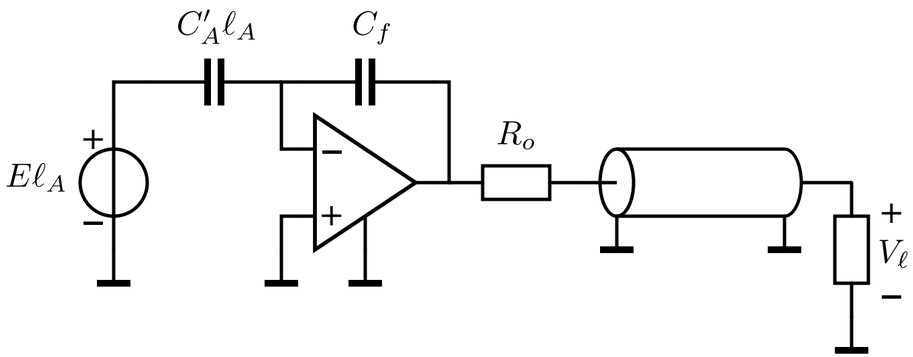
Structured Electronic Design

EE4109
Active antenna
Controller design

Anton J.M. Montagne

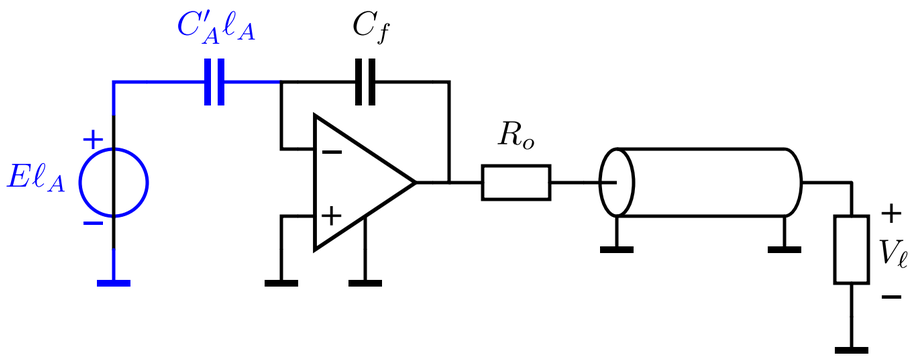
Active antenna

Active antenna



Active antenna

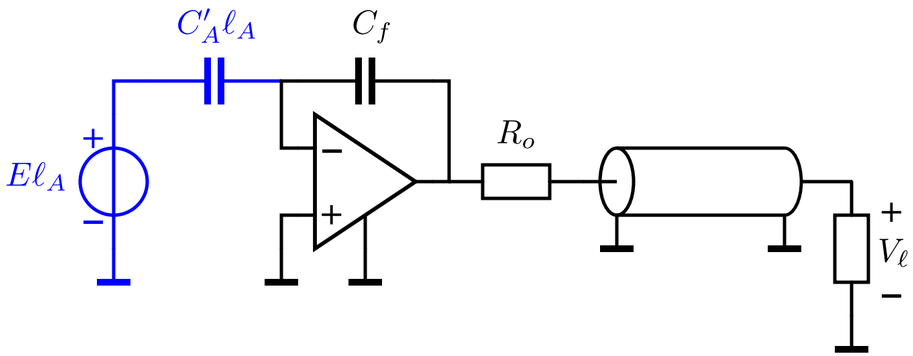
Antenna



Active antenna

Antenna

E-field to voltage conversion

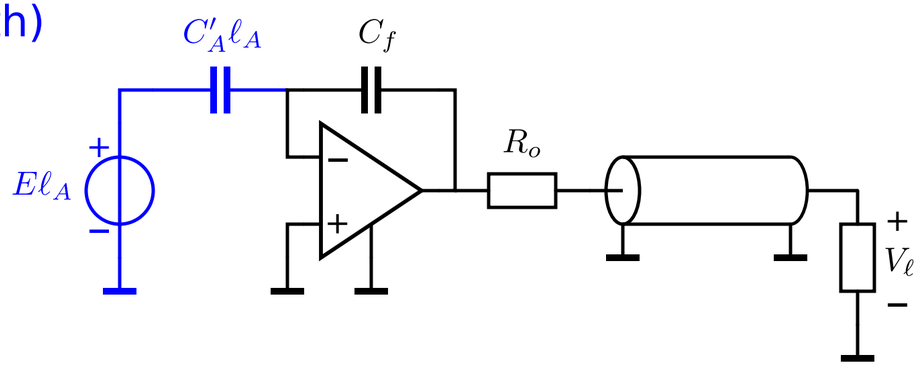


Active antenna

Antenna

E-field to voltage conversion

Gain (length)



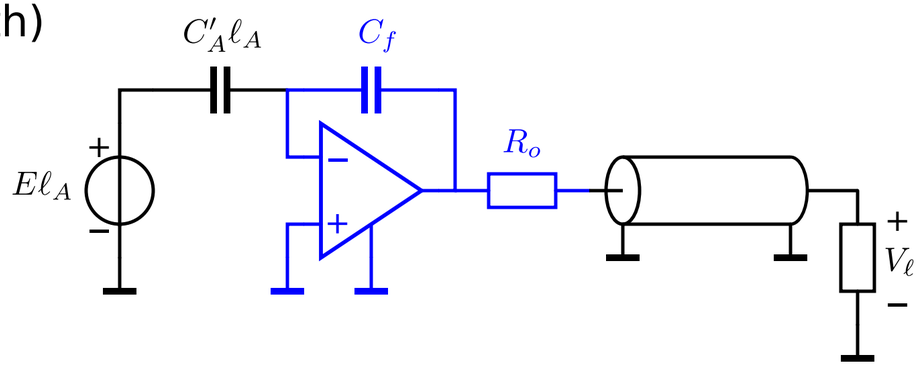
Active antenna

Antenna

Amplifier

E-field to voltage conversion

Gain (length)

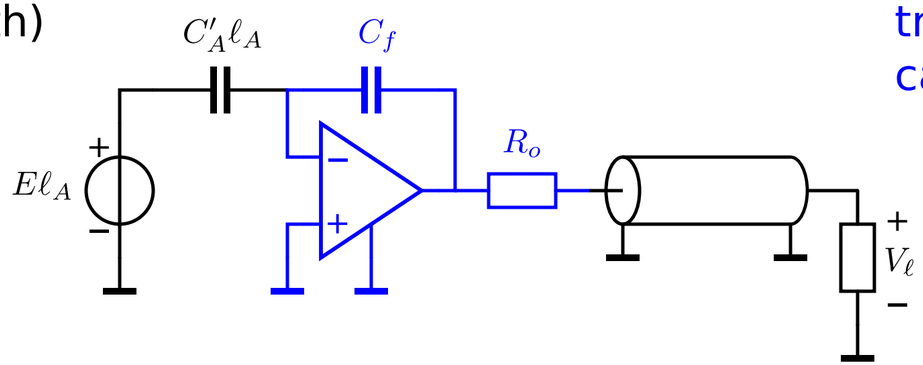


Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Active antenna

Antenna

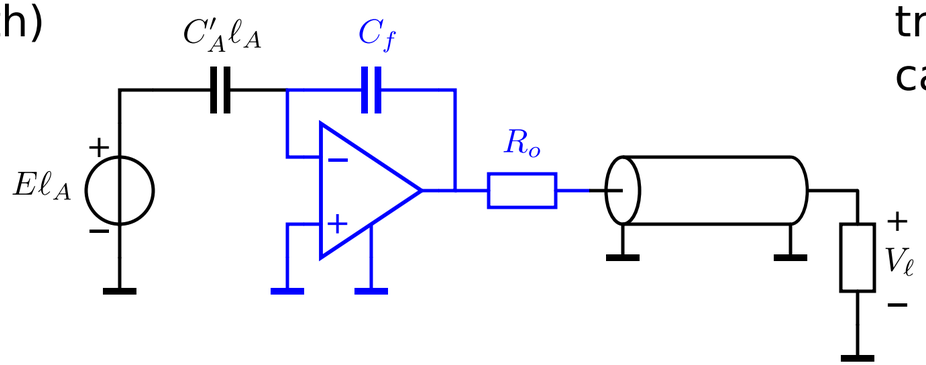
E-field to voltage conversion

Gain (length)

Amplifier

Integrating transimpedance cable driver

Gain and output resistance

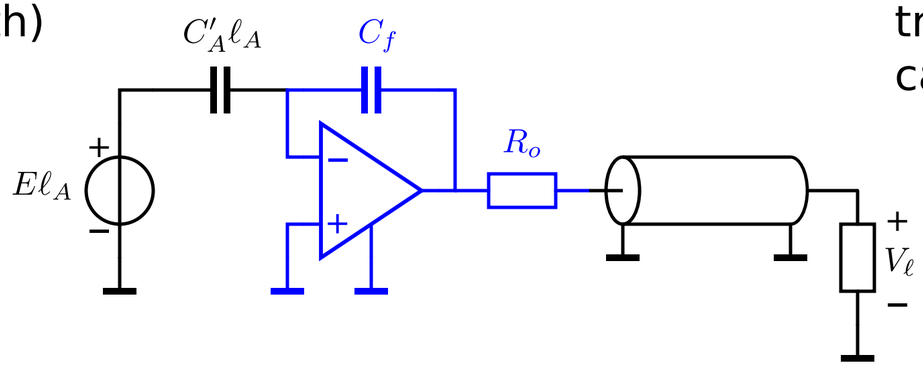


Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance

Noise

Feedback network

Capacitor

Capacitance

Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources

VI-drive capability

Midband loop gain

Loop gain-poles product

Differential error to loop gain ratio

Output resistor

Resistor

Resistance

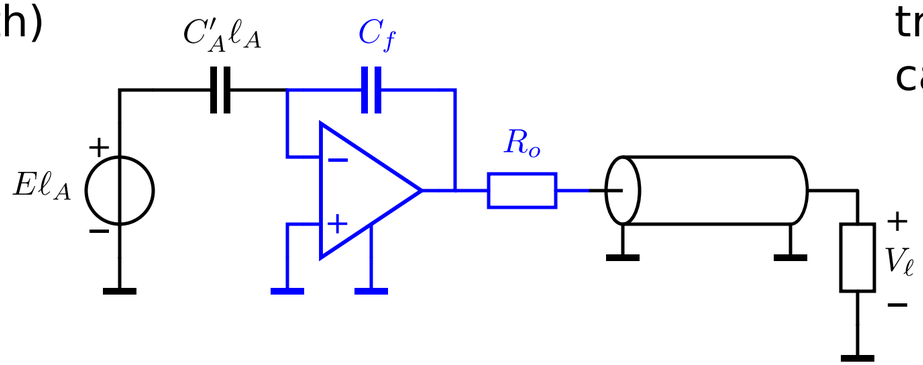
Accuracy

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

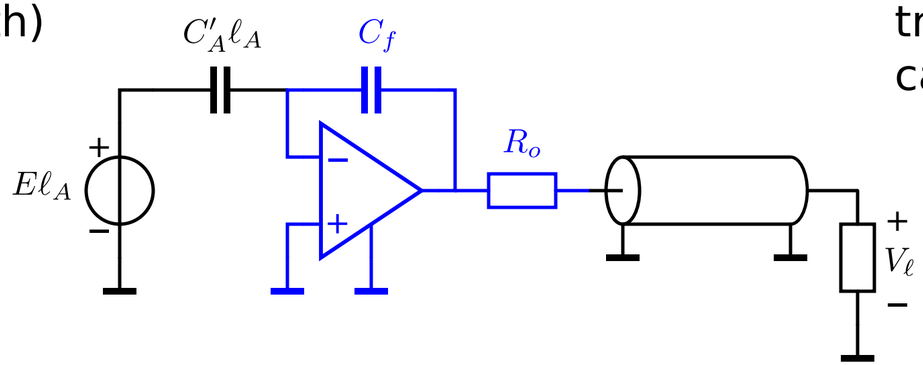
Gain and output resistance
Noise
VI-drive capability

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

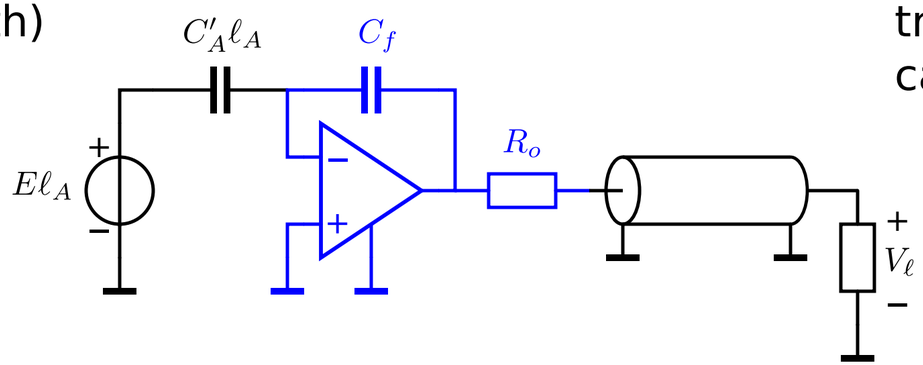
Gain and output resistance
Noise
VI-drive capability
Midband accuracy

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

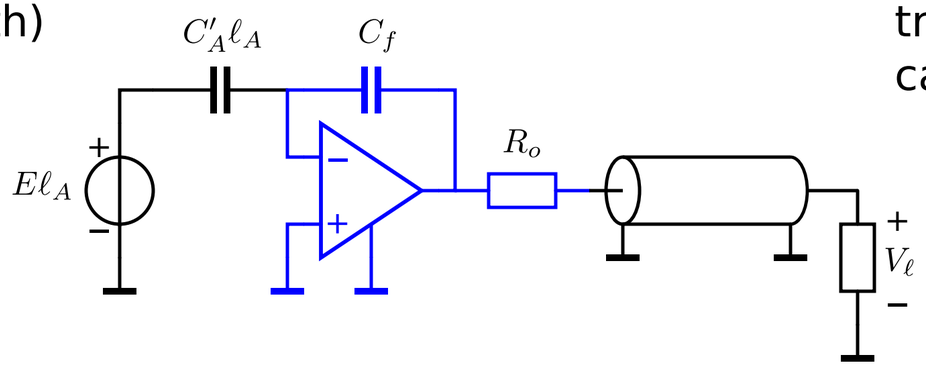
Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

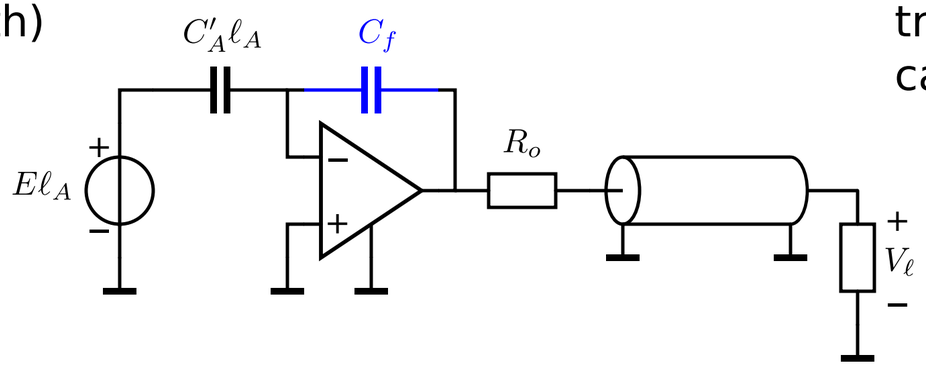
Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

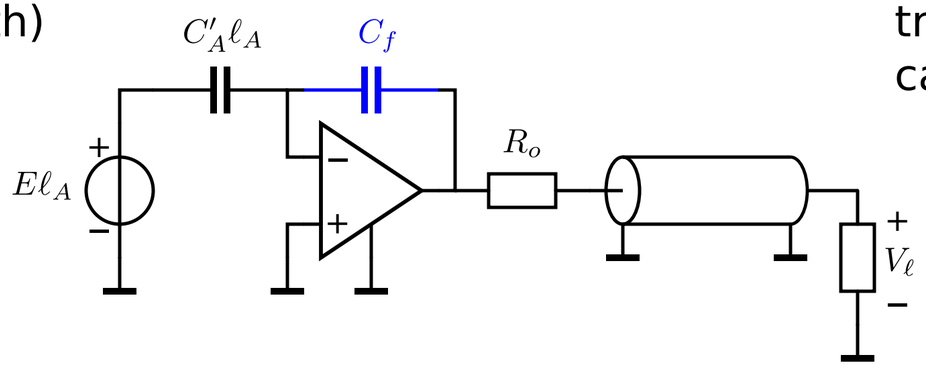
Feedback network

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

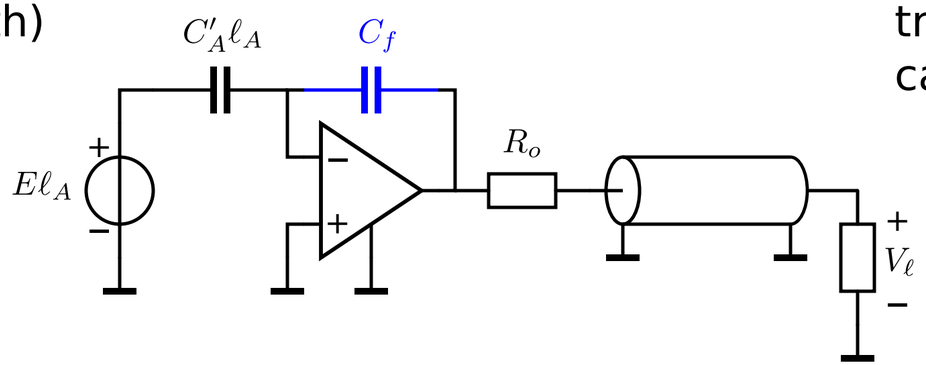
Capacitor

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

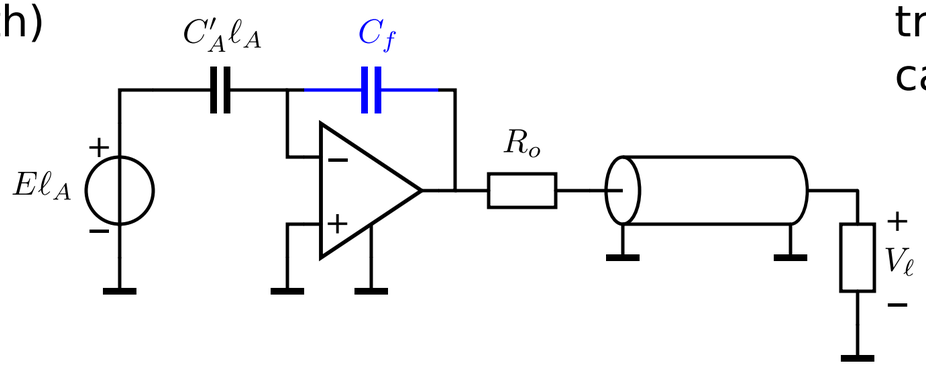
Capacitor Capacitance

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

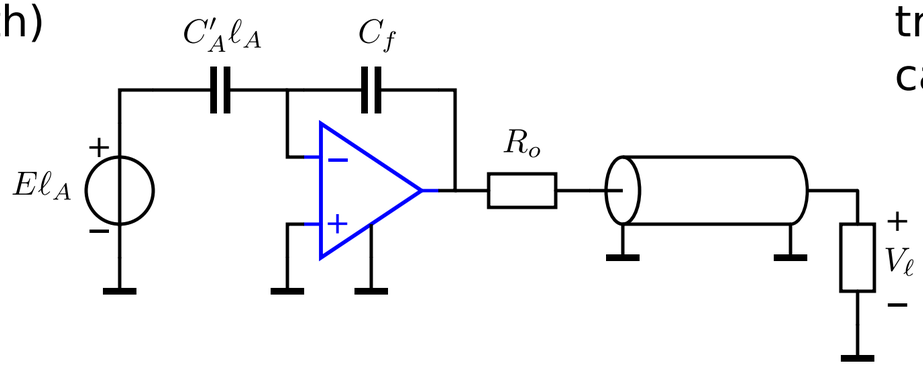
Capacitance
Accuracy

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

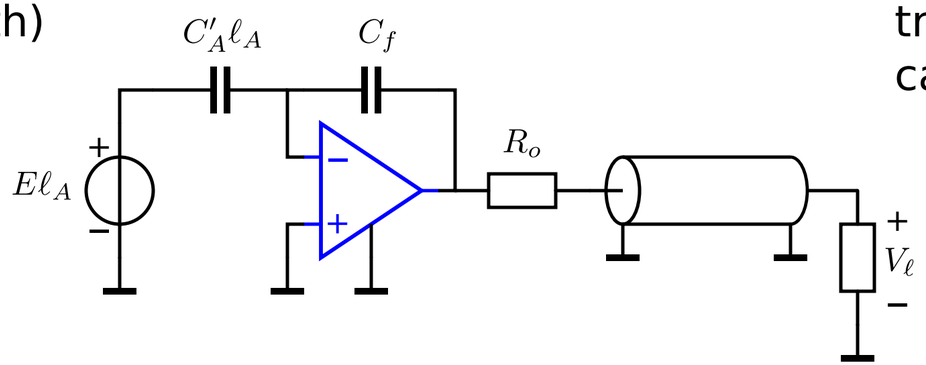
Controller or error amplifier

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

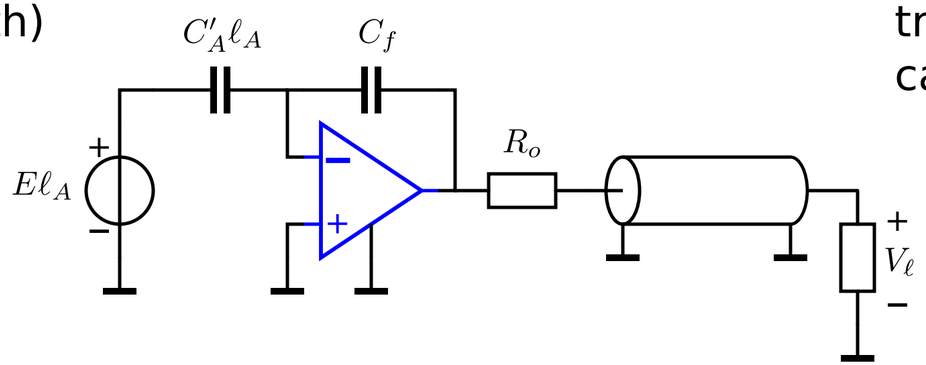
Single-stage or multi-stage amplifier

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

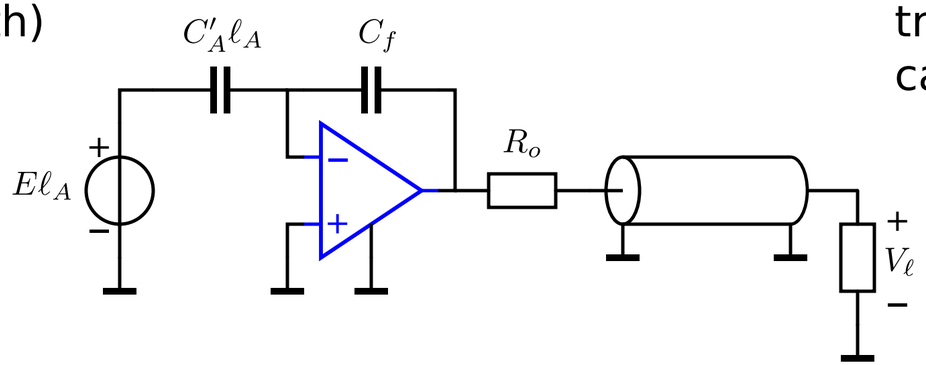
Equivalent-input noise sources

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

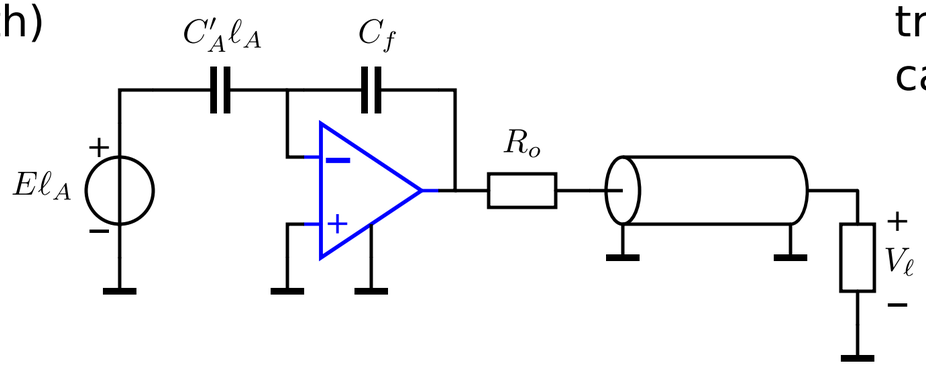
Equivalent-input noise sources
VI-drive capability

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

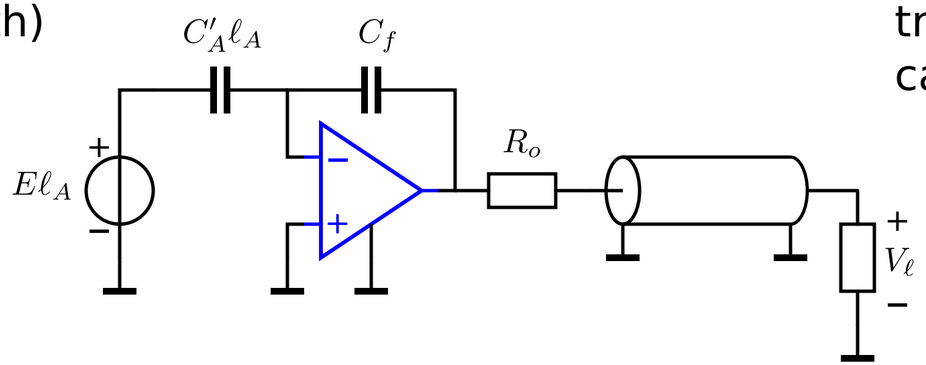
Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

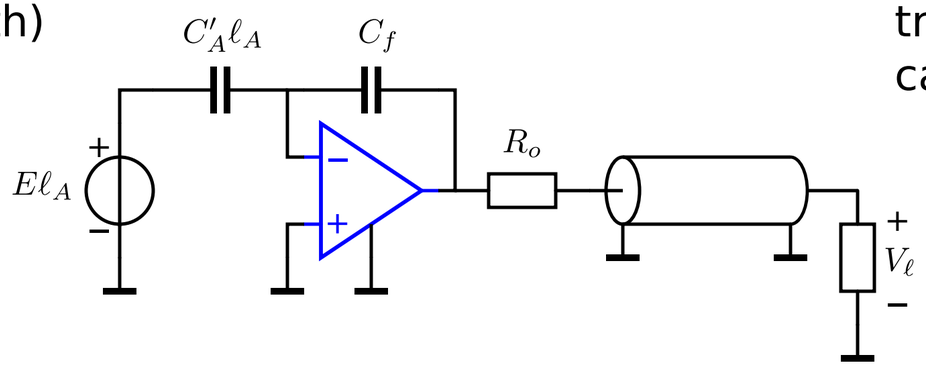
Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

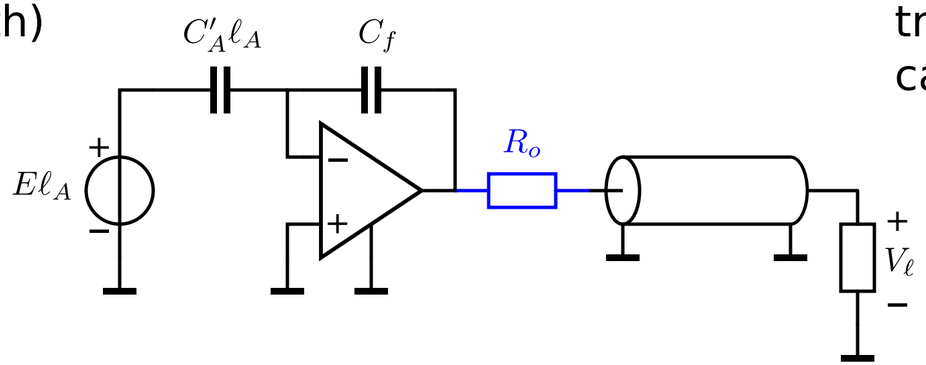
Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

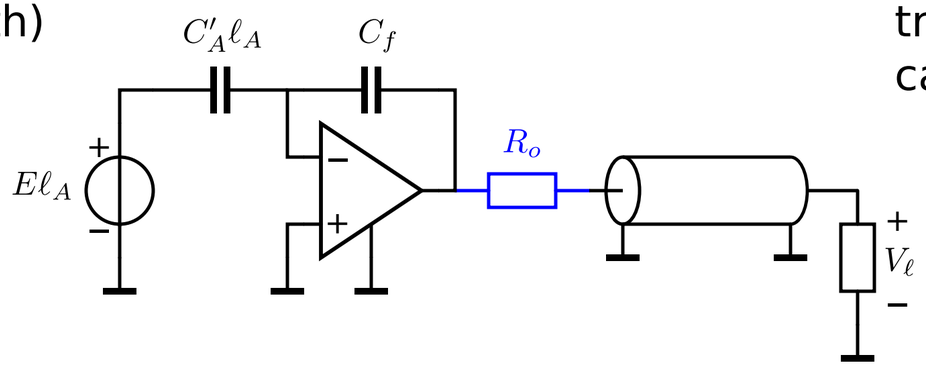
Output resistor

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

Output resistor

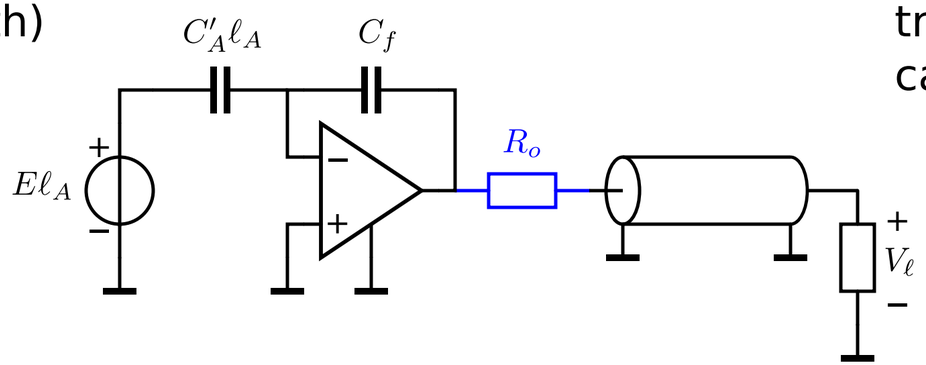
Resistor

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

Output resistor

Resistor

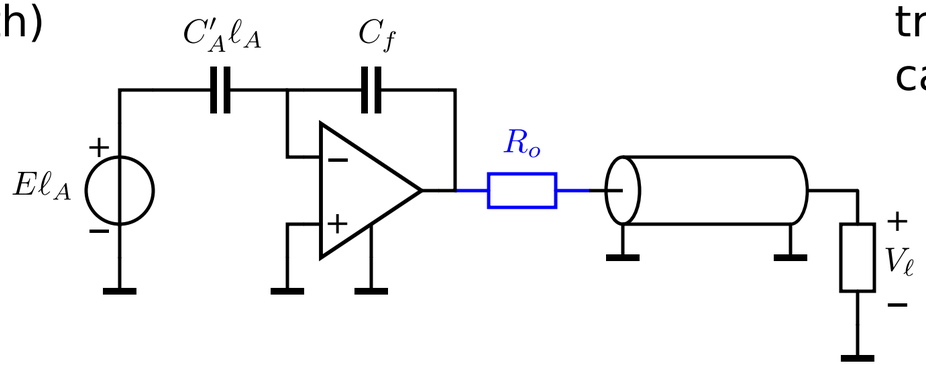
Resistance

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

Output resistor

Resistor

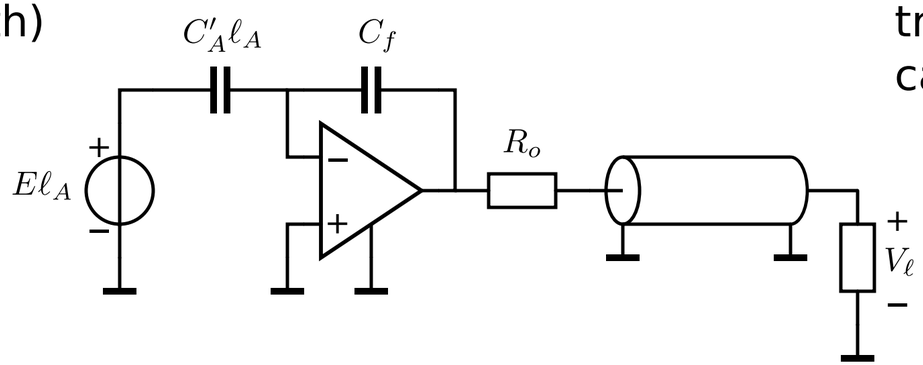
Resistance
Accuracy

Active antenna

Antenna

E-field to voltage conversion

Gain (length)



Amplifier

Integrating transimpedance cable driver

Gain and output resistance
Noise
VI-drive capability
Midband accuracy
Bandwidth
Weak nonlinearity

Feedback network

Capacitor

Capacitance
Accuracy

Controller or error amplifier

Single-stage or multi-stage amplifier

Equivalent-input noise sources
VI-drive capability
Midband loop gain (contribution)
Loop gain-poles product (contribution)
Differential error to loop gain ratio (contribution)

Output resistor

Resistor

Resistance
Accuracy

Structured Electronic Design

EE4109
Controller design:
Design considerations

Anton J.M. Montagne

Controller design

Controller design

Input stage:

Controller design

Input stage: Performance aspect: noise

Controller design

Input stage: Performance aspect: noise

Stage type: CS or balanced

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

Best nullor like stage: minimizes noise contributions of other stages

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

Best nullor like stage: minimizes noise contributions of other stages

Determine design limits for W, L and I_{DS}

Controller design

Input stage: Performance aspect: noise

Stage type: CS or balanced

Best nullor like stage: minimizes noise contributions of other stages

Determine design limits for W, L and I_{DS}

Output stage:

Controller design

Input stage: Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage: Performance aspects: VI-drive capability and power efficiency

Controller design

Input stage: Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage: Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

Controller design

Input stage:
- Performance aspect: noise
- Stage type: CS or balanced
  - Best nullor like stage: minimizes noise contributions of other stages
  - Determine design limits for W, L and I_{DS}

Output stage:
- Performance aspects: VI-drive capability and power efficiency
- Stage type: complementary parallel CS
  - Best nullor like stage: minimizes distortion contributions of other stages

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Controller design

Input stage: Performance aspect: noise
Stage type: CS or balanced
- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage: Performance aspects: VI-drive capability and power efficiency
Stage type: complementary parallel CS
- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Noise performance can be met

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Noise performance can be met

1-st stage can drive 2-nd stage

Controller design

Input stage:

Performance aspect: noise

Stage type: CS or balanced

- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:

Performance aspects: VI-drive capability and power efficiency

Stage type: complementary parallel CS

- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Noise performance can be met

1-st stage can drive 2-nd stage

2-nd stage can drive the load

Controller design

Input stage:
Performance aspect: noise
Stage type: CS or balanced
- Best nullor like stage: minimizes noise contributions of other stages
- Determine design limits for W, L and I_{DS}

Output stage:
Performance aspects: VI-drive capability and power efficiency
Stage type: complementary parallel CS
- Best nullor like stage: minimizes distortion contributions of other stages
- Complementary parallel: improved power efficiency when operating in class AB mode
- Use smallest $L_{P,N}$, and determine design limits for $W_{P,N}$, $V_{DSP,N}$ and I_Q

Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Noise performance can be met

1-st stage can drive 2-nd stage

2-nd stage can drive the load

Multiple-stage

Controller design

Input stage:
Performance aspect: noise
Stage type: CS or balanced
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Output stage:
Performance aspects: VI-drive capability and power efficiency
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Single-stage

Noise and VI-drive can be met with single stage

Dual-stage

Noise performance can be met

1-st stage can drive 2-nd stage

2-nd stage can drive the load

Multiple-stage

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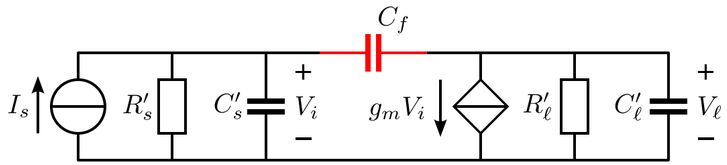

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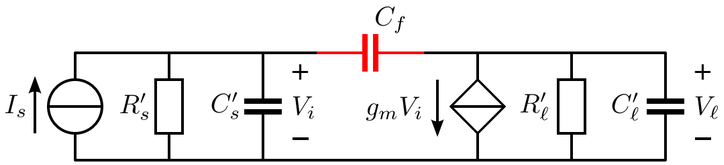

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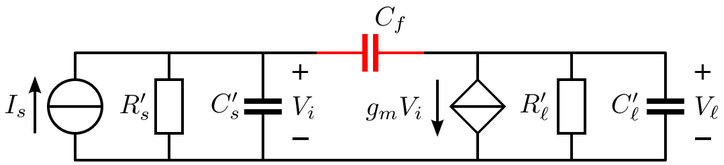

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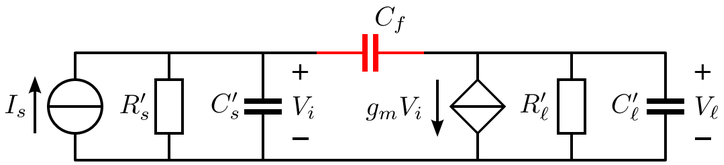

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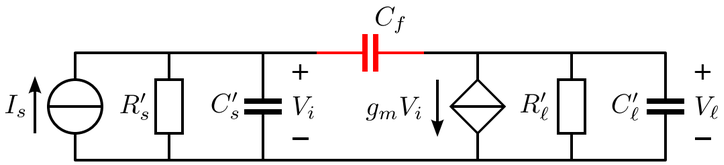

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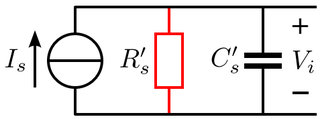

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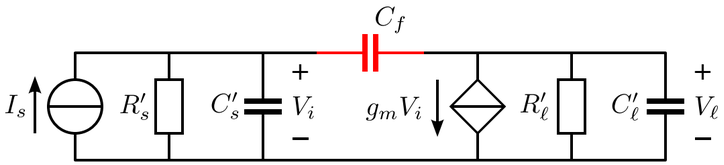

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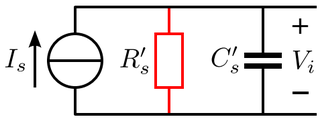

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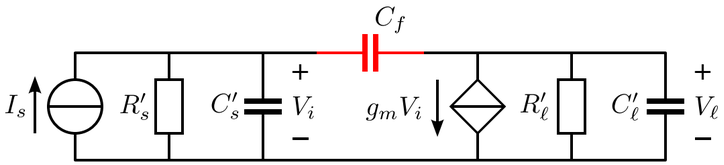

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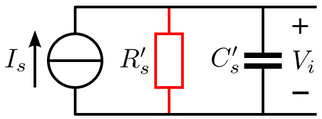

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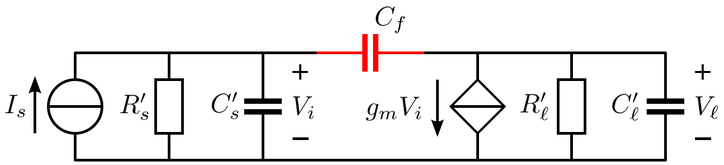

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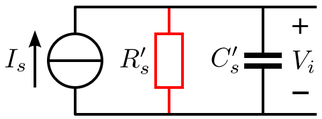

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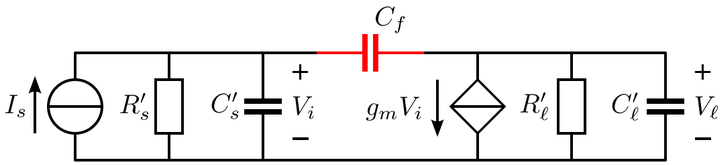

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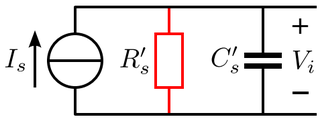

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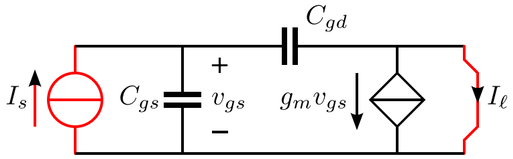

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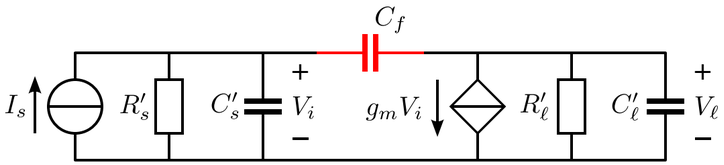

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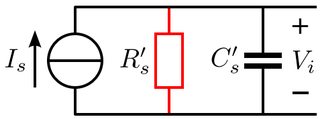

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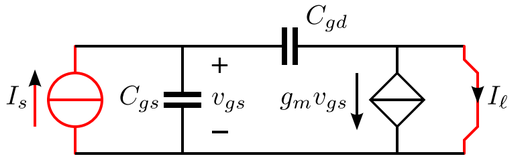

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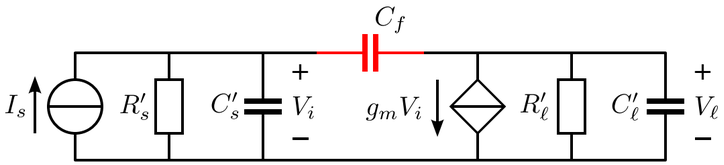

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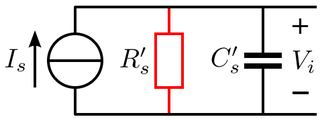

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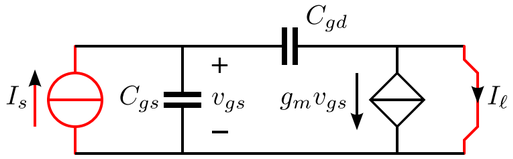

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Biased, current-driven CS-stage with RC load

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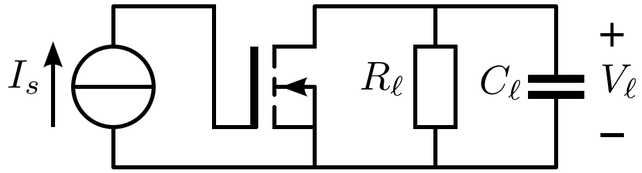

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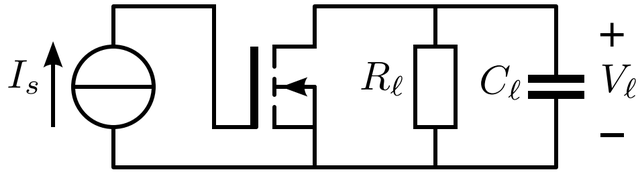

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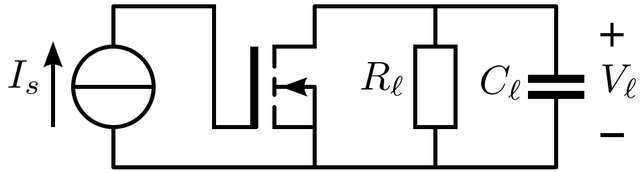

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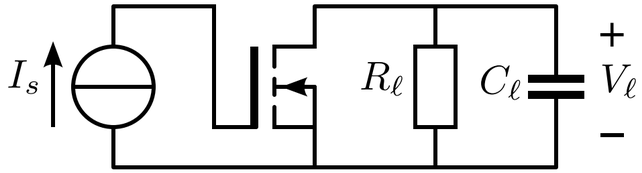

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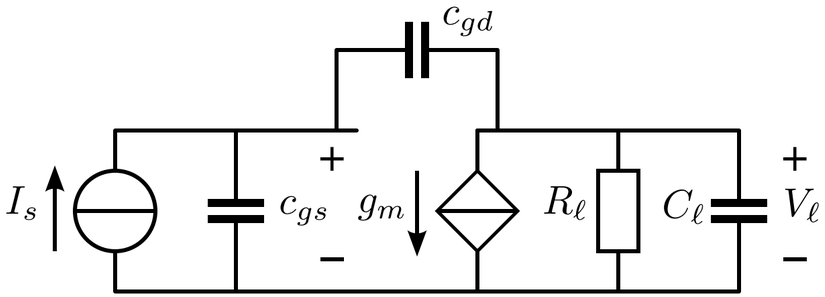

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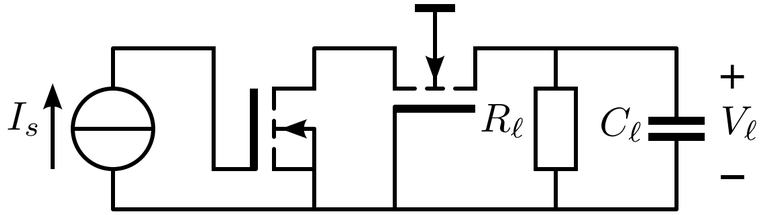

Strong reduction of local capacitive feedback in the stage

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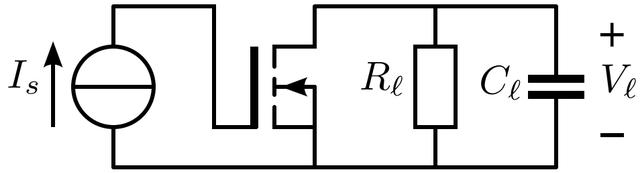

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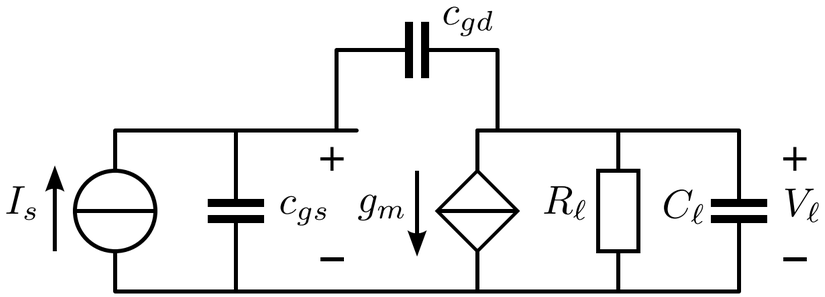

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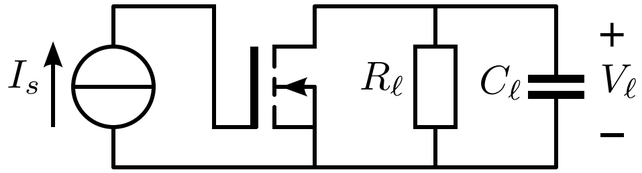

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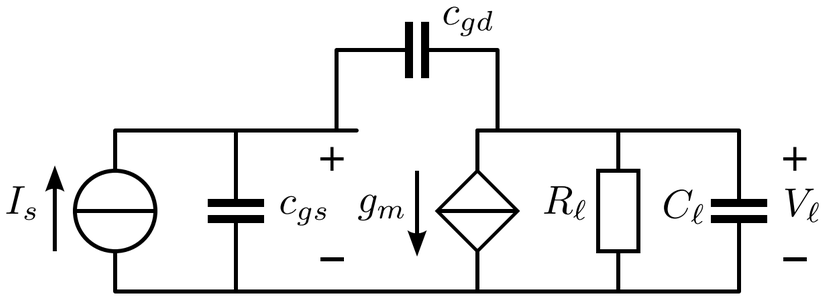

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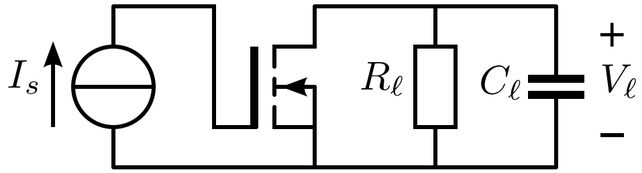

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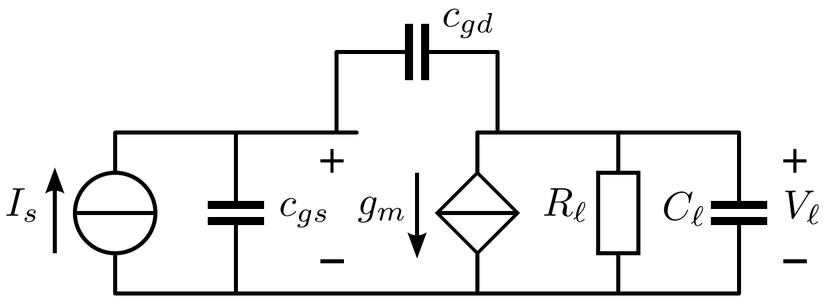

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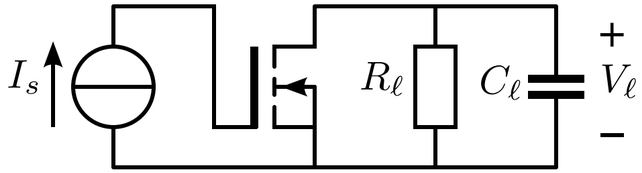

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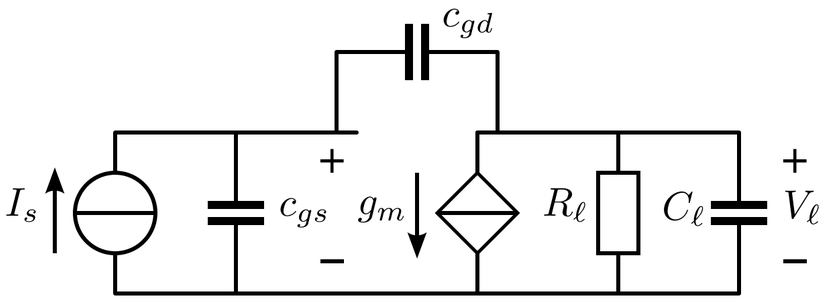

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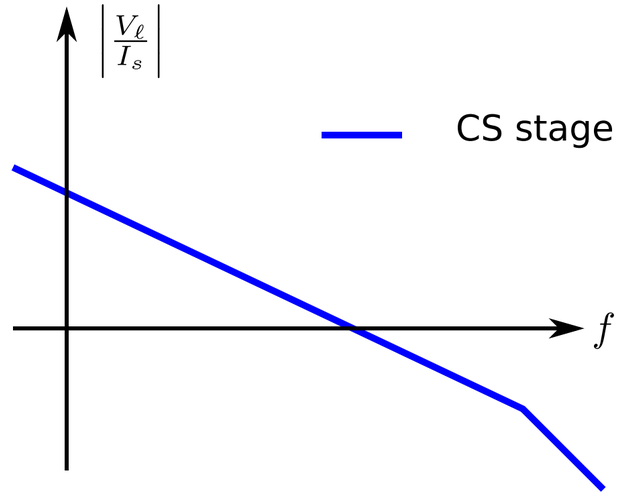
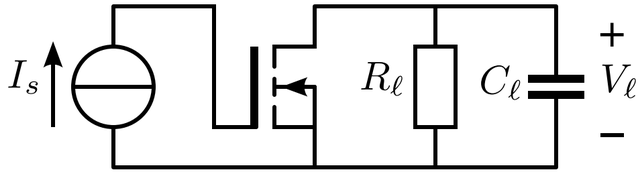


Miller-effect and cascode stage

Biased, current-driven CS-stage with RC load



Biased, current-driven cascode stage with RC load

Local capacitive feedback in the stage

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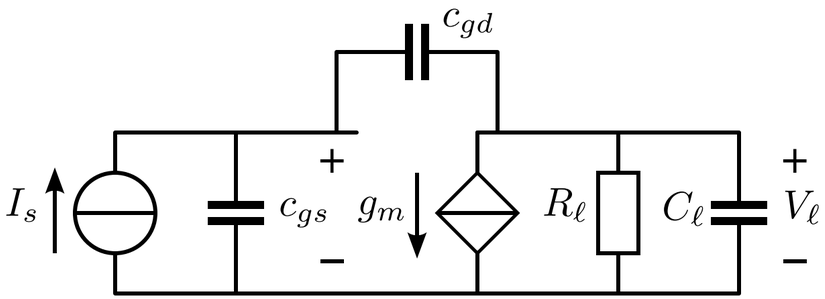

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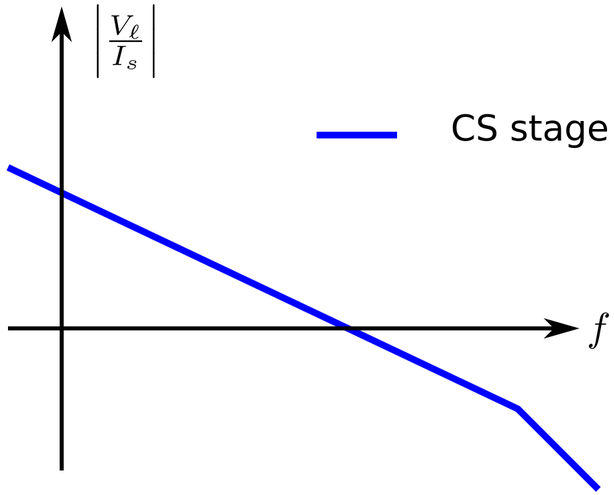

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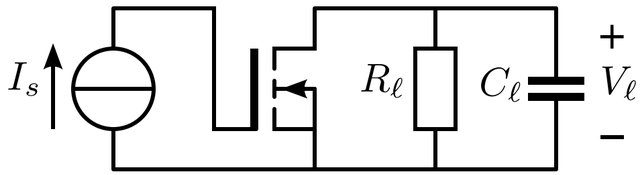

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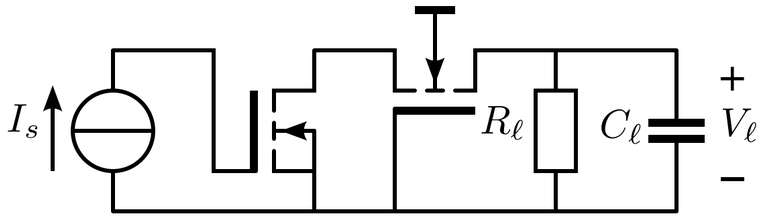

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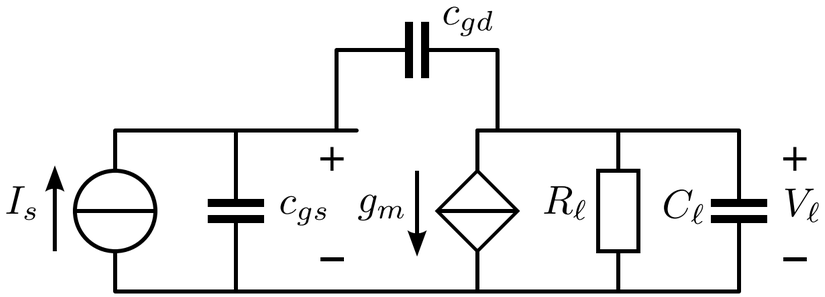

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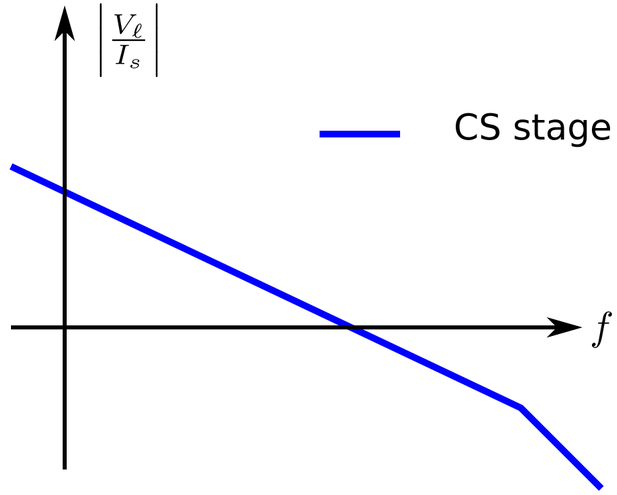

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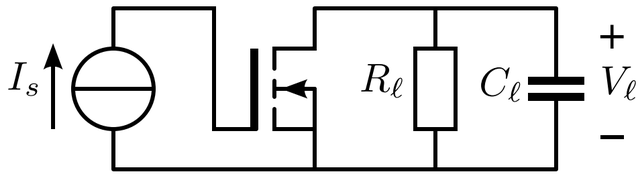

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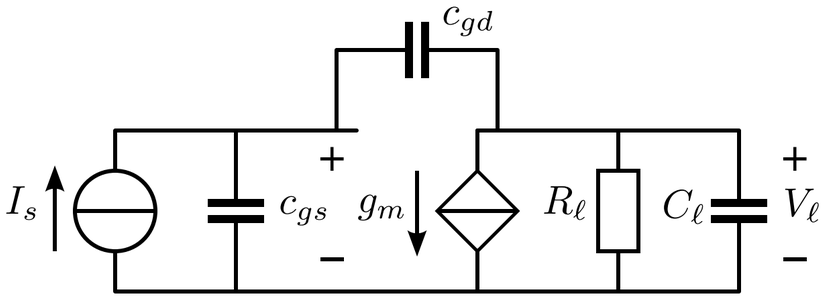

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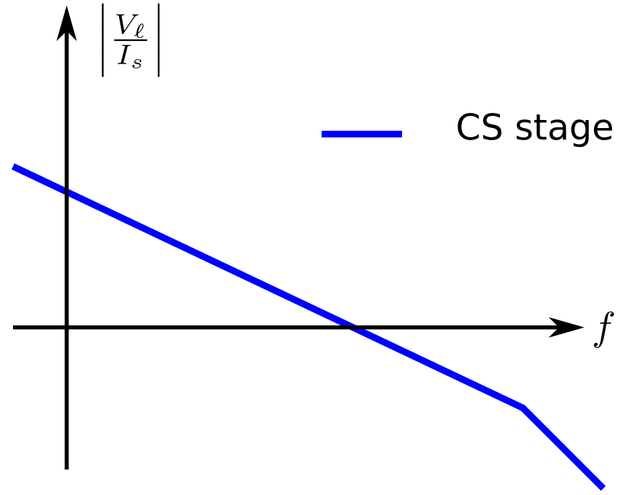

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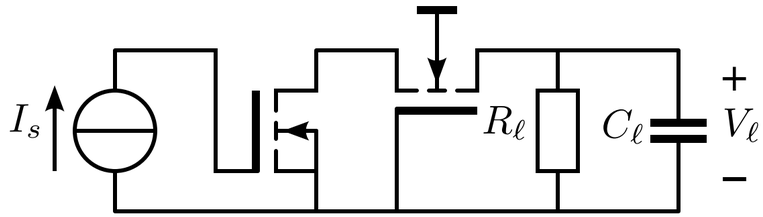

Strong reduction of local capacitive feedback in the stage

Miller-effect and cascode stage

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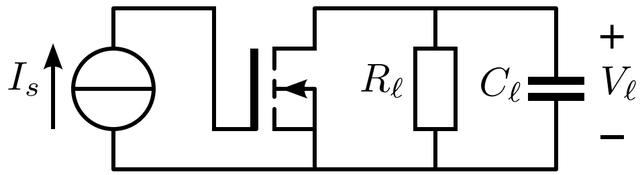

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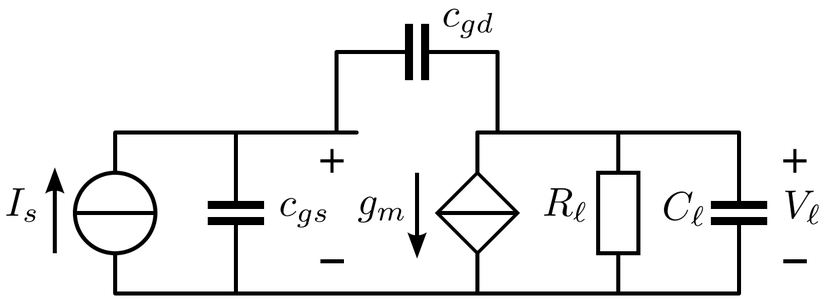

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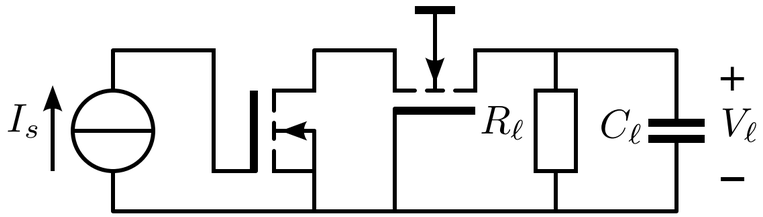

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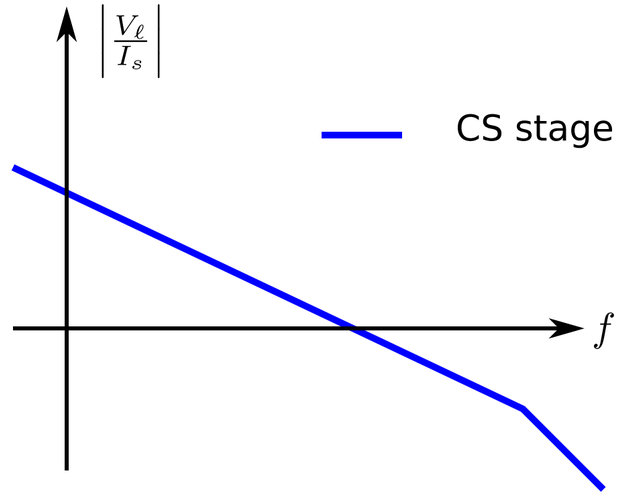

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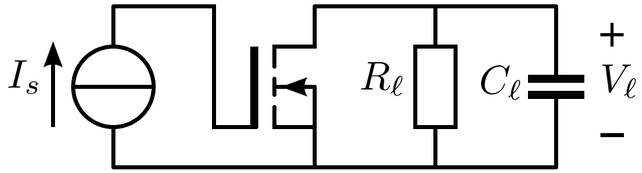

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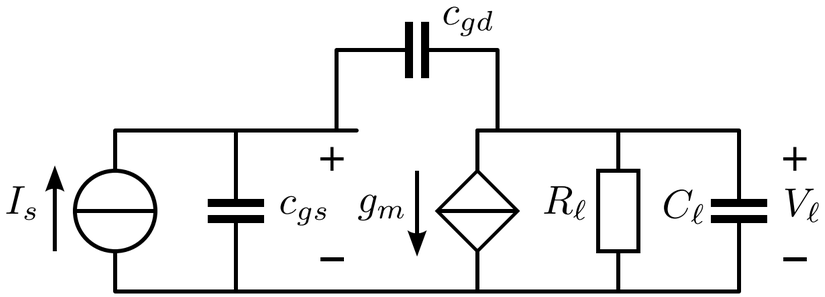

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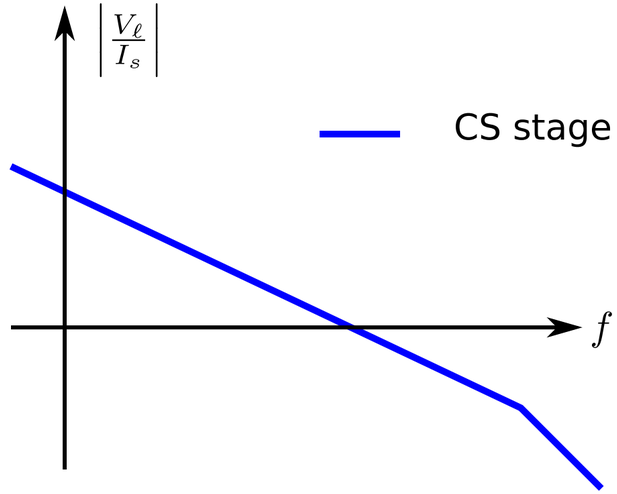

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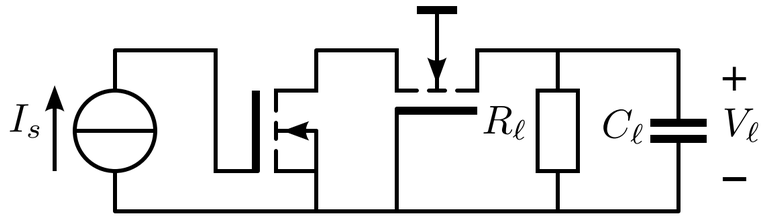

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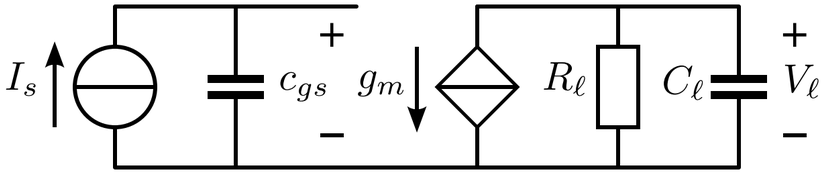

Miller-effect and cascode stage

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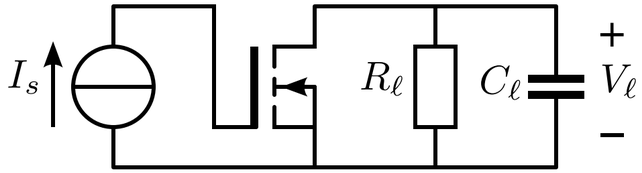

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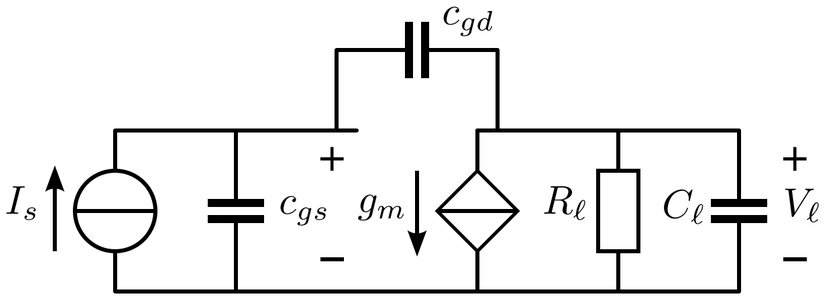

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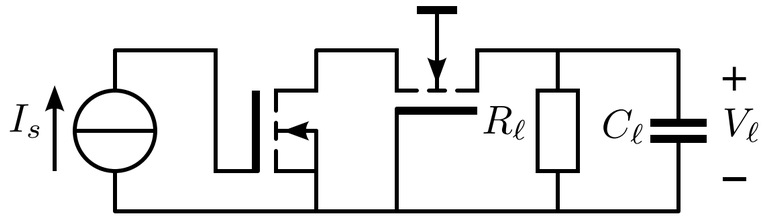

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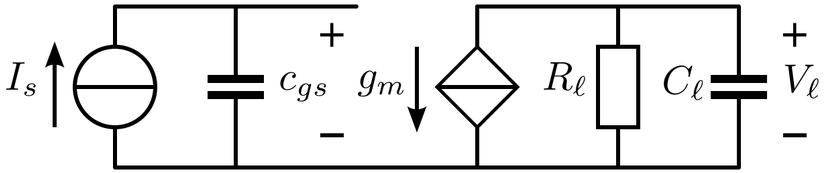

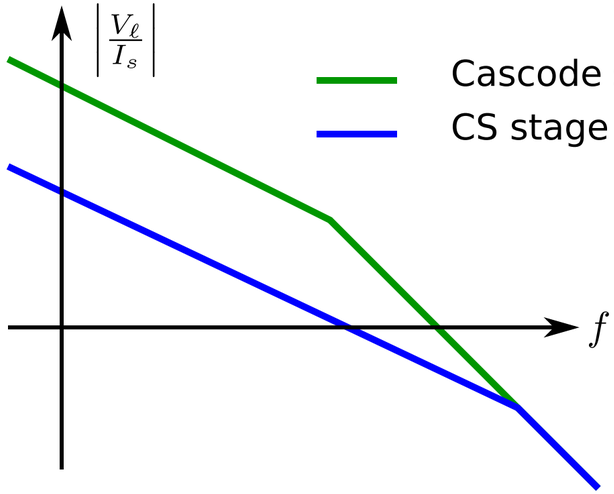

Cascode stage

CS stage

Miller-effect and cascode stage

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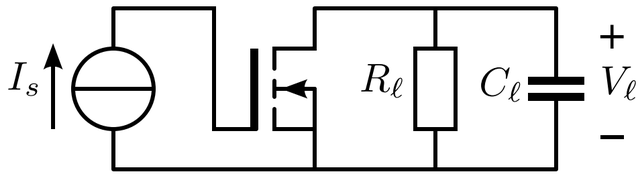

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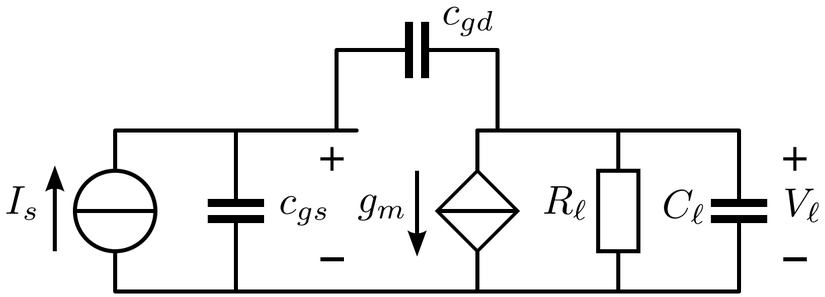

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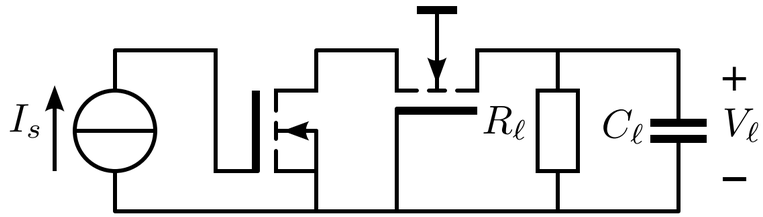

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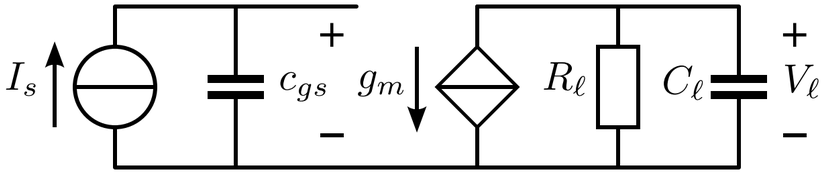

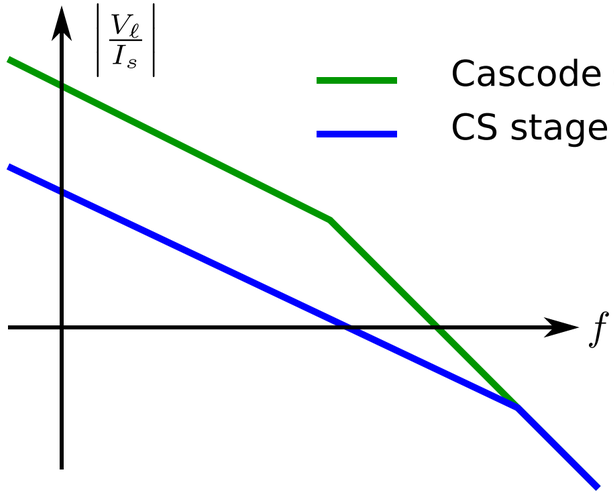

Cascode stage

CS stage

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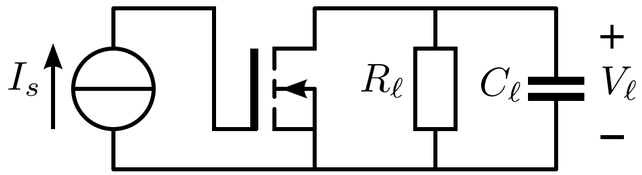

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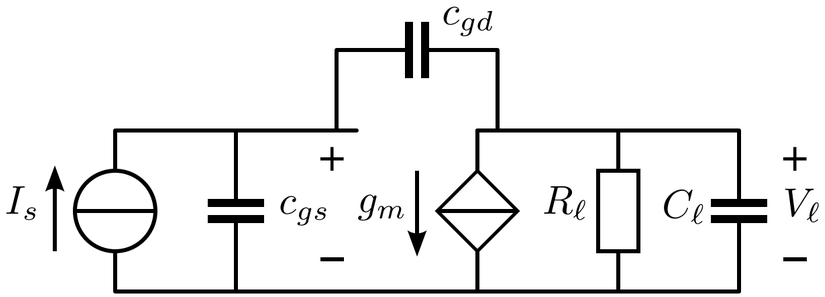

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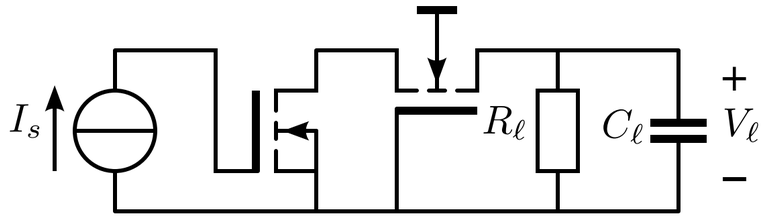

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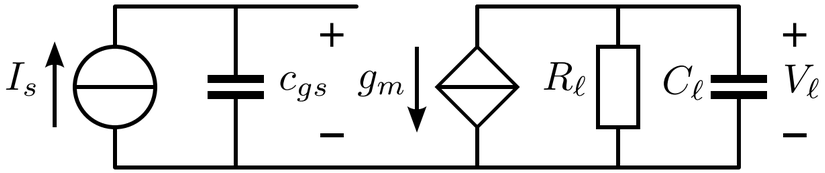

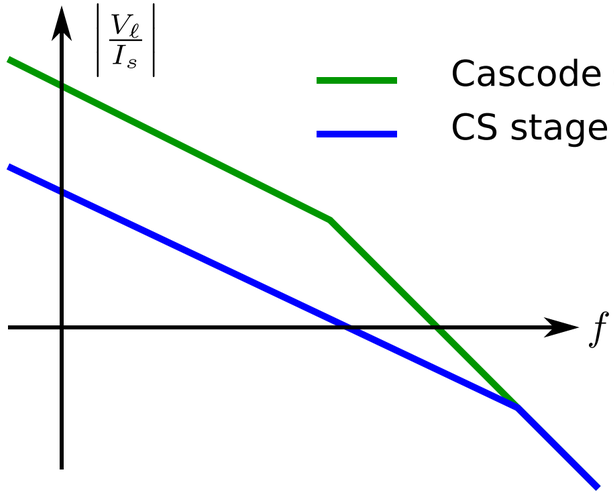

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Miller-effect and cascode stage

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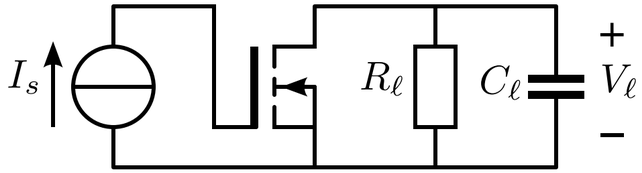

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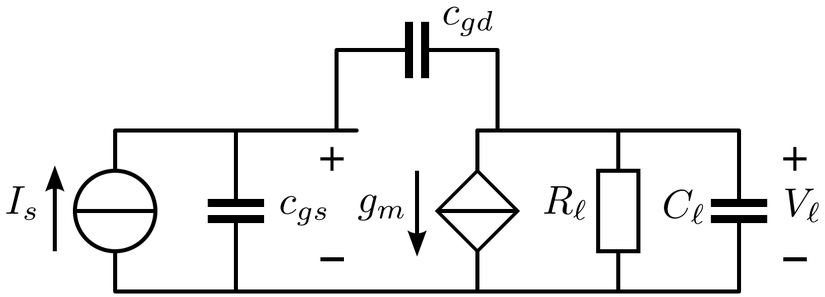

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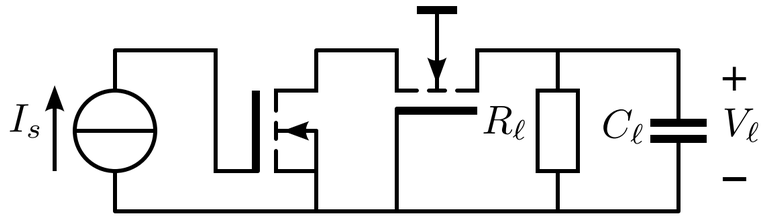

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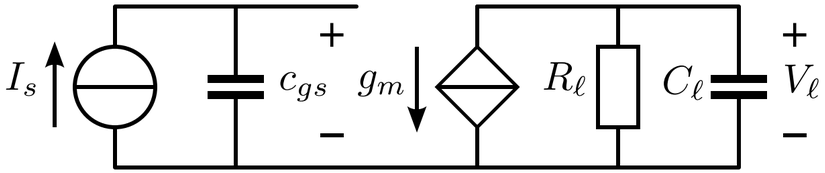

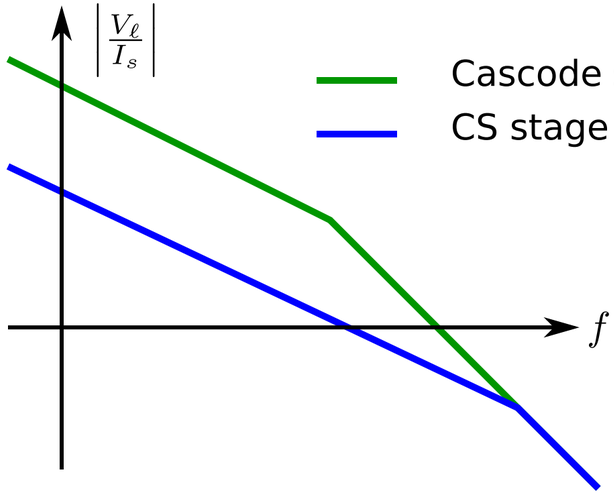

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Uni-lateral stage

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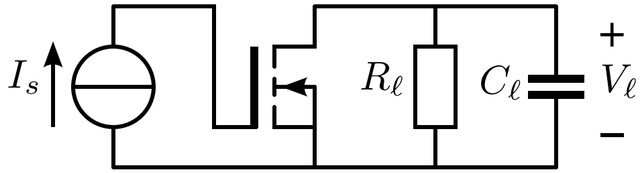

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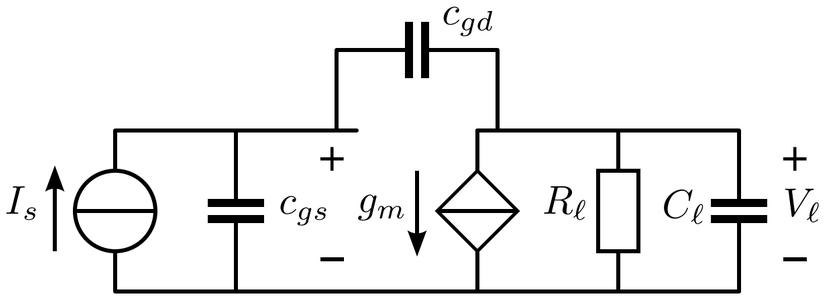

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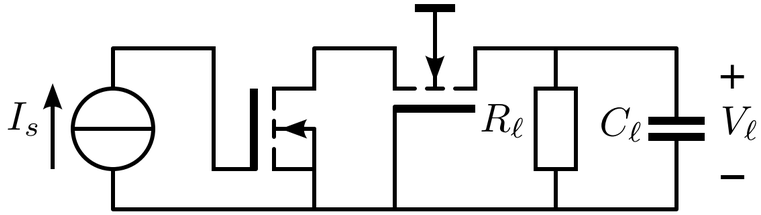

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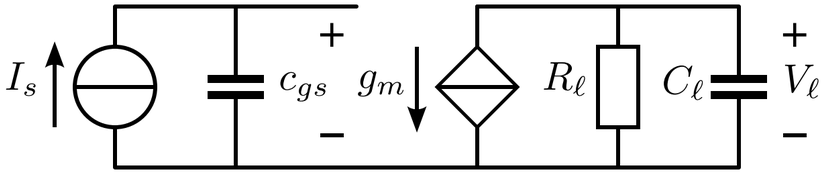

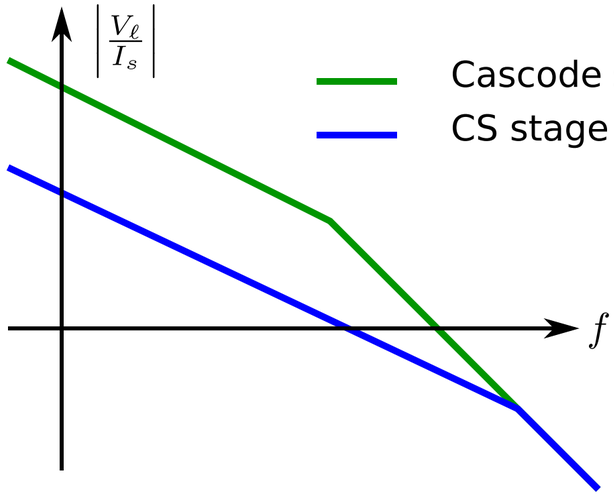

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Uni-lateral stage

Structured Electronic Design

EE4109
Controller design:
Preferred stages

Anton J.M. Montagne

Uni-lateral stages with maximum LP product contribution

Uni-lateral stages with maximum LP product contribution

Three-terminal

Uni-lateral stages with maximum LP product contribution

Three-terminal

inverting
CS-CG cascode stage

Uni-lateral stages with maximum LP product contribution

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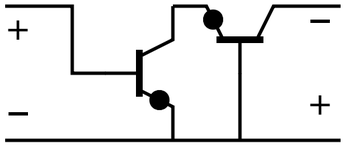

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Three-terminal

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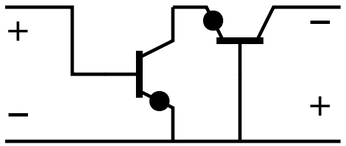
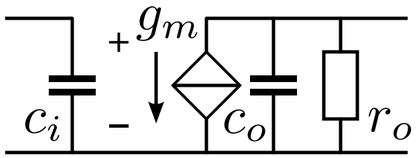


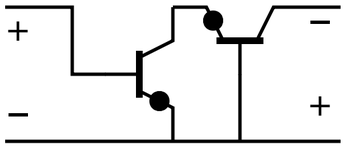


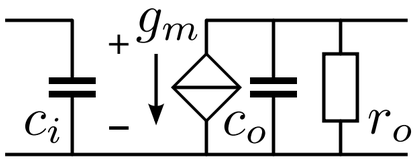
Uni-lateral stages with maximum LP product contribution

Three-terminal

inverting
CS-CG cascode stage

non-inverting
CD-CG cascode stage

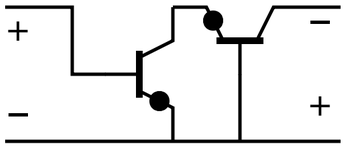




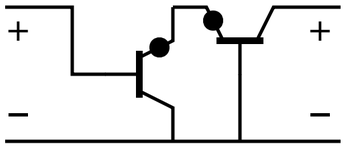
Uni-lateral stages with maximum LP product contribution

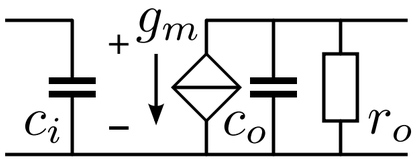
Three-terminal

inverting
CS-CG cascode stage



non-inverting
CD-CG cascode stage

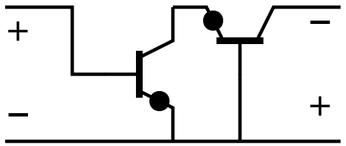


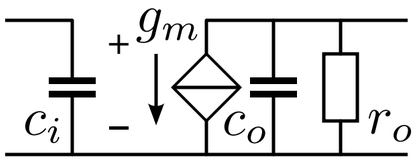


Uni-lateral stages with maximum LP product contribution

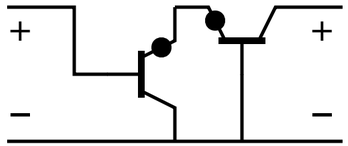
Three-terminal

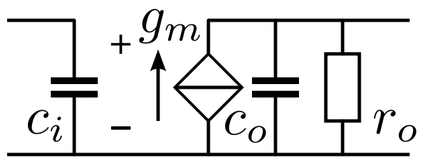
inverting
CS-CG cascode stage





non-inverting
CD-CG cascode stage





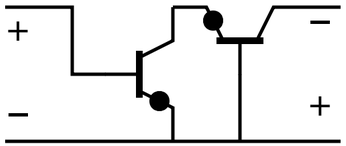
Uni-lateral stages with maximum LP product contribution

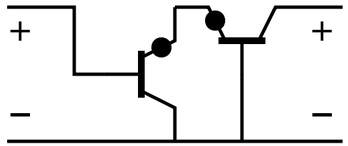
Three-terminal

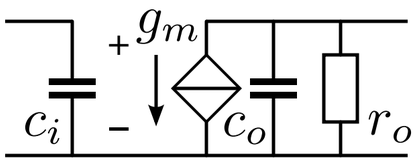
Four-terminal

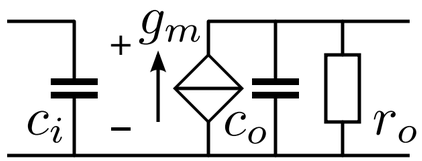
inverting
CS-CG cascode stage

non-inverting
CD-CG cascode stage









Uni-lateral stages with maximum LP product contribution

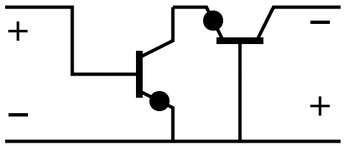
Three-terminal

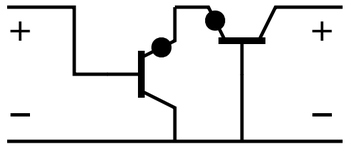
Four-terminal

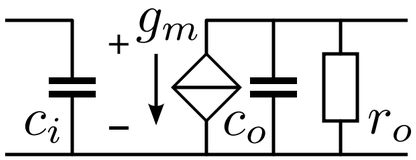
inverting
CS-CG cascode stage

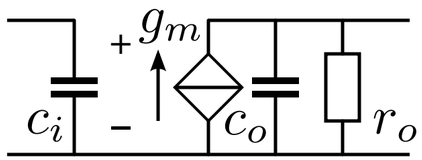
non-inverting
CD-CG cascode stage

differential pair
cascode stage









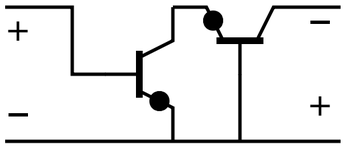
$$g_m = g_{m_1} \quad c_i = c_{gs_1} + c_{gd_1} \quad c_o = c_{gd_2} + c_{db_2}$$

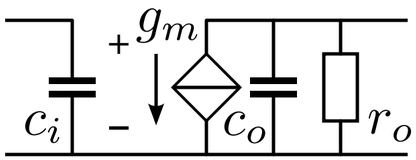
Current driven: $r_o = \left(1 + g_{m_1} r_{o_1}\right) r_{o_2}$

Uni-lateral stages with maximum LP product contribution

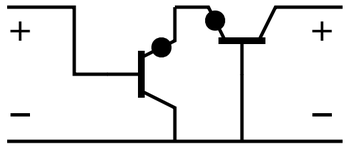
Three-terminal

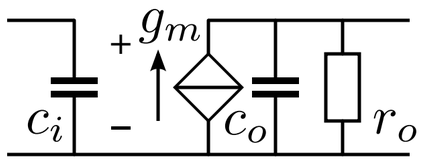
inverting
CS-CG cascode stage





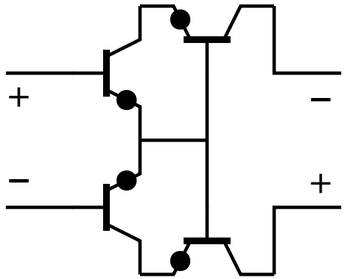
non-inverting
CD-CG cascode stage





Four-terminal

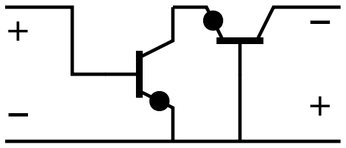
differential pair
cascode stage

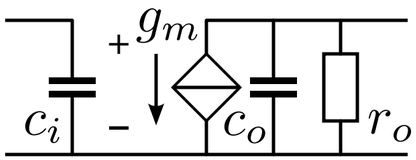


Uni-lateral stages with maximum LP product contribution

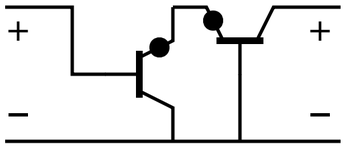
Three-terminal

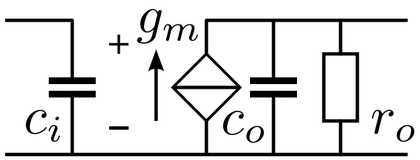
inverting
CS-CG cascode stage





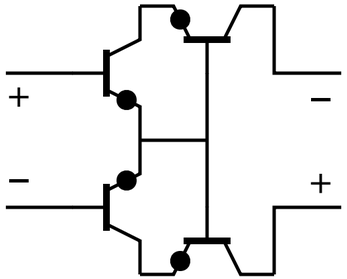
non-inverting
CD-CG cascode stage

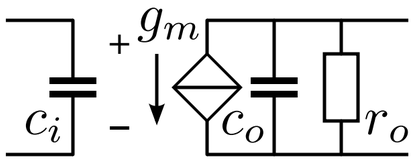




Four-terminal

differential pair
cascode stage

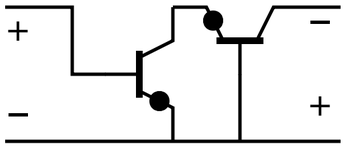


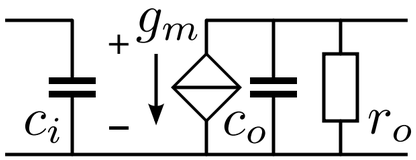


Uni-lateral stages with maximum LP product contribution

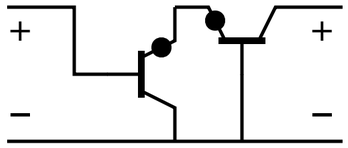
Three-terminal

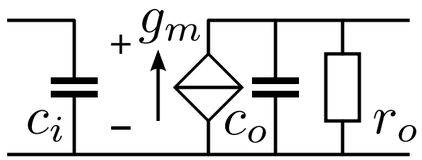
inverting
CS-CG cascode stage





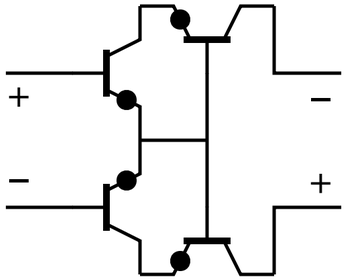
non-inverting
CD-CG cascode stage

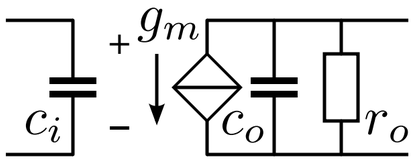




Four-terminal

differential pair
cascode stage



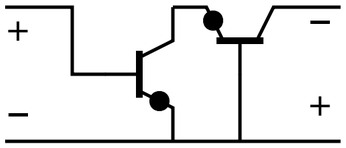


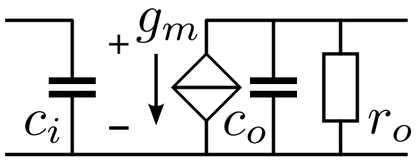
$g_m = g_{m_1}$

Uni-lateral stages with maximum LP product contribution

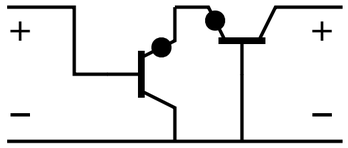
Three-terminal

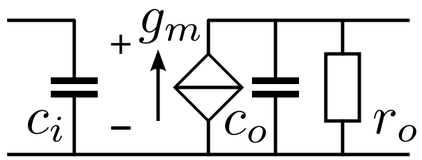
inverting
CS-CG cascode stage





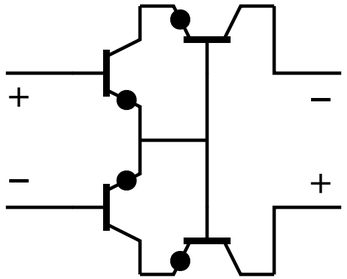
non-inverting
CD-CG cascode stage

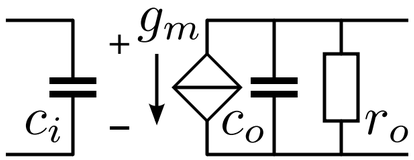




Four-terminal

differential pair
cascode stage





$$g_m = g_{m_1} \quad c_i = c_{gs_1} + c_{gd_1}$$

Uni-lateral stages with maximum LP product contribution

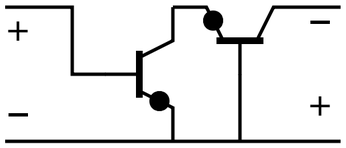
Three-terminal

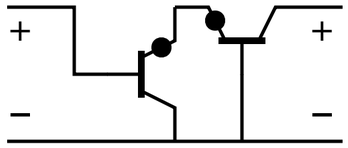
Four-terminal

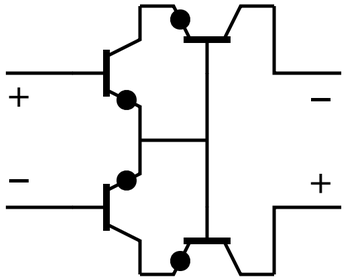
inverting
CS-CG cascode stage

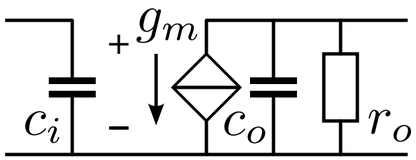
non-inverting
CD-CG cascode stage

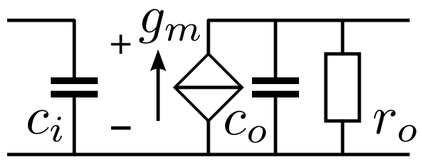
differential pair
cascode stage

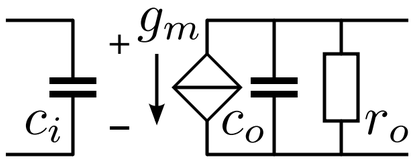












$$g_m = g_{m_1} \quad c_i = c_{gs_1} + c_{gd_1} \quad c_o = c_{gd_2} + c_{db_2}$$

Uni-lateral stages with maximum LP product contribution

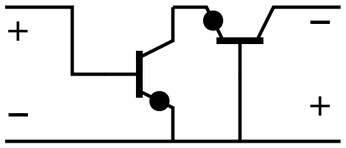
Three-terminal

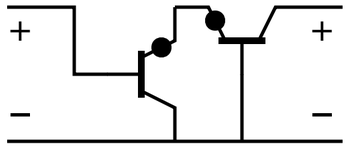
Four-terminal

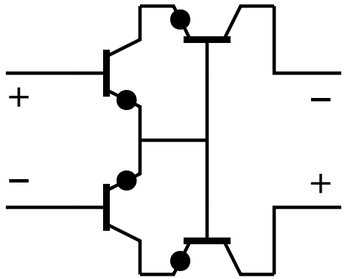
inverting
CS-CG cascode stage

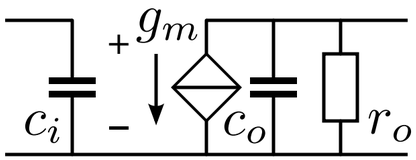
non-inverting
CD-CG cascode stage

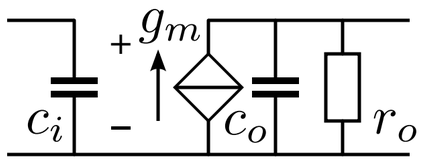
differential pair
cascode stage

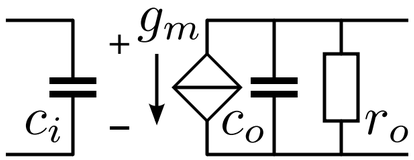












$$g_m = g_{m_1} \quad c_i = c_{gs_1} + c_{gd_1} \quad c_o = c_{gd_2} + c_{db_2}$$

Current driven:

Uni-lateral stages with maximum LP product contribution

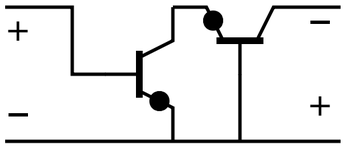
Three-terminal

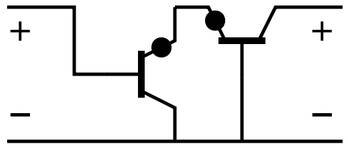
Four-terminal

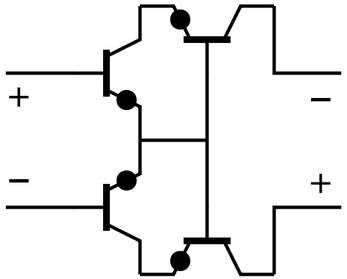
inverting
CS-CG cascode stage

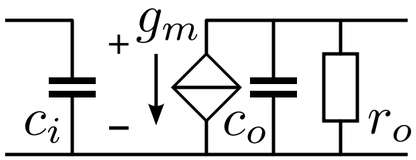
non-inverting
CD-CG cascode stage

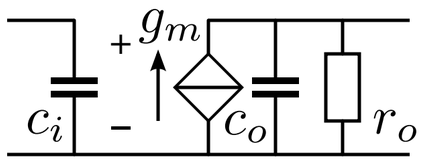
differential pair
cascode stage

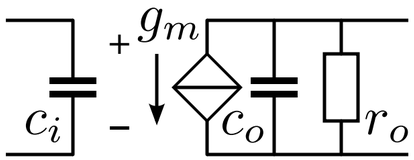












$$g_m = g_{m_1} \quad c_i = c_{gs_1} + c_{gd_1} \quad c_o = c_{gd_2} + c_{db_2}$$

Current driven: $r_o = \left(1 + g_{m_1} r_{o_1}\right) r_{o_2}$

Uni-lateral stages with maximum LP product contribution

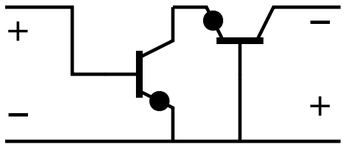
Three-terminal

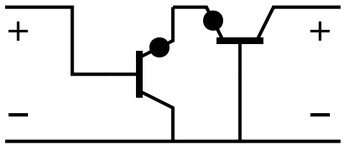
Four-terminal

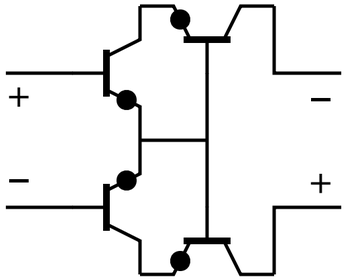
inverting
CS-CG cascode stage

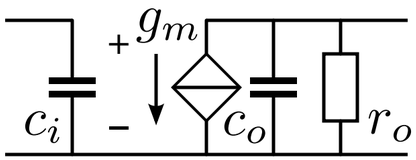
non-inverting
CD-CG cascode stage

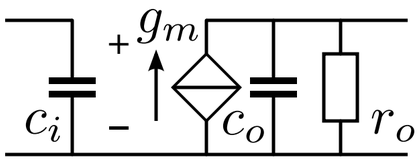
differential pair
cascode stage

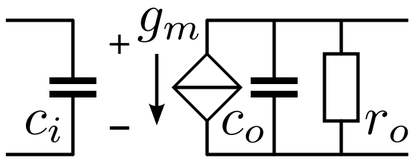












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Number of stages

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Rough estimation based upon required bandwidth:

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ELSE: Design cascade connection of two amplifiers

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ELSE: Design cascade connection of two amplifiers

Structured Electronic Design

EE4109
Controller design:
Interconnection of stages

Anton J.M. Montagne

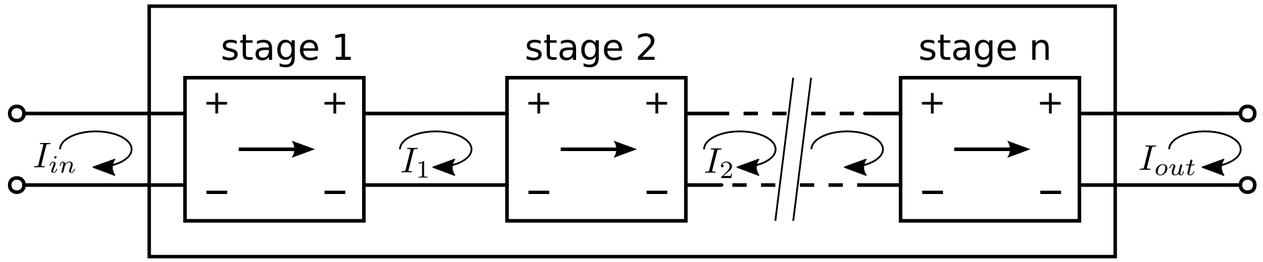
Interconnection of stages

Interconnection of stages

Proper cascade connection

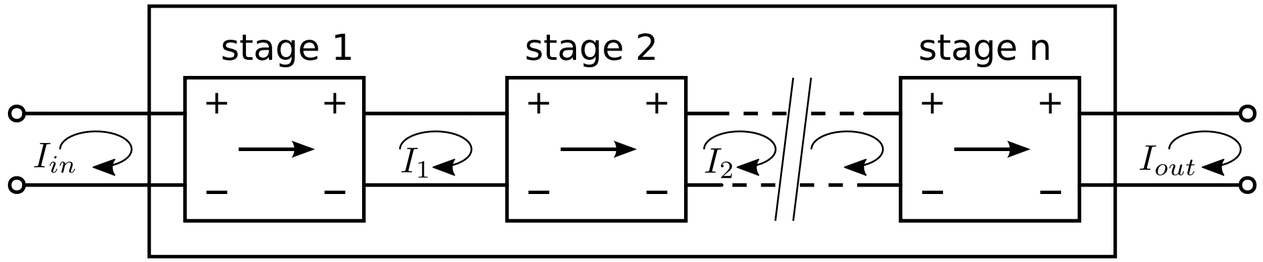
Interconnection of stages

Proper cascade connection



Interconnection of stages

Proper cascade connection



Examples two-stage controllers

Interconnection of stages

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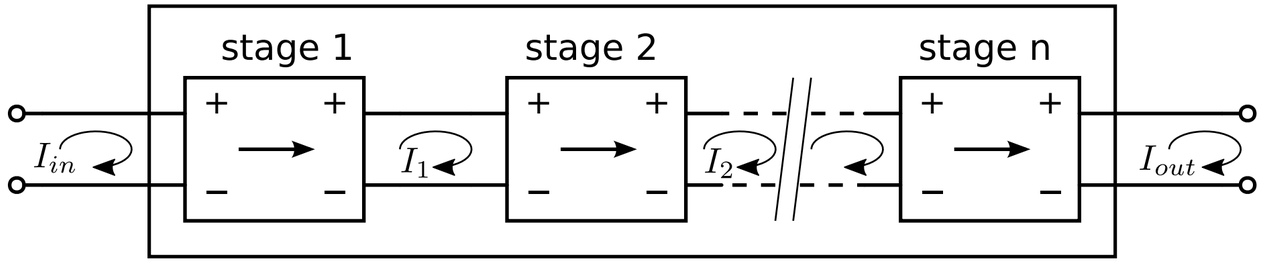

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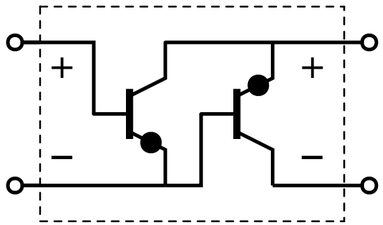

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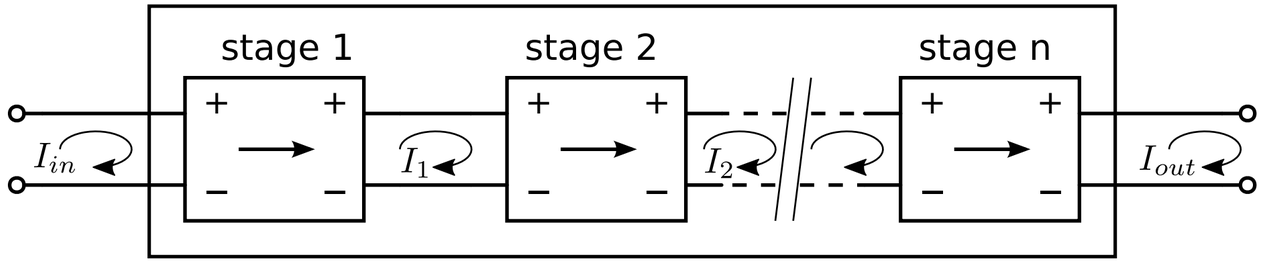

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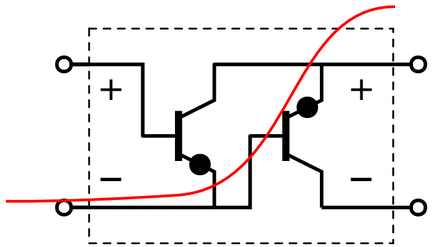

No port isolation.
Can only be used in combination with a transformer connected to one of the ports.

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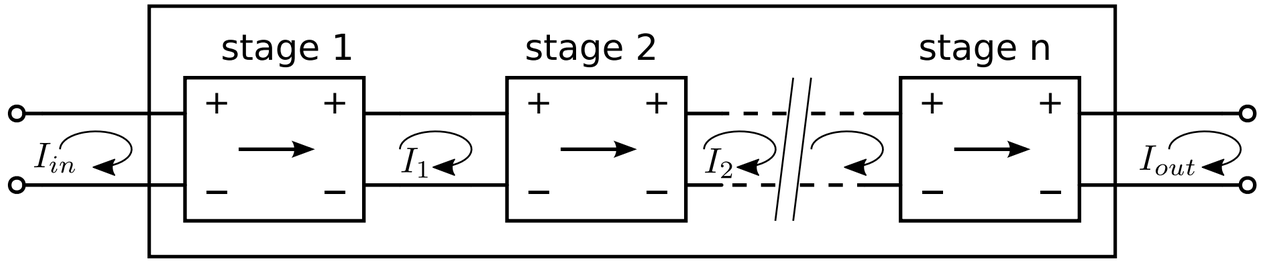

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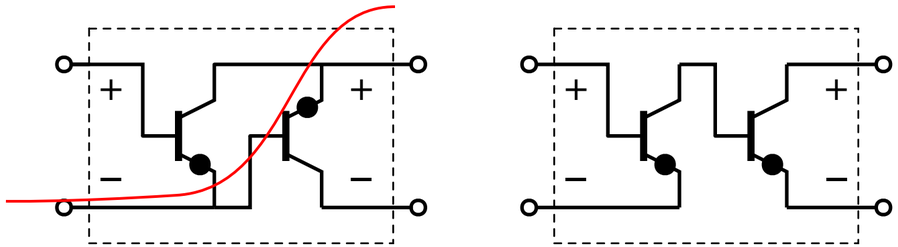

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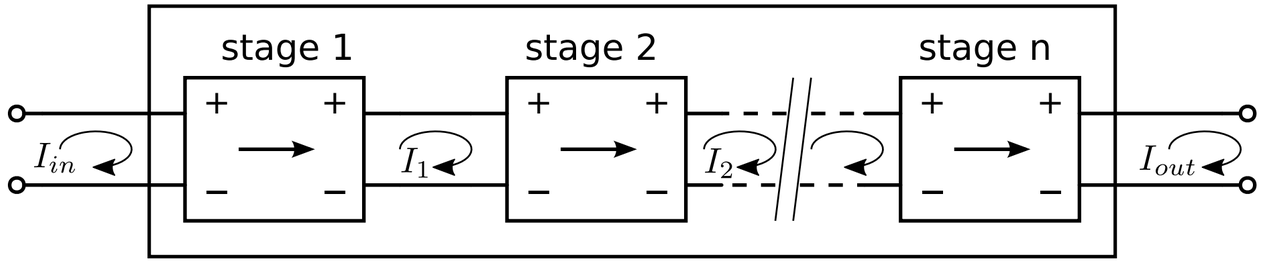

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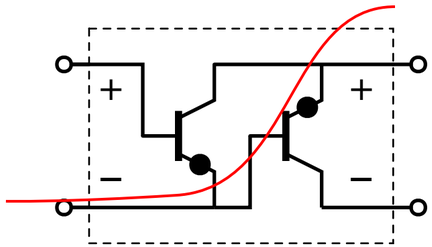

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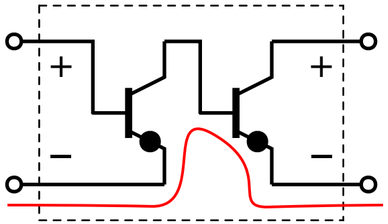
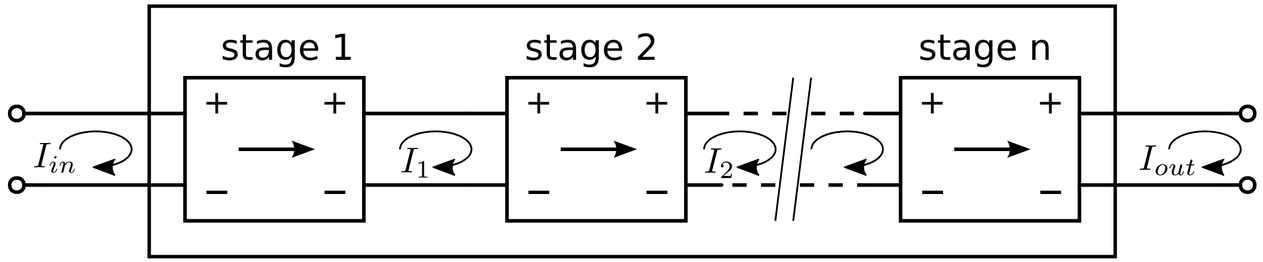


Simple two-transistor controller.
Input current of the second stage flows through the external network.

Interconnection of stages

Proper cascade connection



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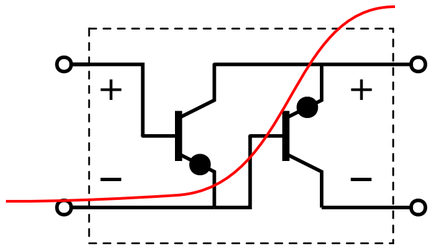

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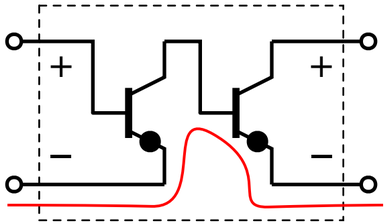

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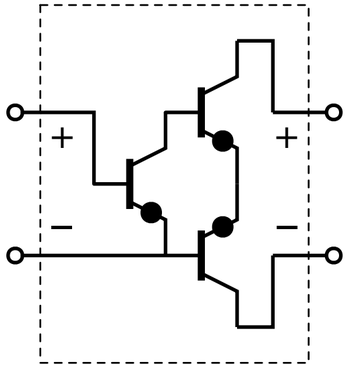

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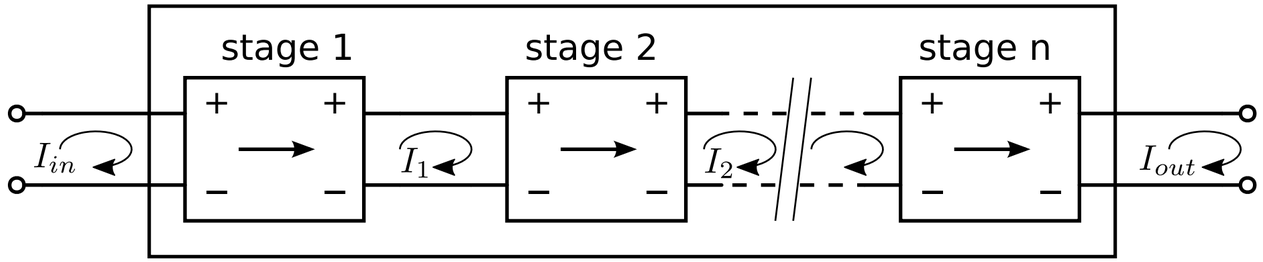

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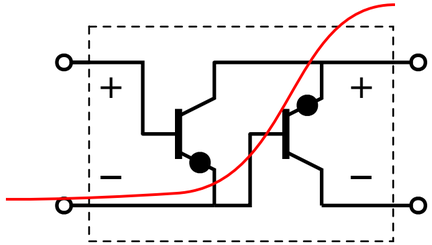

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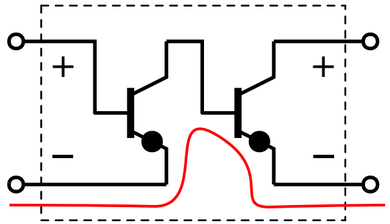

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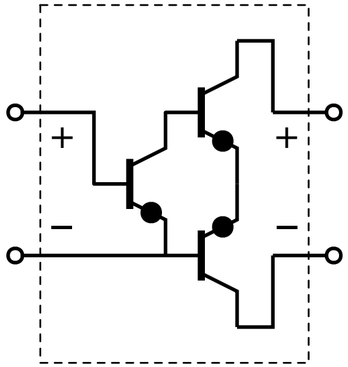
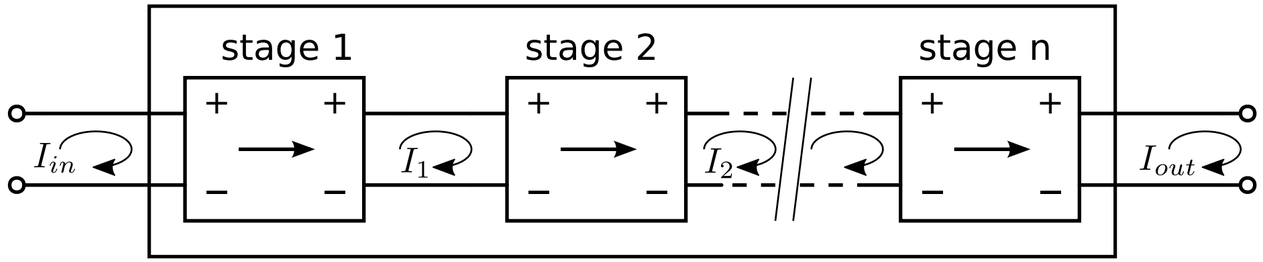


Two-stage controller with anti-series output stage.

Interconnection of stages

Proper cascade connection



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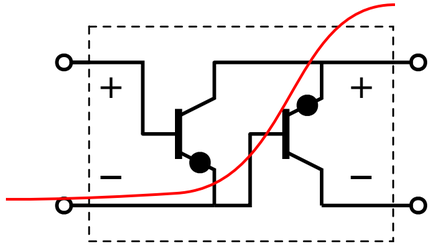

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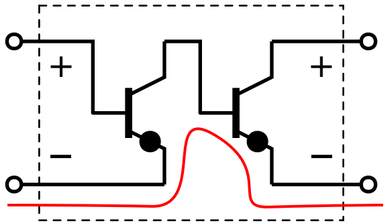

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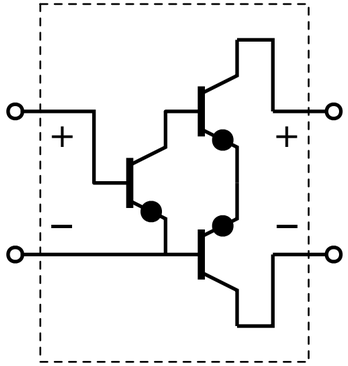

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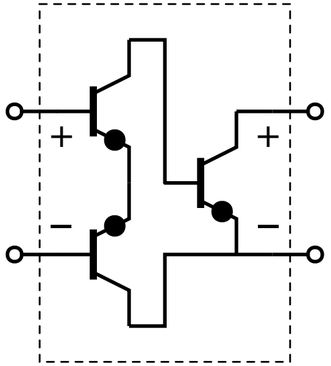
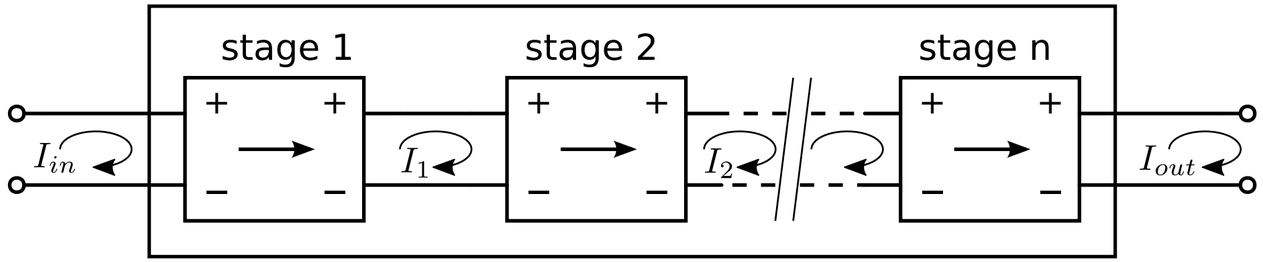


Interconnection of stages

Proper cascade connection



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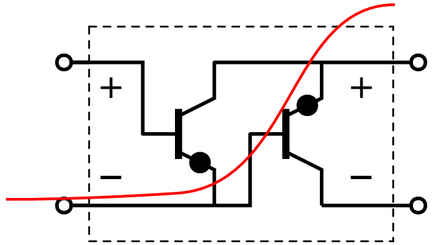

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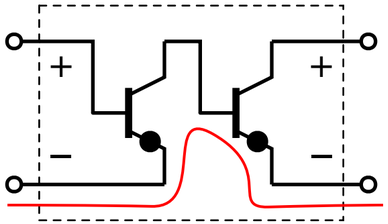

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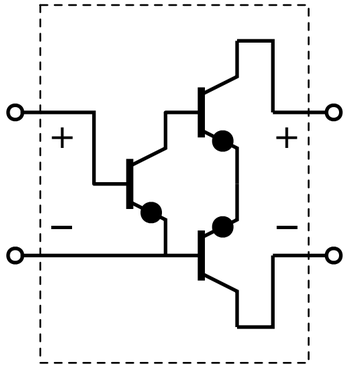
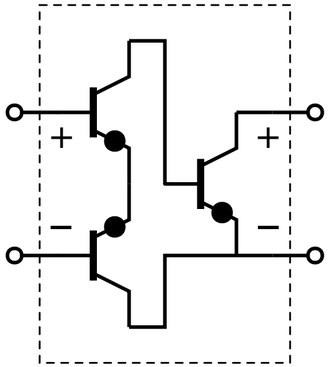


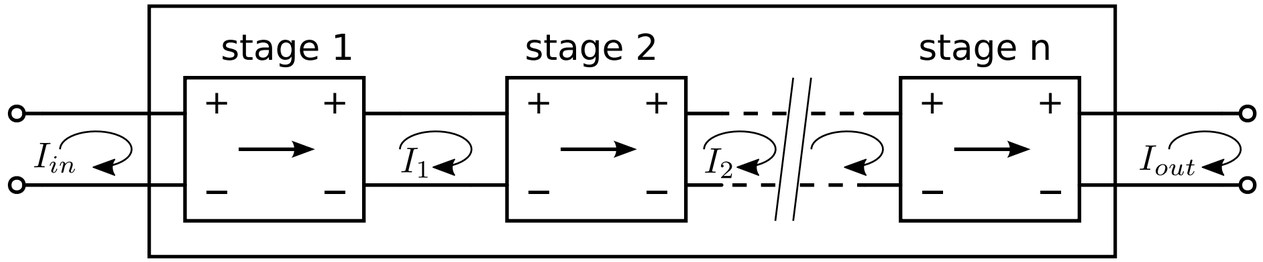
Two-stage controller with anti-series output stage.



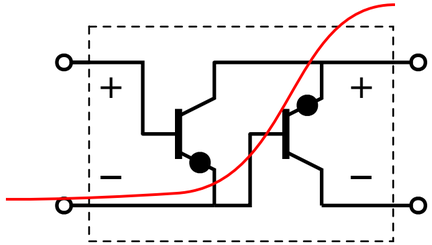
Two-stage controller with anti-series input stage.
A push-pull stage can be used for the second stage.

Interconnection of stages

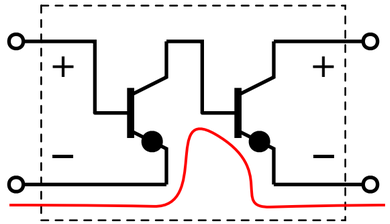
Proper cascade connection



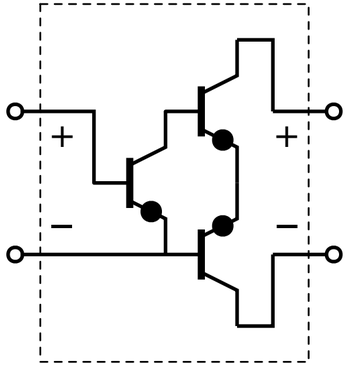
Examples two-stage controllers



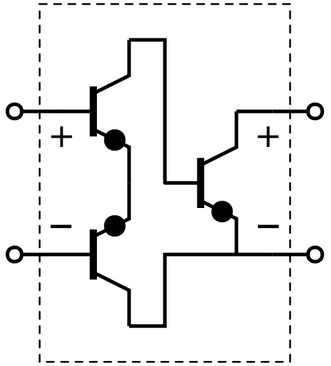
No port isolation.
Can only be used in combination with a transformer connected to one of the ports.



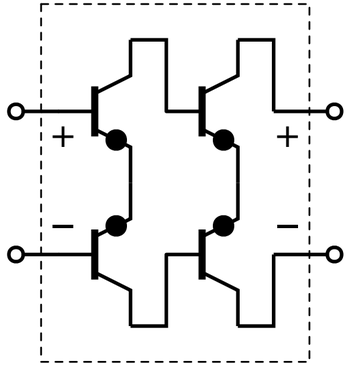
Simple two-transistor controller.
Input current of the second stage flows through the external network.



Two-stage controller with anti-series output stage.

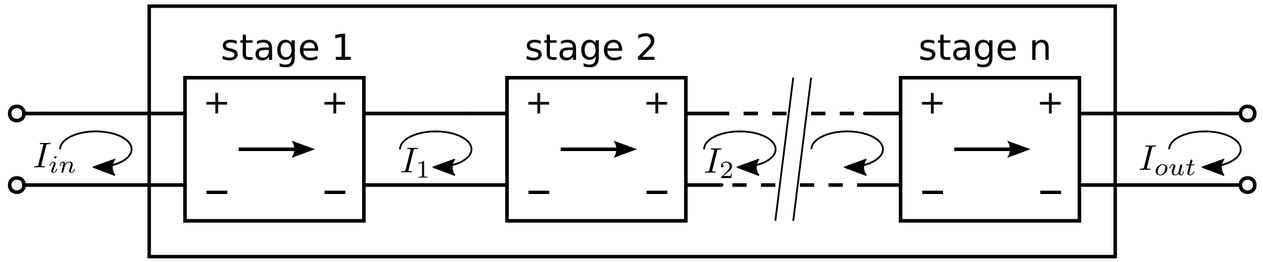


Two-stage controller with anti-series input stage.
A push-pull stage can be used for the second stage.

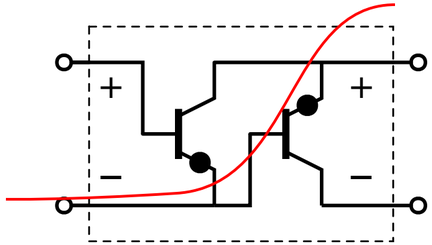


Interconnection of stages

Proper cascade connection



Examples two-stage controllers



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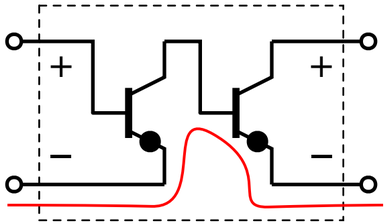

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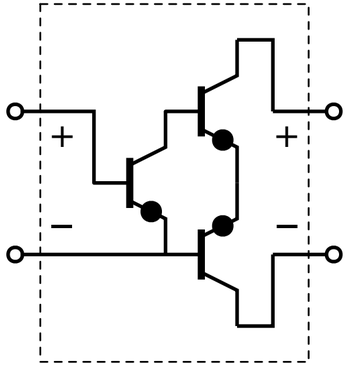
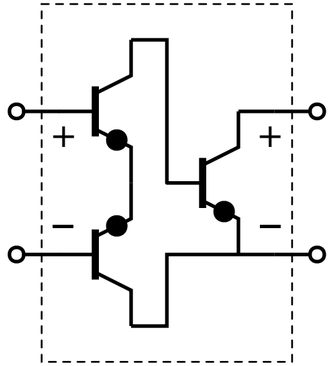


Two-stage controller with anti-series output stage.



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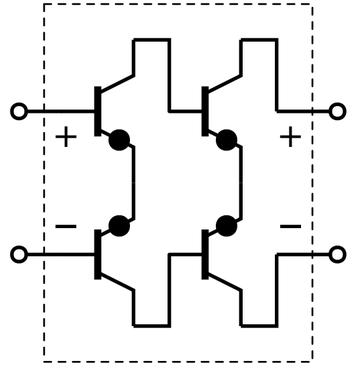
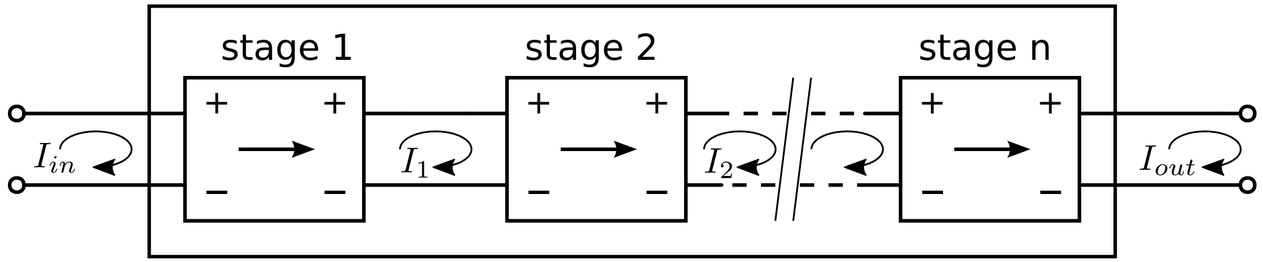


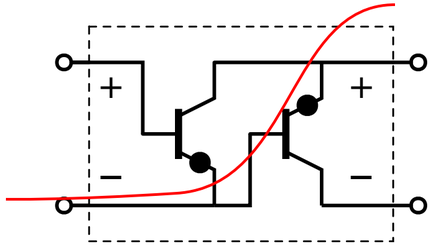
Fully balanced two-stage controller.

Interconnection of stages

Proper cascade connection



Examples two-stage controllers



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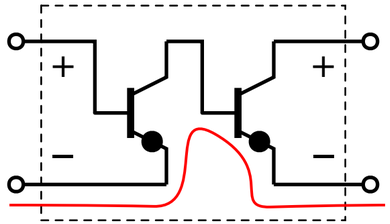

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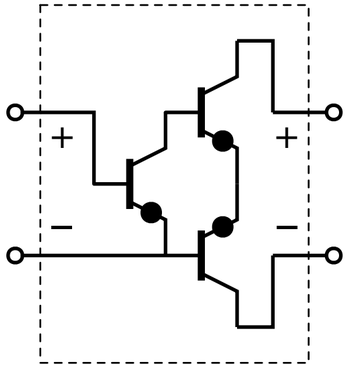
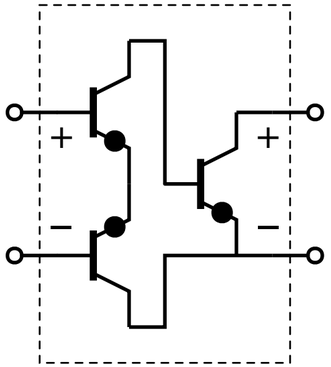


Two-stage controller with anti-series output stage.



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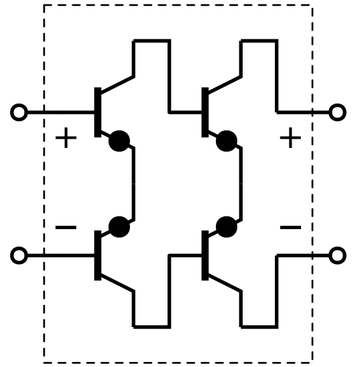

Fully balanced two-stage controller.

Interconnection of stages

Interconnection of stages

Four terminal controller options

Interconnection of stages

Four terminal controller options

Reverse connections of both
the input port and the output port

Interconnection of stages

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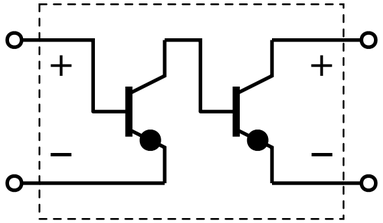

Interconnection of stages

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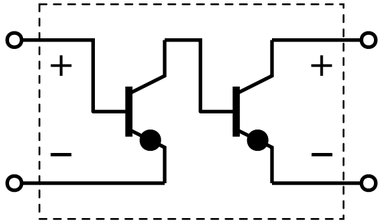

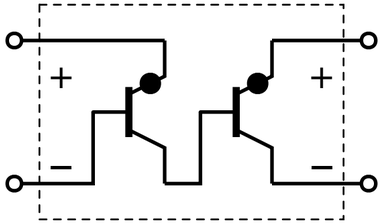

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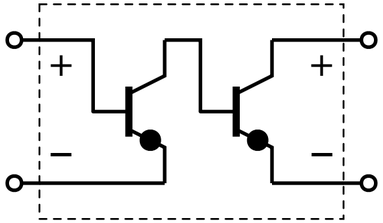

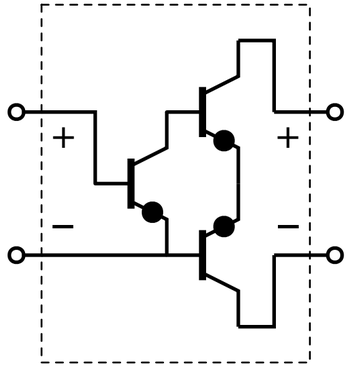

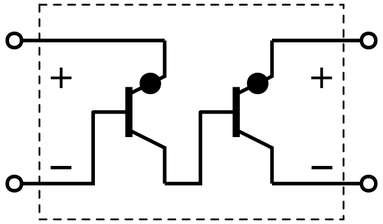

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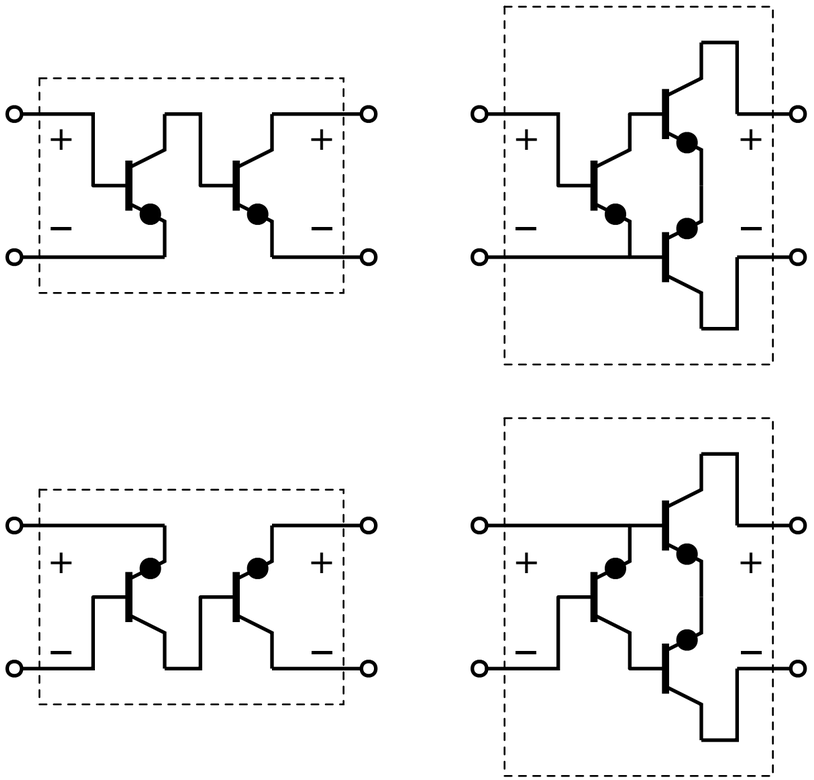

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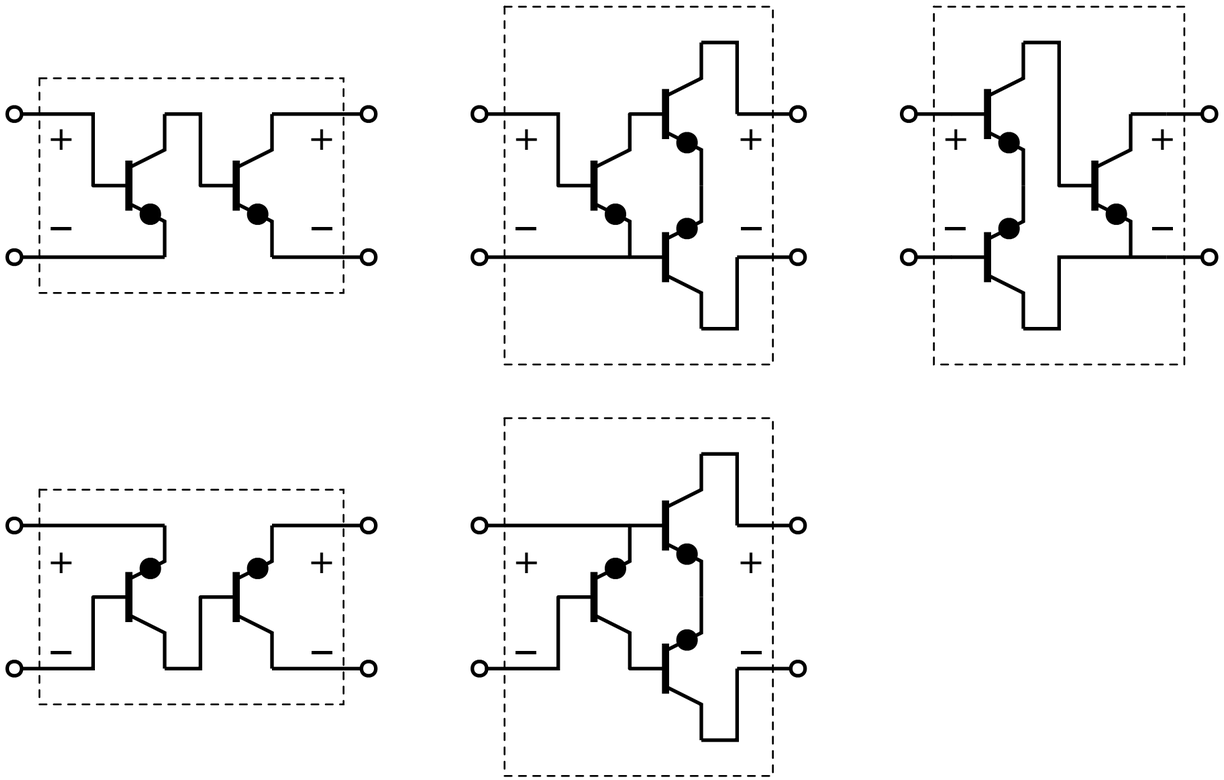

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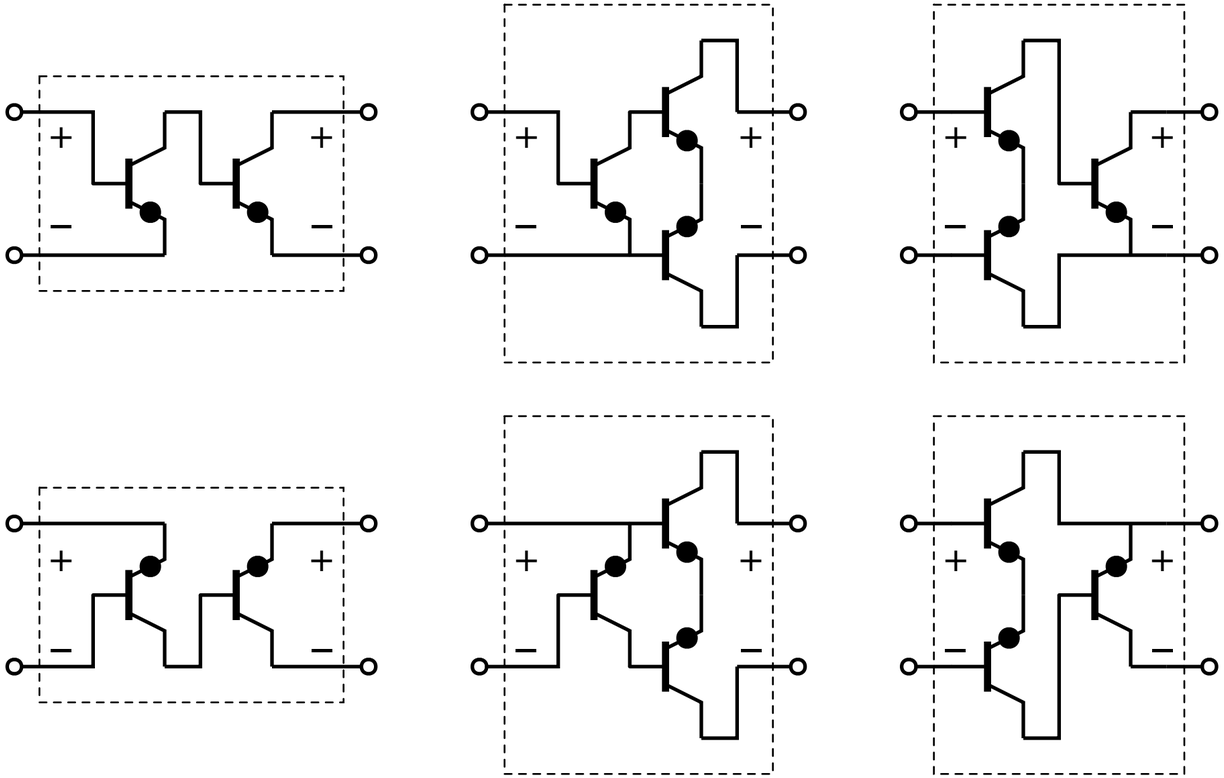

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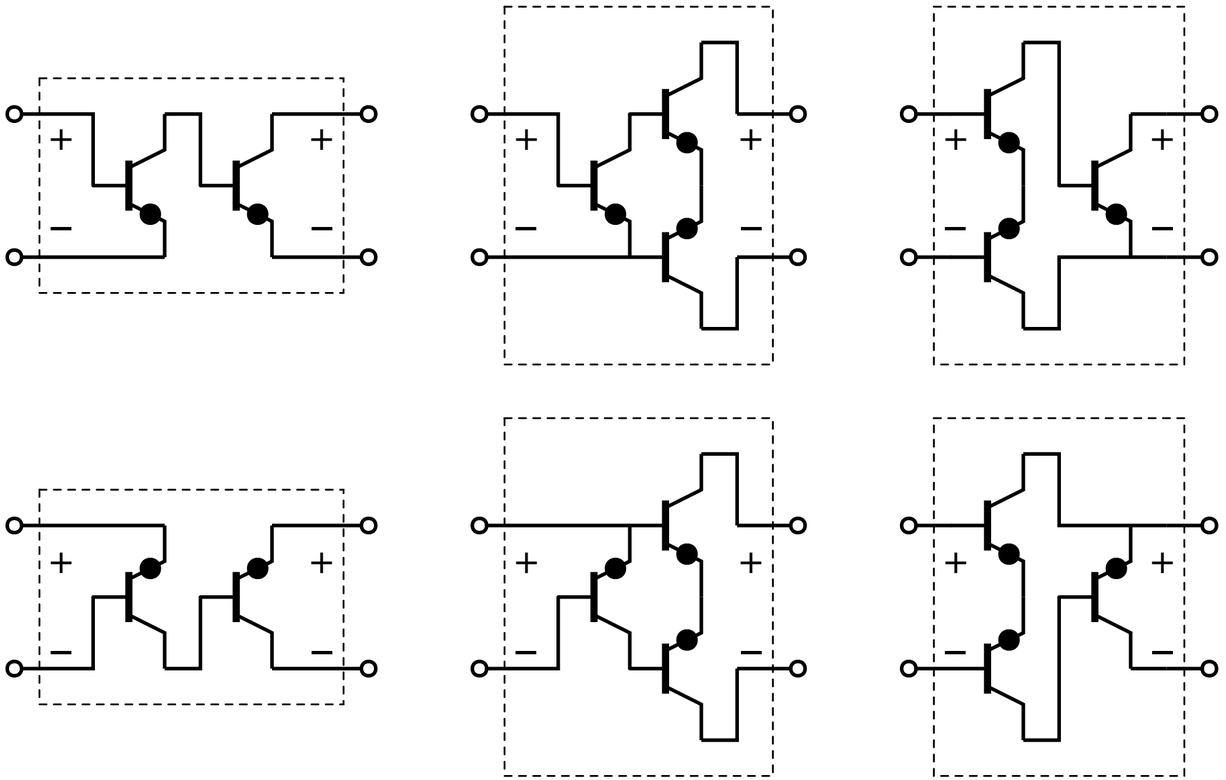

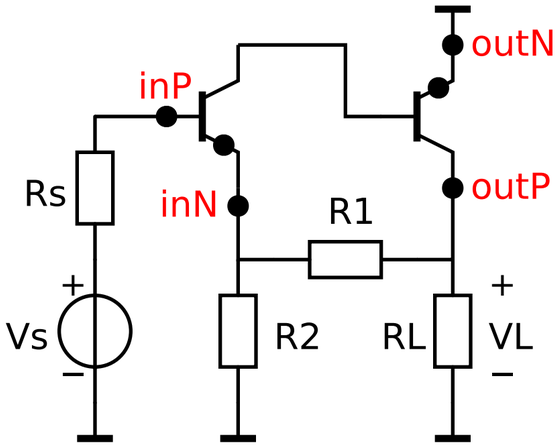

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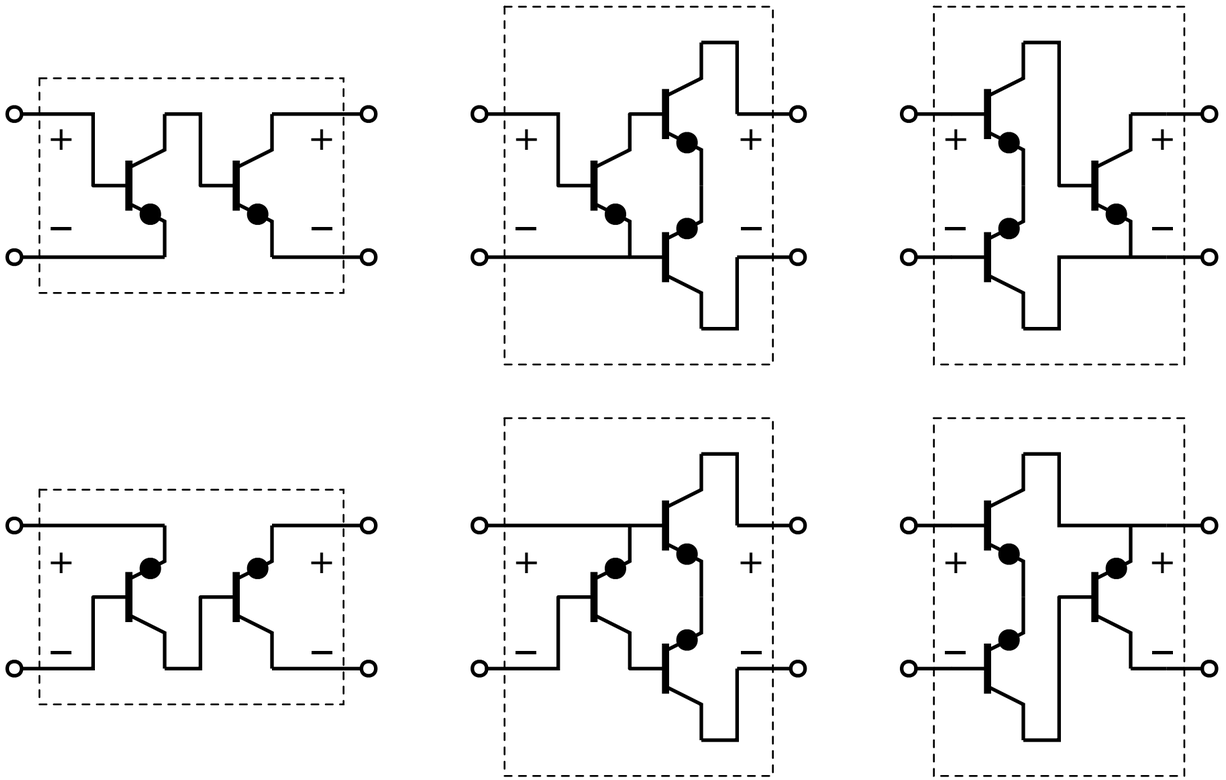

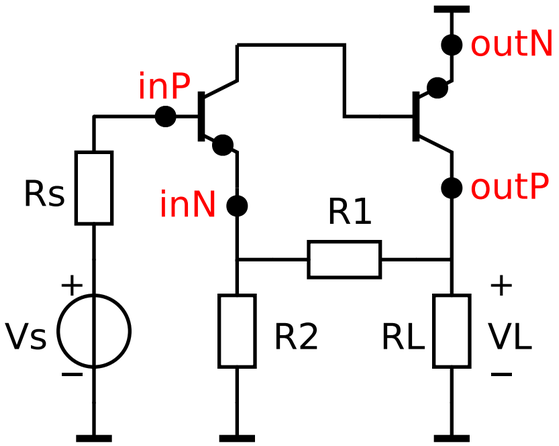

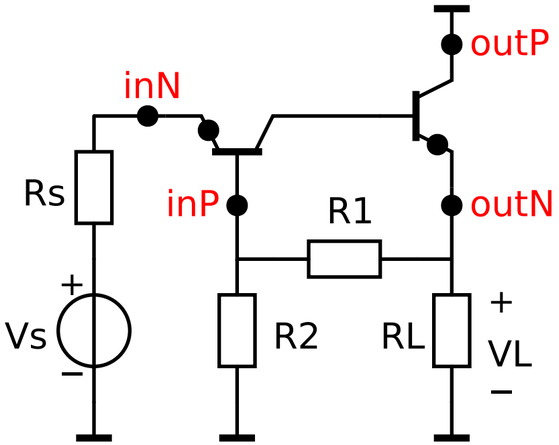

Interconnection of stages

Interconnection of stages

Port isolation considerations

Interconnection of stages

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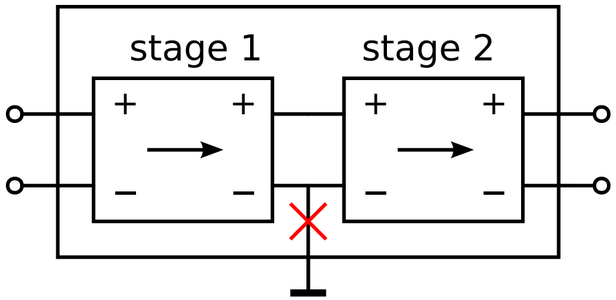

Interconnection of stages

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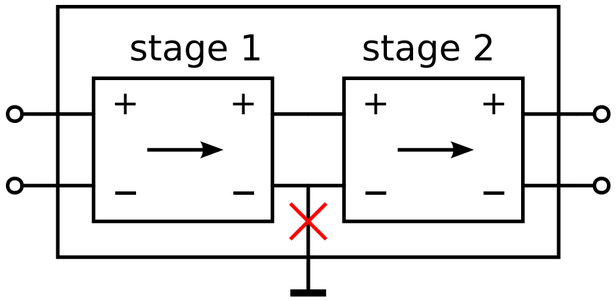
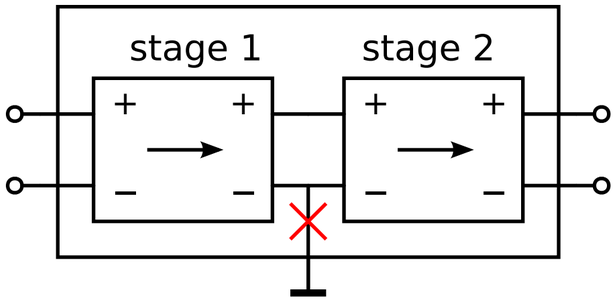


Internal ground connection:

Interconnection of stages

Port isolation considerations

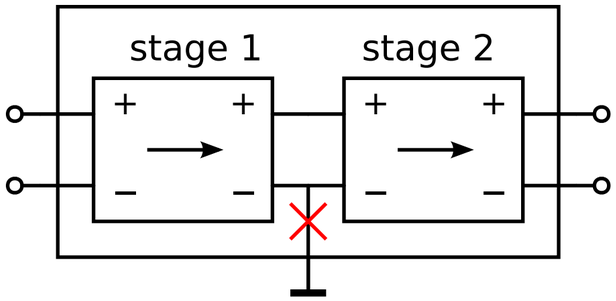


Internal ground connection:

Two-port conditions no longer valid.

Interconnection of stages

Port isolation considerations



Internal ground connection:

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Interconnection of stages

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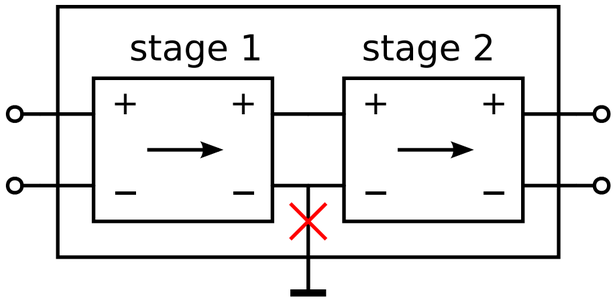

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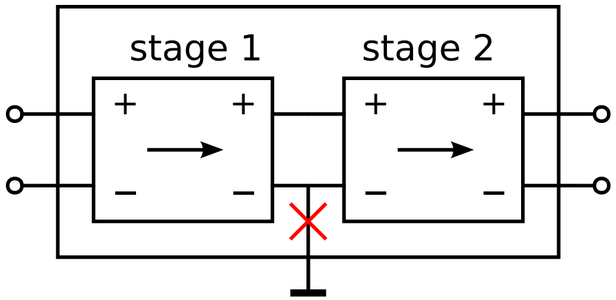
Interconnection of stages

Port isolation considerations



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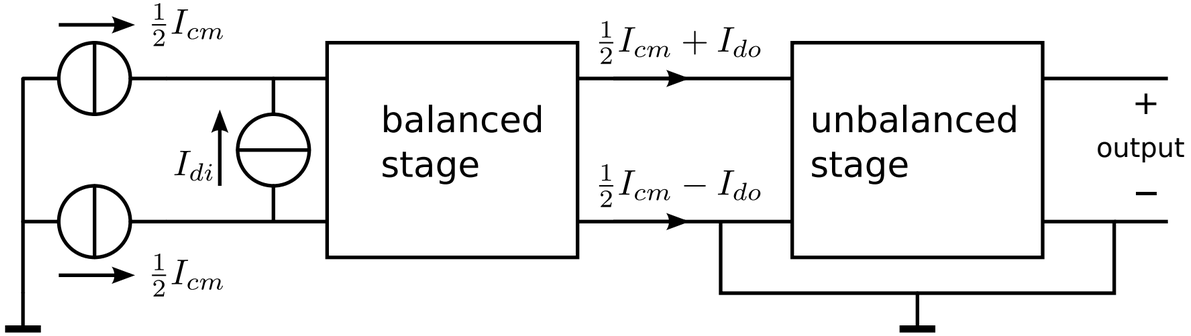

Interconnection of stages

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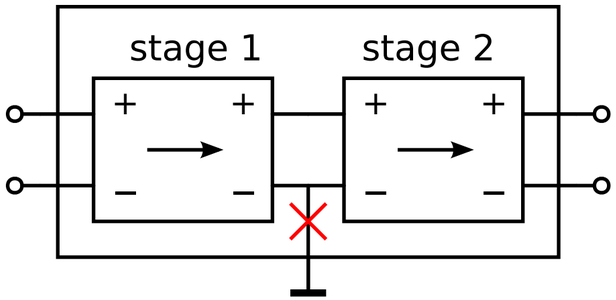

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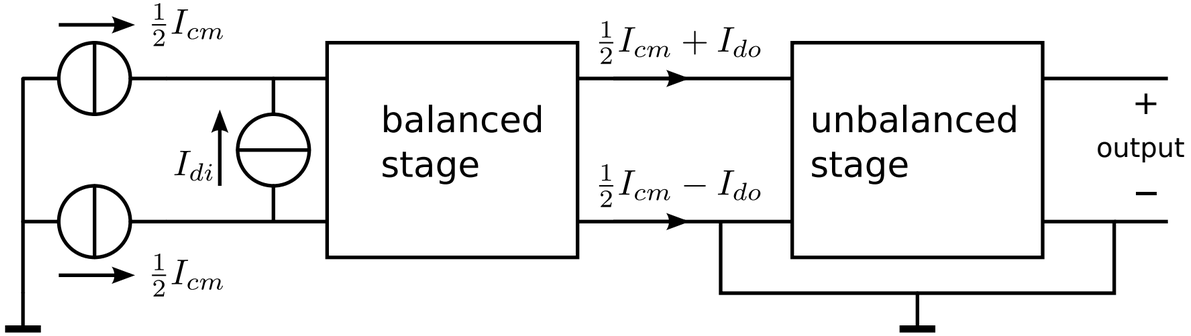
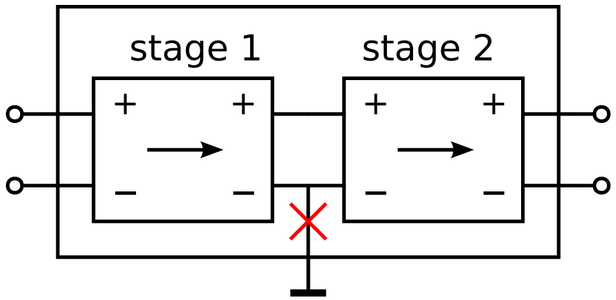


Nonzero common-mode transfer:

Interconnection of stages

Port isolation considerations



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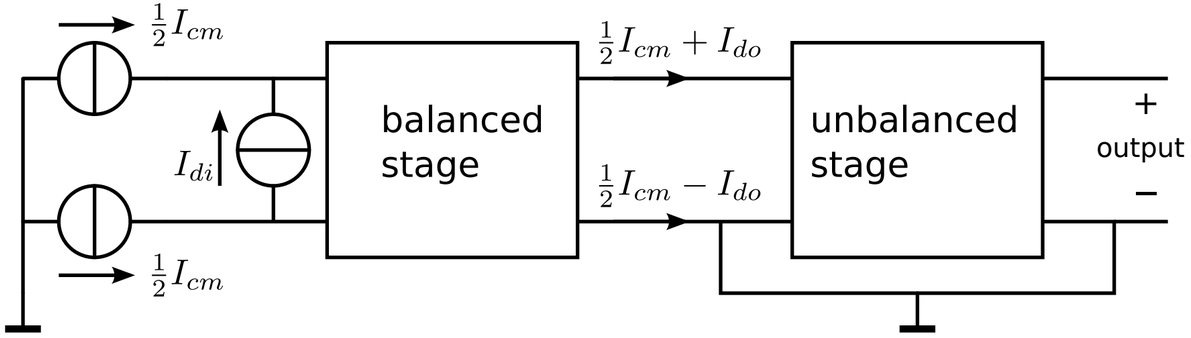
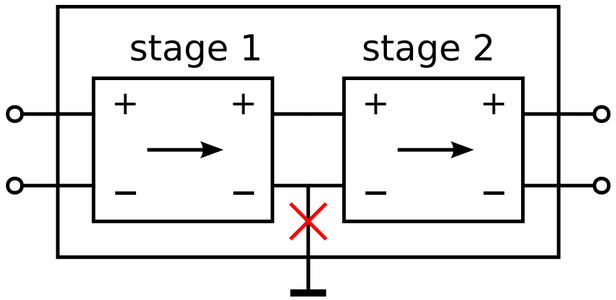


Nonzero common-mode transfer:

Possible limitation of the CMRR

Interconnection of stages

Port isolation considerations



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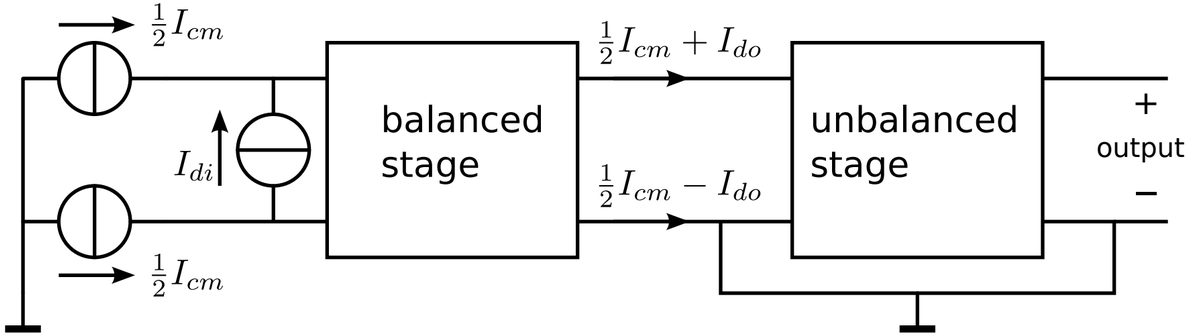
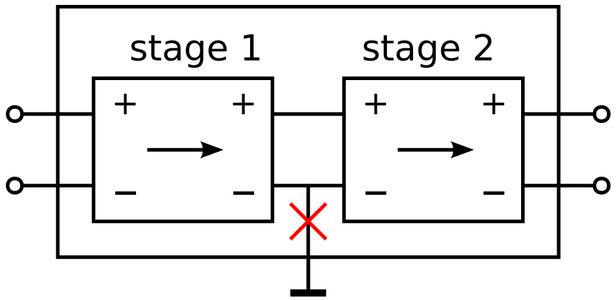


Nonzero common-mode transfer:

- Possible limitation of the CMRR
- If a common-mode signal is converted into a differential mode signal

Interconnection of stages

Port isolation considerations



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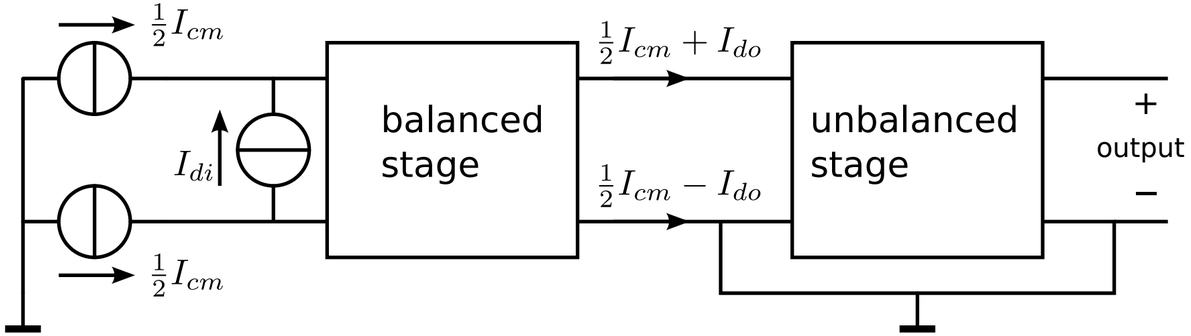

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