = \frac{i_L}{i_e} = \frac{A_{vL} Z_e}{R_L}$$

- **Power gain :**

$$A_p = \frac{v_L i_L}{v_g i_e} = A_{v_c} \cdot A_i$$

# Ideal amplifier

- Gains independent of amplitude and frequency of input signal
- Entrance impedance high ⇔ **low perturbation on the source operation**
- Exit impedance low ⇔ **small perturbation of the load**

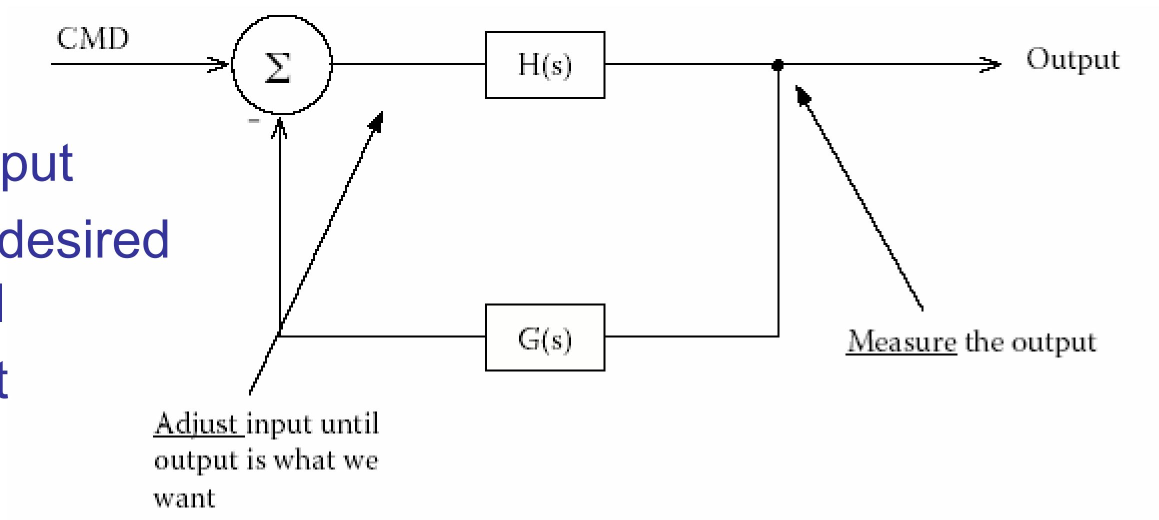
***Real life...***

- **linearity regime : distortion** of signal occurs for high amplitudes
  ***Nonlinearities*** *of some electronics characteristics*

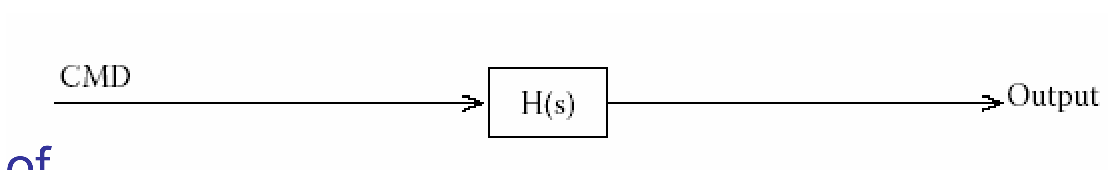
- **limited frequency bandwidth :** gain is a function of signal frequency
  internal capacitance of some components
  capacitors used in the circuits
  input and output impedances depend on frequency

# Feedback Systems

- **Closed loop:**
  - Measure output
  - Compare to desired output signal
  - Correct input accordingly

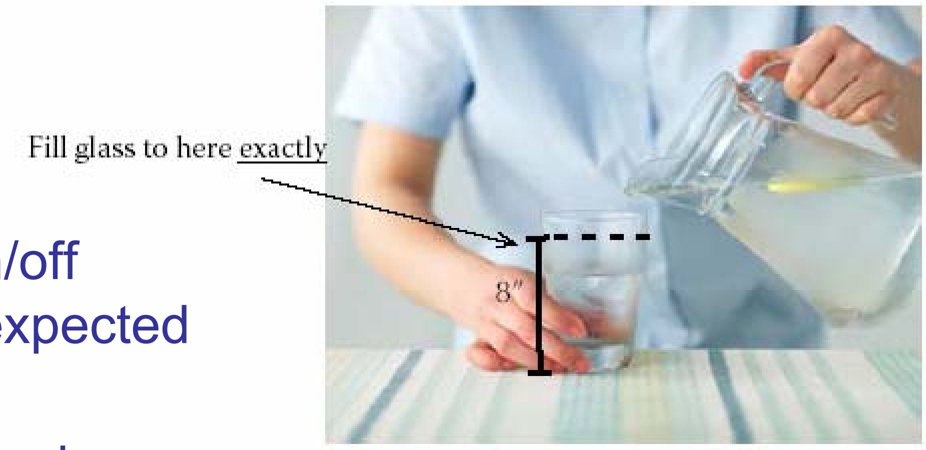



- **Open loop**
  - Design or characterize the transfer function of the system
  - Apply a proper input so that output signal is the desired value

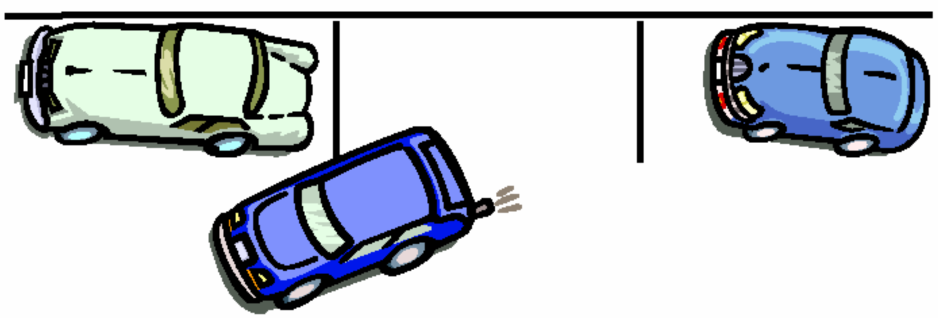


# Feedback Systems (real life… almost)

- **Open loop**
  - Adjust flow and on/off until water reach expected value
  - Your eyes are closed

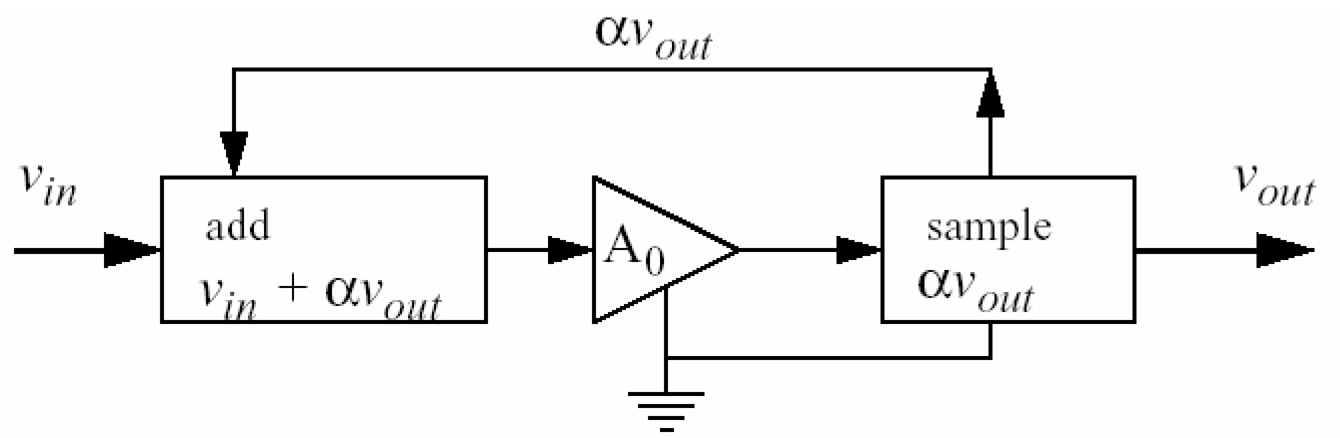



- **Closed loop**
  - Set of constraints
  - Measurement (trust your vision



# Voltage feedback

- Sample part of the output voltage and feedback as input




- Gain of the system is (assume $A_0$ >>1)

$$A = \frac{v_{out}}{v_{in}} = \frac{A_0}{(1 - A_0\alpha)}$$

***problem is $A_0\alpha$ close to 1***

# Voltage feedback

- Gain stability

$$\frac{dA}{A} = \frac{dA_0}{A_0} - \alpha\frac{dA_0}{(1 - A_0\alpha)} = \frac{A}{A_0}\frac{dA_0}{A_0}$$

  - Small change in A0 gain results in change in A

- Input impedance changes

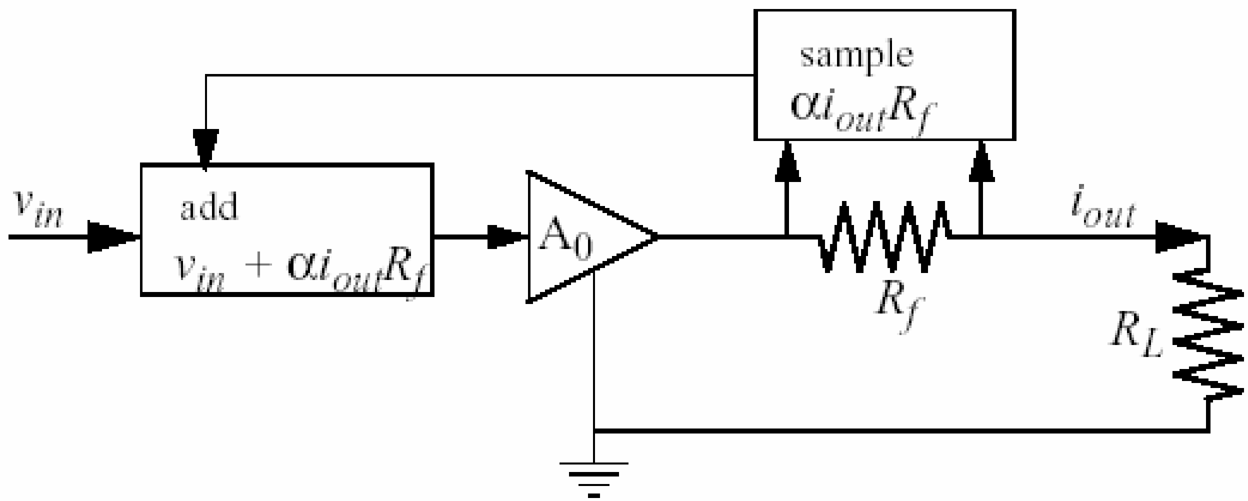
$$Z_{in} = \frac{v_{in}}{i_{in}} = \frac{v_{in0}}{(1 + \alpha A)i_{in}} = \frac{A_0}{A}Z_{in0}$$

- Output impedance also changes

$$Z_{out} = \frac{v_{out}}{i_s} = \frac{Av_{in}}{i_s} = \frac{A}{i_s}\frac{i_s Z_{out0}}{A_0} = \frac{A}{A_0}Z_{out0}$$

# Current feedback

- Sample output current, convert to voltage and add to input




$$i_{out} = \frac{A_0 v_{in}}{R_L + Z_{out0} + (1 - A_0 \alpha) R_f}$$