Analog Electronics
Crash course part 1

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Electro- and Information Technology

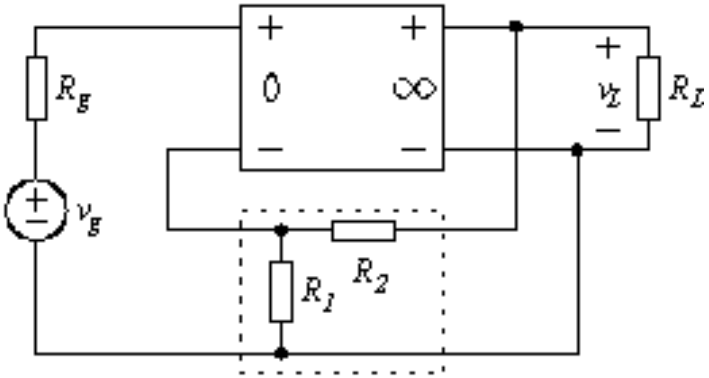
Layout

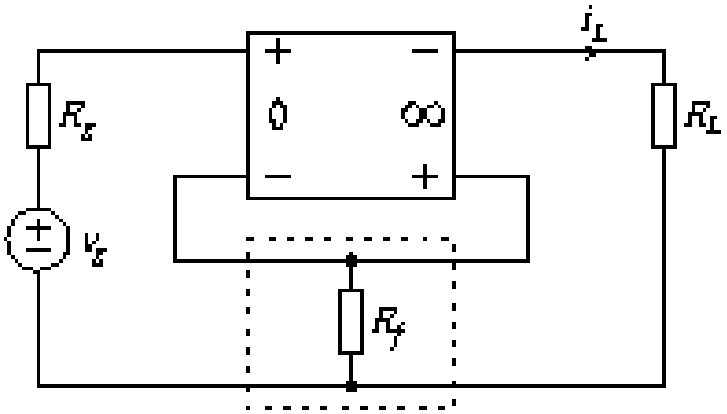
- Feedback using the nullor (e.g. ideal amplifier)
- Transistor (bipolar and FET)
- Liniarization of the transistor (small signal model)
- Implementation (one, two or three amplifying stages)
- Asymptotic gain model

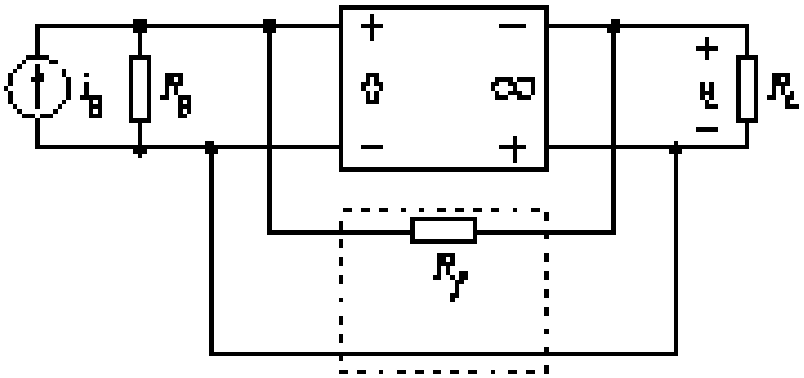
Fundamentals

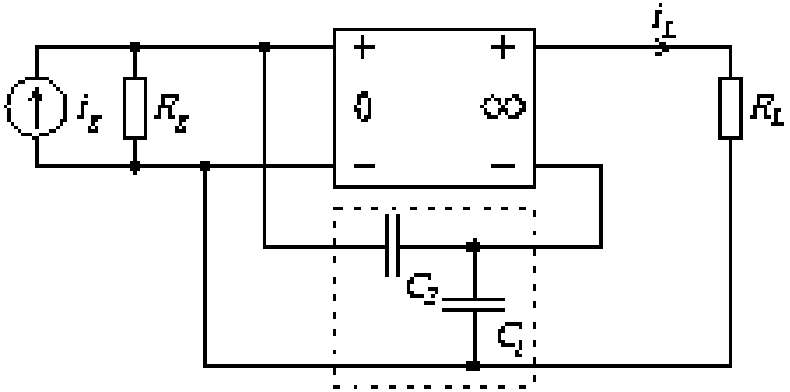
- Why use feedback?
- Why do we want negative feedback?

Nullor circuits



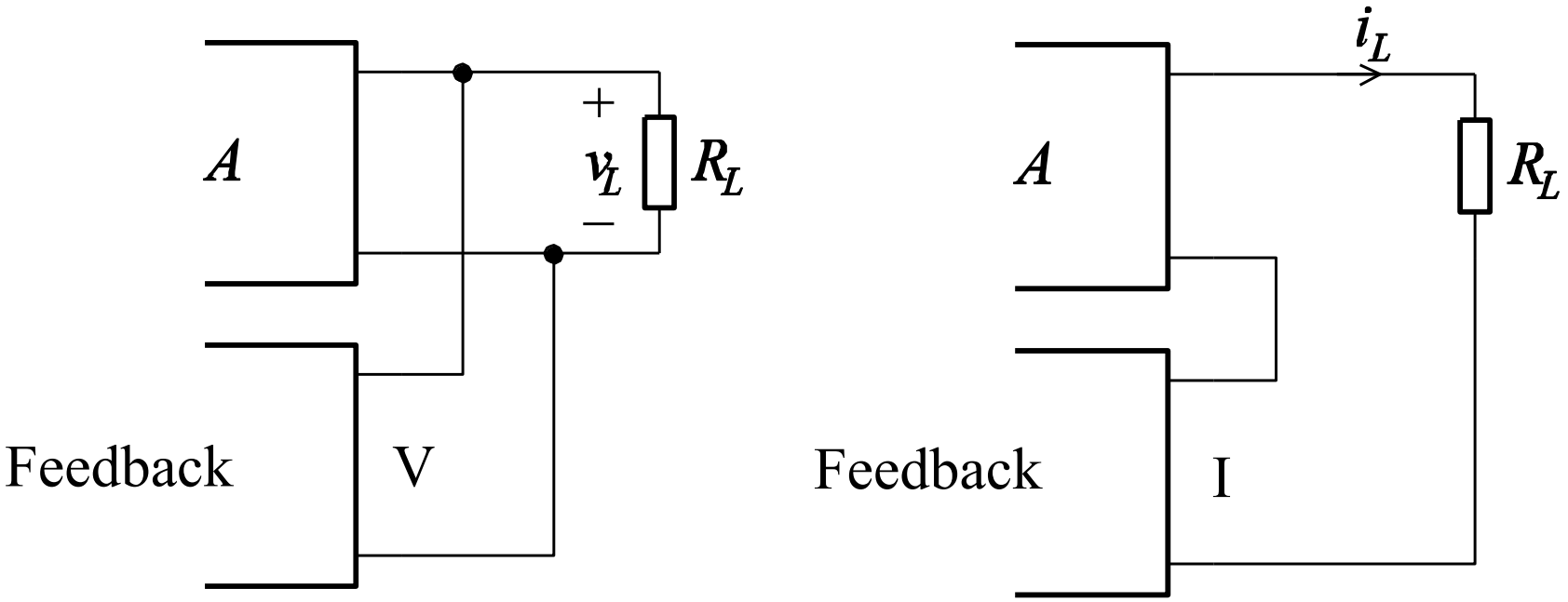






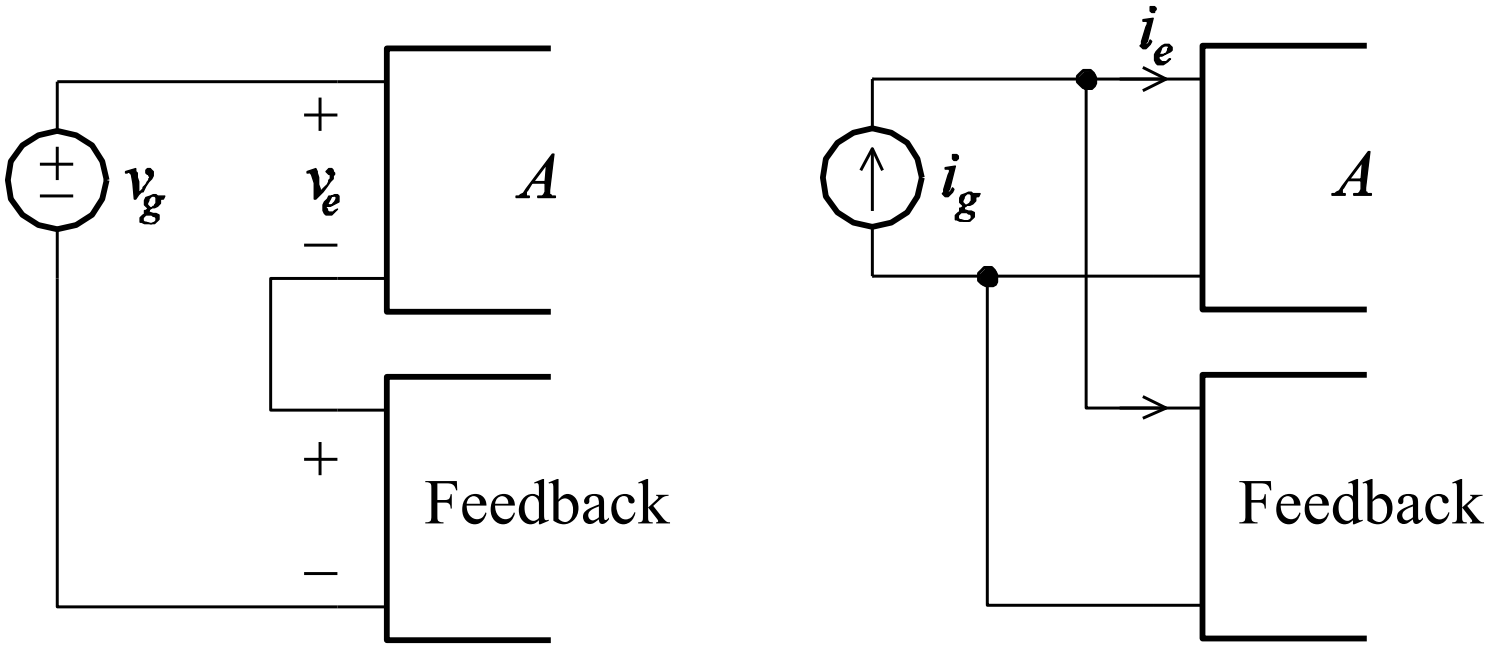
Output

- Load voltage is measured in parallel with the load
  - ”shunt”-measure
- Load current is measured in series with the load



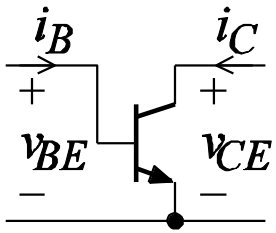
Input

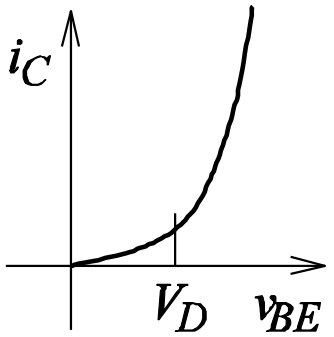
- Voltage is added in series to the source signal
- Current is added in parallel to the source signal

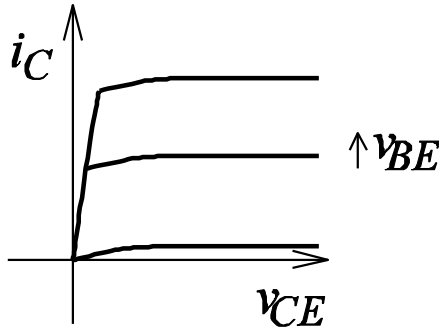


Amplifying elements

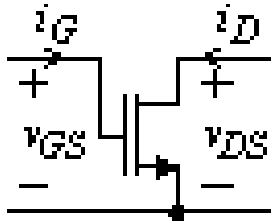
- BJT

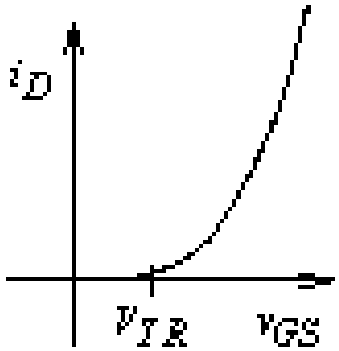


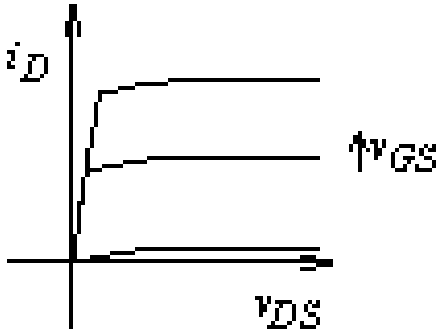




- FET

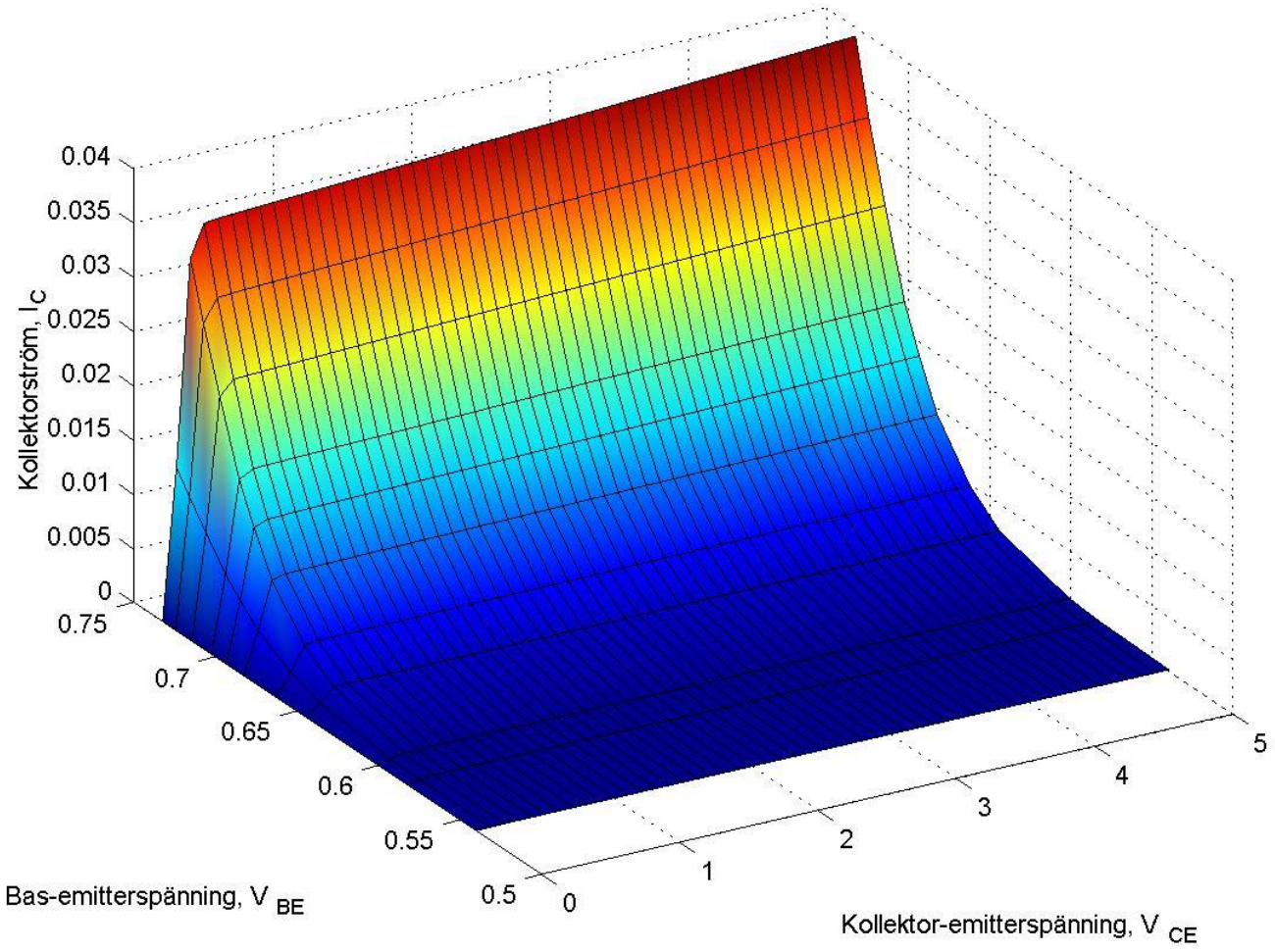






- Both have a non linear relation between input and output signal

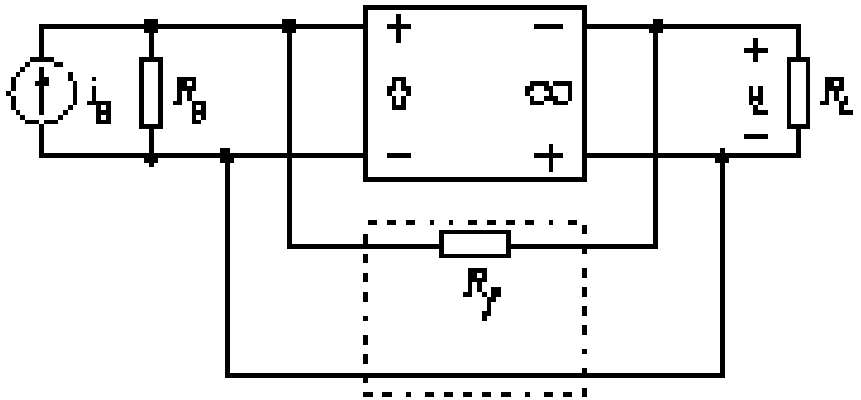
Graphs for BJT



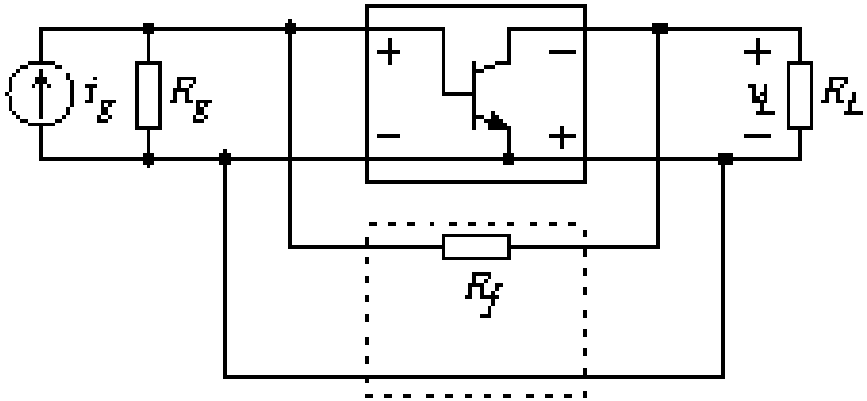
Implementation

- Transimpedance amplifier

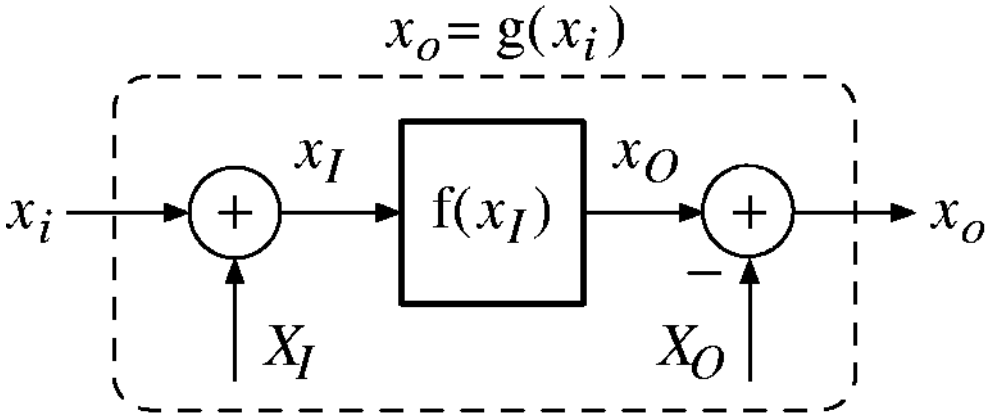
Nullor



CE-stage



Bias is necessary

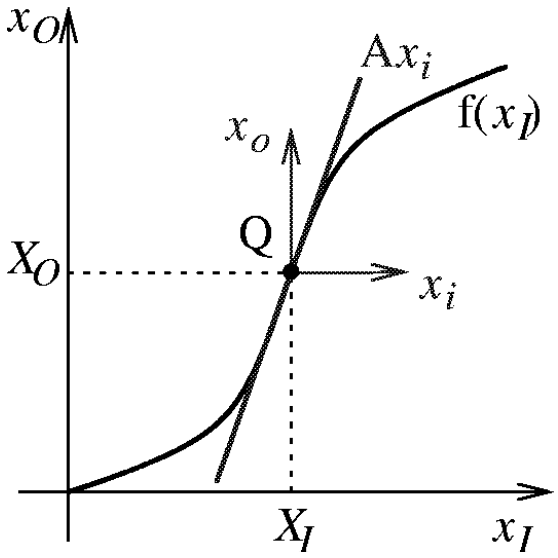


- For small x_i

$$g(x_i) = A \cdot x_i$$

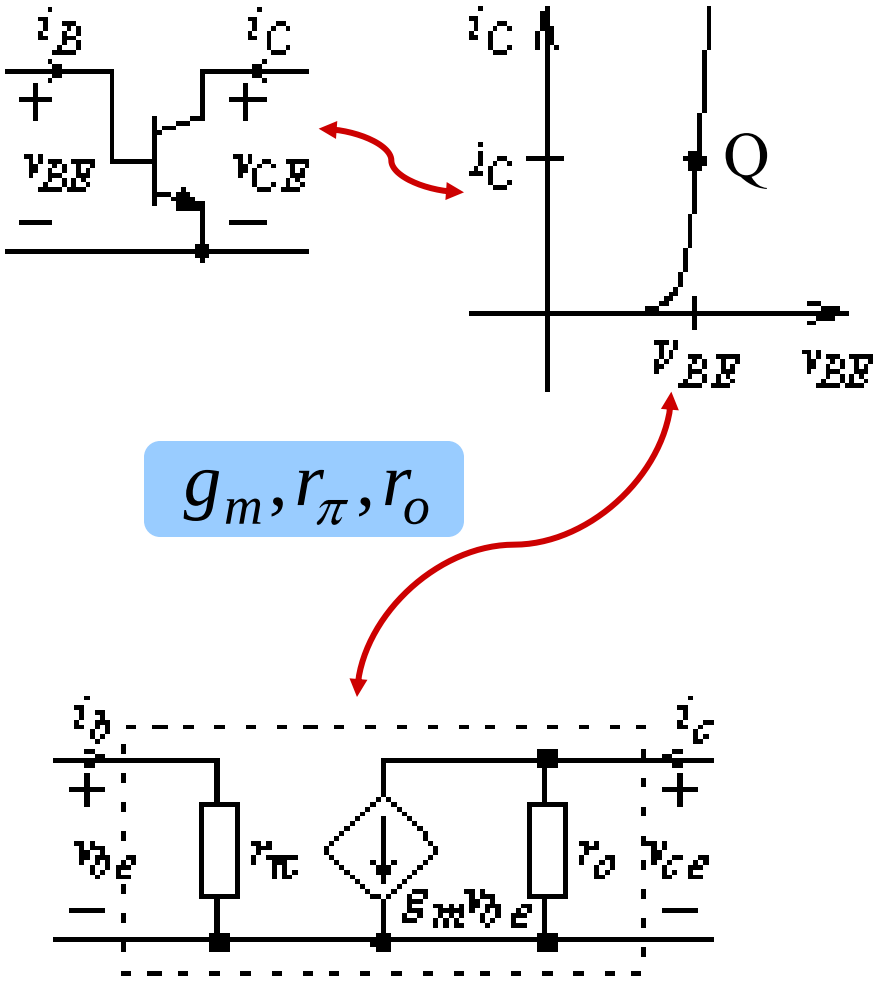
- Note

$$\underbrace{x_I}_{\text{Total}} = \underbrace{x_i}_{\text{Signal}} + \underbrace{X_I}_{\text{Bias}}$$



Transistor models

- Large signal model
  - Non linear equations
  - Bias point
  - Sets the linear model
- Small signal model
  - Linear equations
  - Loop gain



2 minuter

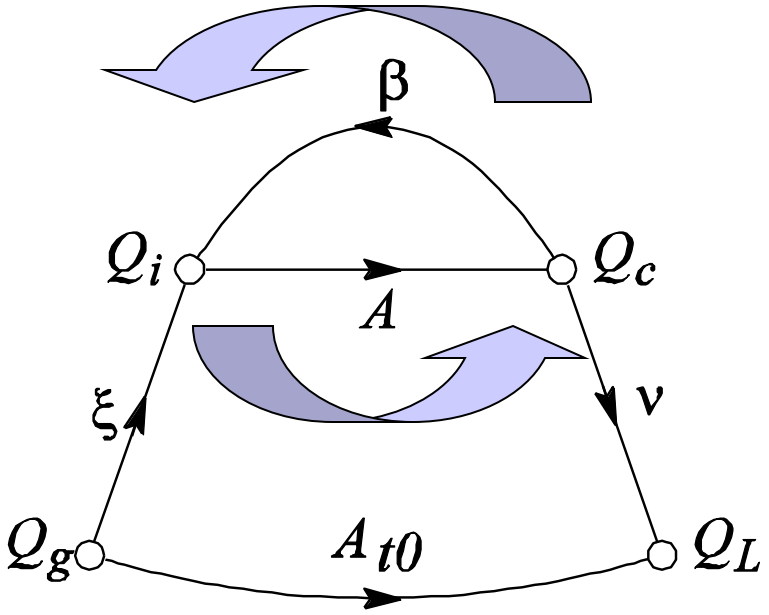
- Suppose you know I_C for a BJT
  - What is g_m?
  - What is r_π?

Superposition model

- Relation of load and source signal

$$\begin{cases} Q_i = \xi Q_g + \beta Q_c \\ Q_L = A_{t0} Q_g + \nu Q_c \end{cases}$$

$$Q_c = A Q_i$$



$$A_t = \frac{Q_L}{Q_g} = A_{t0} + \frac{\xi \nu A}{1 - A\beta}$$

Loop gain

How to calculate A_t

$$A_t = \frac{1}{\beta}\frac{\xi\nu A\beta}{1-A\beta} + A_{t0}\frac{1-A\beta}{1-A\beta} = A_{t\infty}\frac{-A\beta}{1-A\beta} + A_{t0}\frac{1}{1-A\beta}$$

Discrepancy factor

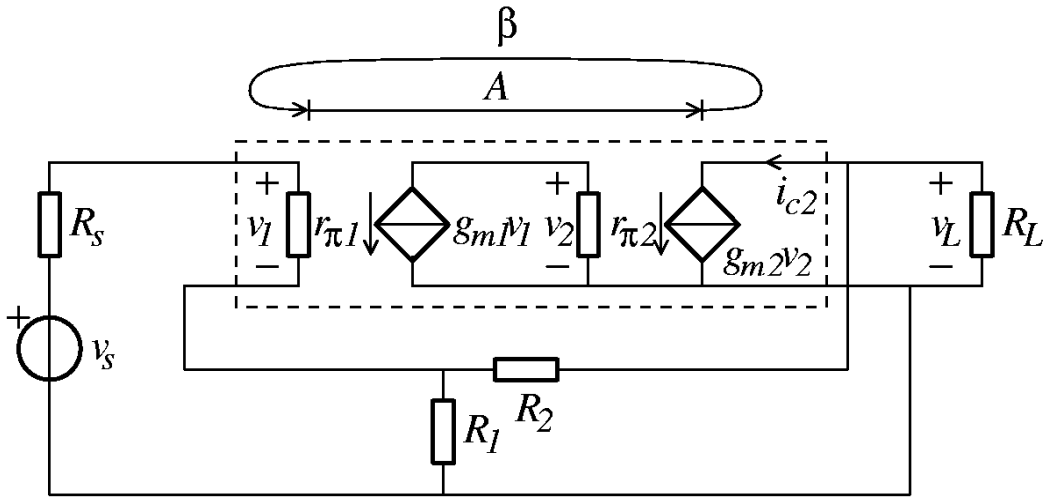
Neglect

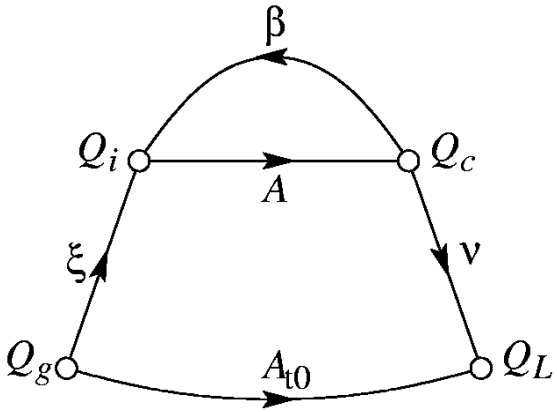
- $A_{t\infty}$ is set by the nullor circuit

$$A_t \approx A_{t\infty}\frac{-A\beta}{1-A\beta}$$

Calculate loopgain Aβ

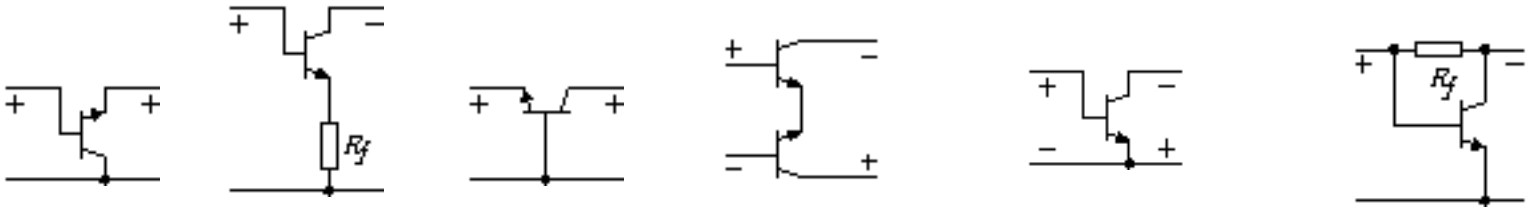
- Identify the ”natural” A and β
  - Feedback $\beta = \left.\frac{v_1}{i_{c2}}\right|_{v_s=0}$
  - Controlled sources gain $A = \frac{i_{c2}}{v_1}$





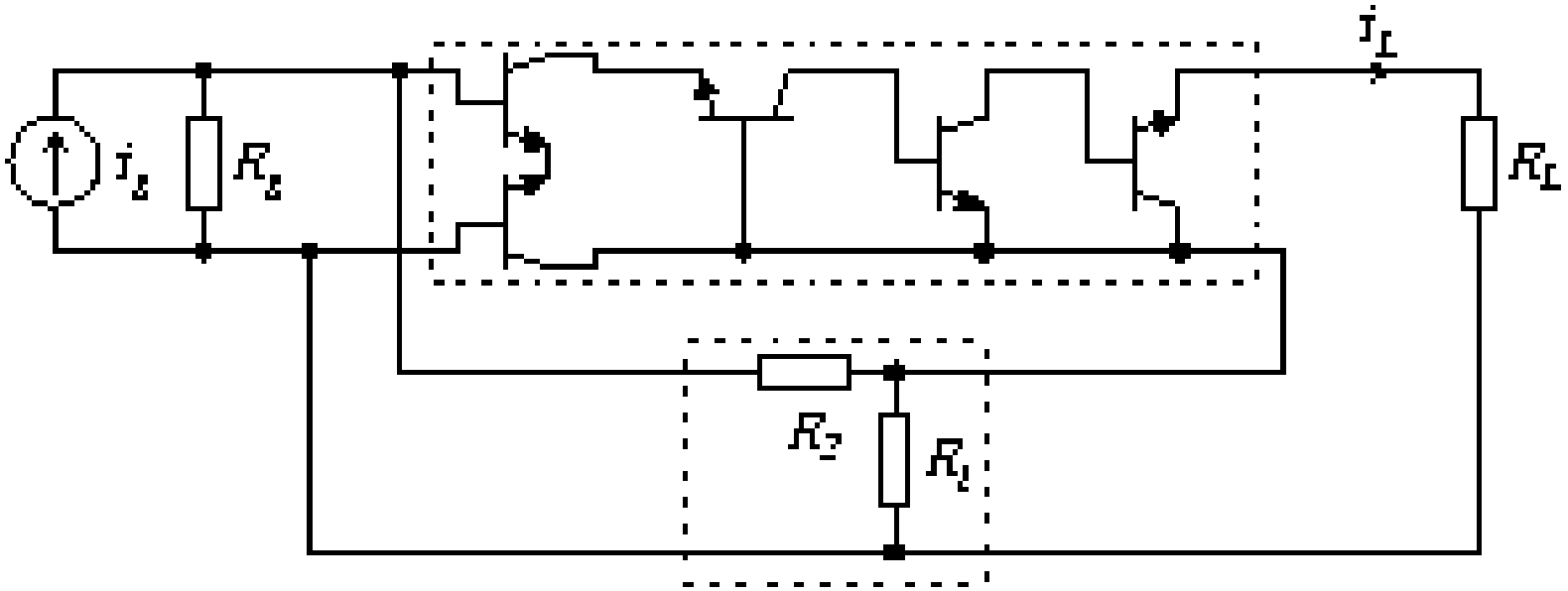
Amplifying stages

CE-steg	negative transfer	no feedback
AS-steg	neg./pos. transfer	no feedback
CC-steg	positive transfer	feedback
CB-steg	positive transfer	feedback
Series-stage	negative transfer	feedback
Shunt-stage	negative transfer	feedback



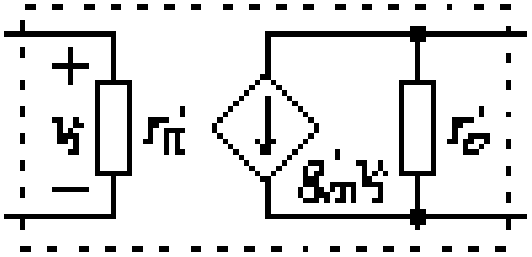
2 minuter

- Identify amplifying stages for the current amplifier and name them
- Check for negative feedback



Antiseries stage

- Small-signal model for the AS-stage is very similar to the hybrid-π-model for CE-stage
- No connection between in- and output
- Parameters of the model
  - Transconductance g_m'
  - Input impedance r_π'
  - Output impedance r_o'



- In this cource we neglect r_o' if nothing else is stated!

Time to get going

- You are to design a 2-stage V ⟶ I amplifier
- Which stages do you choose? Motivate!
- Theoretical, what is the maximum loop gain?
  - Assume you have BJT transistors at hand
- Which bias current influence Aβ?