# Aplication of negative feedback

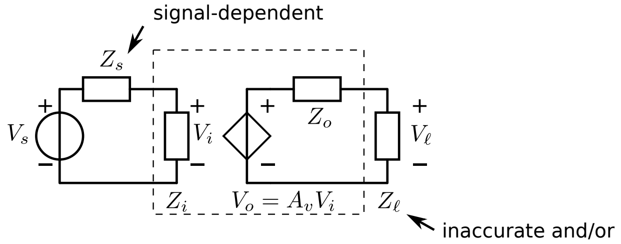
## Application of negative feedback

1. Amplification mechanism found in biased amplifying devices suffers from numerous imperfections
2. We need error reduction techniques to improve the performance-to-cost ratio

### Negative (corrective) feedback

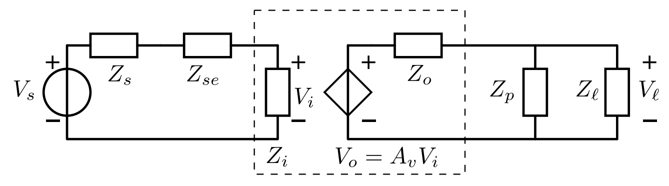
- Makes the properties of the amplifier less dependent on those of the biased amplifying devices
- Uses an accurate feedback network as reference for the transfer
- Allows the use of a feedback network with an available power gain equal or less than unity
  * Accurate (passive) components available for the feedback network
- Strongly facilitates orthogonal design of performance aspects

**Example:** The effects of **brute-force** reduction of the influence of source and load impedance variations on the accuracy of the transfer of a voltage amplifier




$$\frac{V_\ell}{V_s}=\frac{Z_i}{Z_i+Z_s}A_v\frac{Z_\ell}{Z_\ell+Z_o}$$

**Brute-force:** Insert dominant, high-accuracy and linear impedances in the signal path:



$$\frac{V_\ell}{V_s}=\frac{Z_i}{Z_i+Z_s+Z_{se}}A_v\frac{Z_\ell\|Z_p}{Z_\ell\|Z_p+Z_o}\approx\frac{Z_i}{Z_i+Z_{se}}A_v\frac{Z_p}{Z_p+Z_o}$$

**Remember:** Thou shalt not insert impedances in series or in parallel with the signal path

**Conclusion:** If you do: strong interaction between:
- accuracy and noise addition
- accuracy and power inefficiency
- accuracy and source-to-load transfer

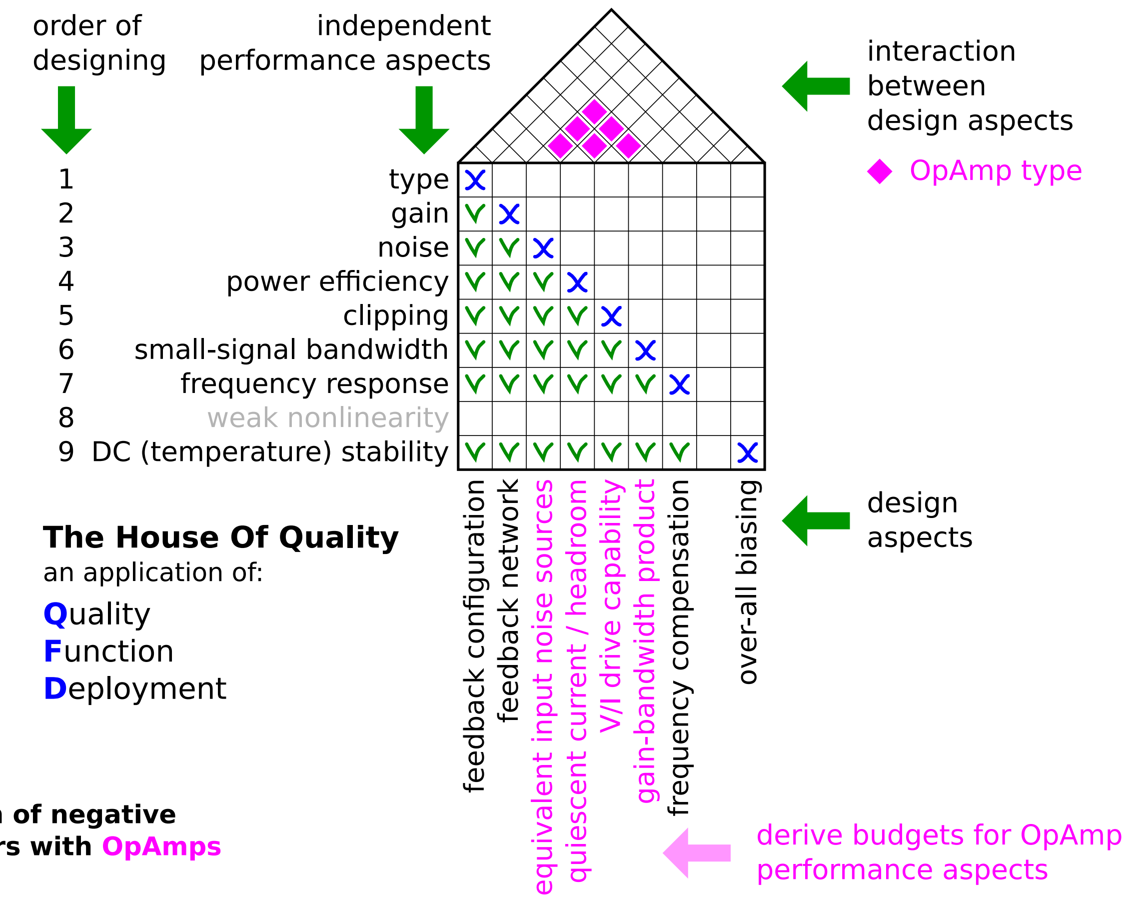
At the source: reduction of the signal to noise ratio

At the load: decrease of power efficiency

Source-to-load transfer: reduced as a result of attenuation

### The House Of Quality

an application of:
**Q**uality
**F**unction
**D**eployment




### The House Of Quality

an application of:
**Q**uality
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**Orthogonal design of negative feedback amplifiers with OpAmps**

### The Design Procedure

**1. Measure the load signal (V or I)**

a. Voltage should be measured across (in parallel with) the load
b. Current should be measured through (in series with) the load

**2. Design a network that generates of copy of the source signal (V or I) from the measured load signal**

a. The transfer of this network is the reciprocal of the desired source-to-load transfer

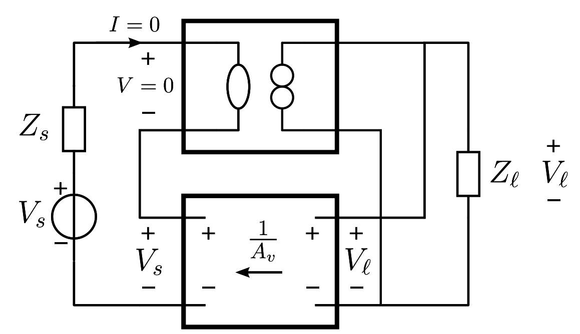
**3. Subtract the copy from the source signal**

a. In case of a voltage source signal, the signal source and the output of the feedback network should be connected anti-series
b. In case of a current source signal, the signal source and the output of the feedback network should be connected anti-parallel

**4. Nullify the difference**

a. In case of a voltage source signal, a nullator closes the loop of the above anti-series connection
b. In case of a current source signal, a nullator is placed in parallel with the above anti-parallel connection
c. In case of a voltage load signal, a norator is placed in parallel with the load
d. In case of a current load signal, a norator closes the loop of the series connection of the load and the input of the feedback network

Nullor is ideal controller

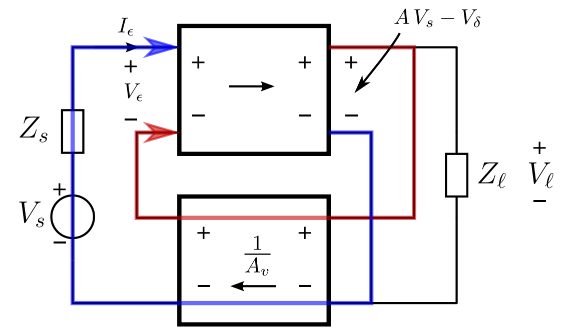



### Types of feedback

Implementation of the feedback network

1. Nonenergic feedback
   a. Transformers, gyrators
   b. Short and open circuit
2. Passive feedback
   a. Non-dissipative: inductors and/or capacitors
   b. Dissipative: includes resistors
3. Active feedback
   a. Feedback network comprises an amplifier

### Negative feedback and ideal gain



1. The ideal gain is the source-to-load transfer in the case of a nullor as controller
2. Practical controllers have a finite gain and bandwidth
   a. Negative (corrective) feedback if transfer from the positive output of the controller to its positive input is inverting:

### Single-loop negative Feedback Amplifiers

| Source | Load | Amplifier | A, B, C, D | Feedback method |
|---|---|---|---|---|
| V | V | Voltage amplifier | A, 0, 0, 0 | Output voltage sensing / parallel feedback<br>Input voltage comparison / series feedback |
| V | I | Transadmittance | 0, B, 0 ,0 | Output current sensing / series feedback<br>Input voltage comparison / series feedback |
| I | V | Transimpedance | 0, 0, C, 0 | Output voltage sending / parallel feedback<br>Input current comparison / parallel feedback |
| I | I | Current amplifier | 0, 0, 0, D | Output current sensing / series feedback<br>Input current comparison / parallel feedback |

### Conclusions feedback configurations

1. All port (isolation) configurations can be realized using nonenergic feedback with natural two-ports (gyrator, transformer)
2. If the feedback network is not a natural two-port:
   a. Source and load are electrically connected
   b. Sign of transfer depends on amplifier type
   c. Port isolation and/or sign inversion requires:
      - Active feedback
      - Balanced feedback
      - Indirect feedback
      - Transformers

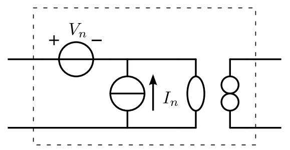
### Noise performance nonenergic feedback amplifiers

The equivalent input noise sources of the amplifier are equal to those of the controller

### Error reduction capabilities of negative feedback

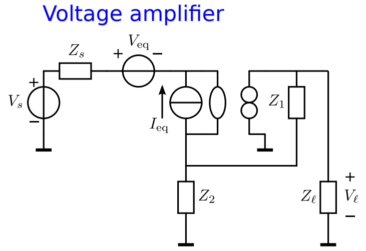
- With a high-gain controller the static and dynamic transfer are predominantly determined by the feedback network
- This is not the case for the noise behavior
  a. The equivalent input noise sources of the controller should be kept small
  b. Deterioration of the signal to noise ratio by the feedback network should be kept small

Model the controller as a noisy nullor

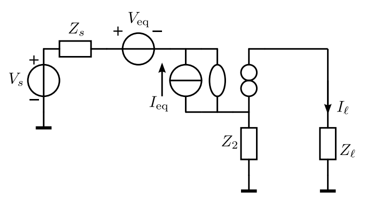


### Single-loop passive feedback configurations and their equivalent input noise models

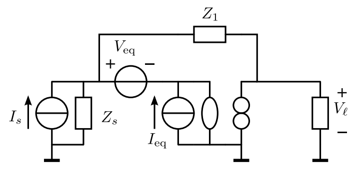
Voltage amplifier



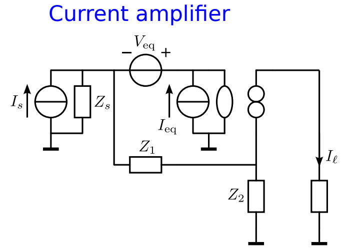
Transadmittance



Transimpedance

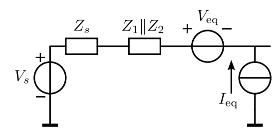


Current amplifier



The noise contribution of the feedback impedances and their influence on the contribution of the equivalent input noise sources of the controller can be found:

As if the parallel connection of the feedback impedances is in series with the source



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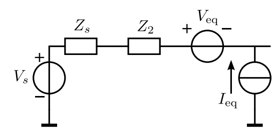

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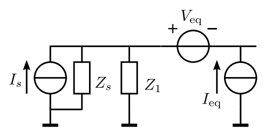

As if the series connection of the feedback impedances is in series with the source