Amplifier characterization

Ideal Behavior and Manifestation of Errors

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Perscitec

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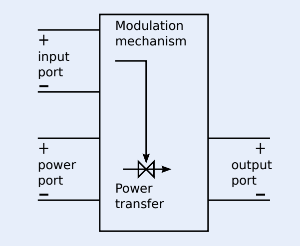
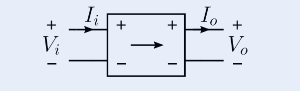
Introduction

Amplifier: the concept





- Amplifiers provide their load (observer) with an accurate copy of their source signal, while they increase the *available power* to the load
- The load power is primarily obtained from a power source
- The amplification mechanism is embodied in *active devices*
- Ideal functional behavior: conceptual amplifier is modeled as a two-port:
  - Linear
  - Instantaneous
  - Time-invariant (if fixed transfer)
  - Time-variant (if time-dependent transfer)

Introduction

Amplifiers: error sources

Physical behavior: error sources

- Real-world amplifier = multi-port:
  - Undesired transfer to and from power port
- Violation of port constraints:
  - Non-ideal port isolation
- Noise limitation:
  - Deterioration of signal-to-noise ratio
- Power and speed limitation:
  - Nonlinear, dynamic behavior causes signal distortion.

Introduction

Amplifiers: Manifestation of errors and Performance specification

Manifestation of errors depends on

- Applied technology
- Way in which the information is embedded in the signal
- Observer's sensitivity to specific information processing errors

Performance specification

- Desired functional (two-port) behavior
- Undesired transfer from and to power port
- Manifestation errors due to fundamental physical limitations, interference sources and environmental changes, ageing, ...
- Specification of power source(s).

Introduction

Amplifiers: Environmental specification and cost factors

Environment

- Temperature
- Humidity
- Shock and vibrations
- EMI sources
- Any physical property of the environment that may affect the signal processing quality
- May relate to any life cycle process (not only operation)

Cost factors

- Space
- Weight
- Available power
- May relate to any life cycle process (not only operation)

Selection of port quantities

- In case of sensors and actuators:
  - The electrical quantity (current or voltage) that shows the best reproducing relation to the transducer's input/output physical quantity.
- In case of interconnected electronic circuits:
  - Distribution with common-ground: voltage
  - Combination with common ground: current
  - Dominant parasitic impedances in parallel with the signal path: current
  - Dominant parasitic impedances in series with the signal path: voltage.

Amplifier types

Overview port impedance requirements

Nine unilateral amplifier types:

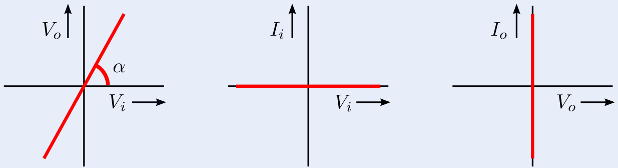
1. Amplifier's input impedance independent of load impedance
2. Amplifier's output impedance independent of source impedance

no	source quantity	load quantity	Z_i	Z_o
1	voltage	voltage	∞	0
2	voltage	current	∞	∞
3	voltage	voltage or current	∞	Z_{charo}
4	current	voltage	0	0
5	current	current	0	∞
6	current	voltage or current	0	Z_{charo}
7	voltage or current	voltage	Z_{chari}	0
8	voltage or current	current	Z_{chari}	∞
9	voltage or current	voltage or current	Z_{chari}	Z_{charo}

Amplifier types

Characterization of ideal functional behavior

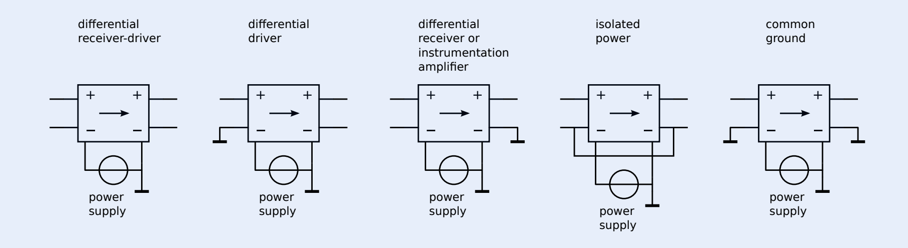
- Port v-i characteristics
  - Modeled by v-i characteristics of input and output port
  - Linear, time-invariant, instantaneous
- Transfer characteristics:
  - Desired transfer from input port to output port
  - Linear, time-invariant, instantaneous
- Example voltage amplifier:



$\frac{dV_o}{dV_i} = \tan(\alpha)$ $R_i = \frac{dV_i}{dI_i} = \infty$ $R_o = \frac{dV_o}{dI_o} = 0$

Amplifier types

Port isolation

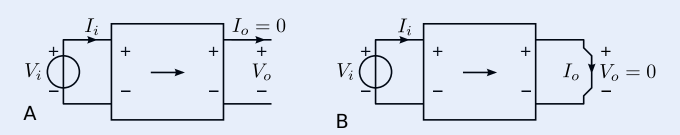


Port isolation configurations

1. Floating source and load
2. Grounded source, floating load
3. Grounded load, floating source
4. Floating source and load with common
5. Grounded source and load

Two-port representation with transmission-1 matrix

$$\begin{pmatrix} V_i \\ I_i \end{pmatrix} = \begin{pmatrix} A & B \\ C & D \end{pmatrix} \begin{pmatrix} V_o \\ I_o \end{pmatrix}$$



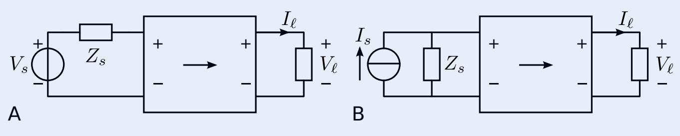
$$A = \frac{1}{\mu} = \left.\frac{V_i}{V_o}\right|_{I_o=0} \qquad B = \frac{1}{\gamma} = \left.\frac{V_i}{I_o}\right|_{V_o=0}$$

$$C = \frac{1}{\zeta} = \left.\frac{I_i}{V_o}\right|_{I_o=0} \qquad D = \frac{1}{\alpha} = \left.\frac{I_i}{I_o}\right|_{V_o=0}$$

Amplifier types

Source-load transfer

Source-load transfer expressed in transmission parameters:



Source-load transfers expressed with matrix parameters and Z_s and Z_ℓ:

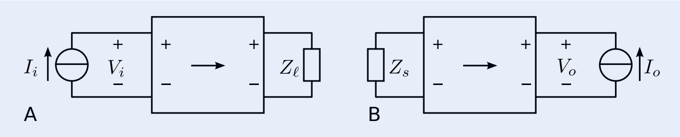
$$A_v = \frac{V_\ell}{V_s} = \frac{1}{A + B\frac{1}{Z_\ell} + CZ_s + D\frac{Z_s}{Z_\ell}}, \quad A_y = \frac{I_\ell}{V_s} = \frac{1}{AZ_\ell + B + CZ_\ell Z_s + DZ_s}$$

$$A_z = \frac{V_\ell}{I_s} = \frac{1}{A\frac{1}{Z_s} + B\frac{1}{Z_s Z_\ell} + C + D\frac{1}{Z_\ell}}, \quad A_i = \frac{I_\ell}{I_s} = \frac{1}{A\frac{Z_\ell}{Z_s} + B\frac{1}{Z_s} + CZ_\ell + D}$$

Amplifier types

Driving-point impedances

Port impedances expressed in transmission parameters:



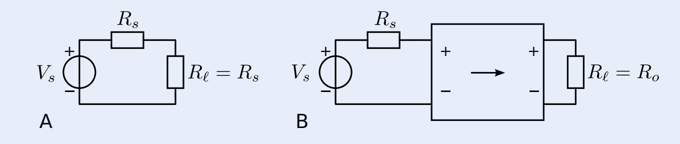
Port impedances expressed with matrix parameters and Z_s and Z_ℓ:

$$Z_i = \frac{V_i}{I_i} = \frac{AZ_\ell + B}{CZ_\ell + D} \qquad Z_o = \frac{V_o}{I_o} = \frac{DZ_s + B}{CZ_s + A}$$

Amplifier types

Available power gain

Available power gain expressed in transmission parameters:



Source available power:

$$P_{S,Av} = \frac{V_s^2}{4\,\mathrm{Re}(Z_s)}$$

Output port available power:

$$P_{O,Av} = \frac{V_o^2}{4\,\mathrm{Re}(Z_o)}$$

Available power gain two-port; instantaneous case:

$$G_p = \frac{P_{O,Av}}{P_{S,Av}} = \frac{1}{AD + AB/R_s + BC + CDR_s}$$

Amplifier types

Conclusions modeling functional behavior

Transmission parameters of unilateral amplifier types:

no	Z_i	Z_o	A	B	C	D
1	∞	0	A	0	0	0
2	∞	∞	0	B	0	0
3	∞	Z_{char}	A	B	0	0
4	0	0	0	0	C	0
5	0	∞	0	0	0	D
6	0	Z_{char}	0	0	C	D
7	Z_{char}	0	A	0	C	0
8	Z_{char}	∞	0	B	0	D
9	Z_{chari}	Z_{charo}	A	B	C	D

Unilateral: $AD = BC$

Error modeling

Modeling of non-ideal port isolation and power supply transfer

Non-ideal port isolation

- A real-world amplifier does not behave as a natural two-port:
  - physical amplifier = multi-port:
    - transmission from and to power supply
  - violation of port constraints:
    - non-ideal port isolation

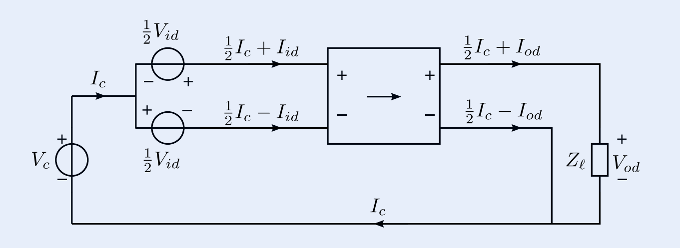
Modeling requires description of amplifier as multi-terminal network.

- Often incomplete specification of the amplifier's behavior

Error modeling

Modeling of non-ideal port isolation

Non-ideal port isolation (input-output)



- Requires five extra parameters
- Usually only two parameters are modelled:

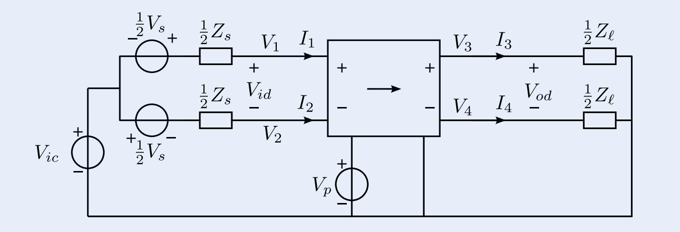
$$CMRR_V = \frac{V_{id}}{V_{cm}}, \quad Z_{cm} = \frac{V_{cm}}{I_{cm}}$$

- Only complete with specified source and load impedances.

Error modeling

Modeling of non-ideal power-supply

Non-ideal power-supply isolation



- Requires 19 extra parameters
- Usually only two extra parameters are modelled:

$$PSRR = \frac{V_{id}}{V_{cc}}, \quad F = \frac{V_{od}}{V_{id}}\frac{V_{ic}}{V_{oc}}$$