Department of Electrical and Electronic Engineering
Shahjalal University of Science and Technology

EEE 222: Electronic Circuit Simulation Laboratory
EXPERIMENT NO. 03

Name of the Experiment: STUDY OF CASCADED AND FEEDBACK AMPLIFIER CIRCUITS USING BJT.

OBJECTIVE

The objective of this experiment is to simulate and observe the characteristics of the following amplifier circuits using BJT's

- A two-stage cascaded amplifier.
- Feedback Amplifiers
  - Voltage-series feedback amplifier.
  - Voltage-shunt feedback amplifier.
  - Current-series feedback amplifier.
  - Current-shunt feedback amplifier.

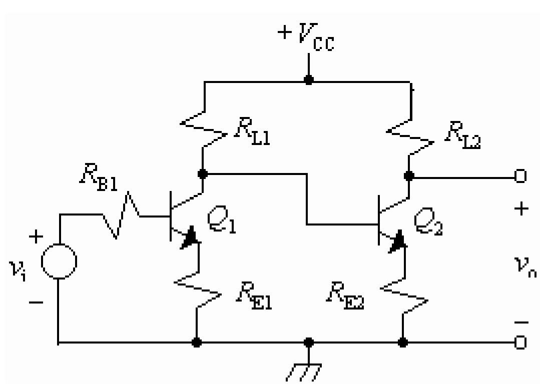
CASCADE AMPLIFIER

Amplifiers are *cascaded* when the output of the first is the input to the second. The combined gain is

$$A_v = \frac{v_{o1}}{v_{i1}} \cdot \frac{v_{o2}}{v_{i2}} = \frac{v_{o2}}{v_{i1}} = A_{v1} \cdot A_{v2}$$

where $v_{i2} = v_{o1}$. The total gain is the product of the cascaded amplifier *stages*.

The complication in calculating the gain of cascaded stages is the non-ideal coupling between stages due to loading. Two cascaded CE stages are shown below.



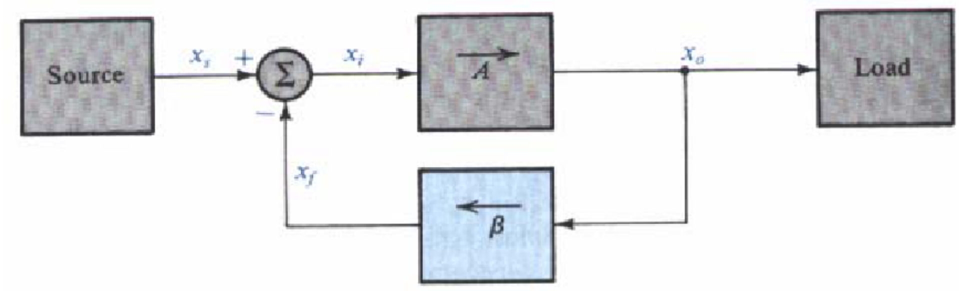
Because the input resistance of the second stage forms a voltage divider with the output resistance of the first stage, the total gain is not the product of the individual (separated) stages.

The total voltage gain can be calculated in either of two ways. First way: the gain of the first stage is calculated including the loading of r_{i2}. Then the second-stage gain is calculated from the output of the first stage. Because the loading (output divider) was accounted for in the first-stage gain, the second-stage gain input quantity is the Q_2 base voltage, $v_{B2} = v_{o1}$.

Second way: the first-stage gain is found by disconnecting the input of the second stage, thereby eliminating output loading. Then the Thevenin-equivalent output of the first stage is connected to the input of the second stage and its gain is calculated, including the input divider formed by the first-stage output resistance and second-stage input resistance. In this case, the first-stage gain output quantity is the Thevenin-equivalent voltage, not the actual collector voltage of the stage-connected amplifier. The second way includes interstage loading as an input divider in the gain of the second stage while the first way includes it as an output divider in the gain of the first stage.

By cascading a CE stage followed by an emitter-follower (CC) stage, a good voltage amplifier results. The CE input resistance is high and CC output resistance is low. The CC contributes no increase in voltage gain but provides a near voltage-source (low resistance) output so that the gain is nearly independent of load resistance. The high input resistance of the CE stage makes the input voltage nearly independent of input-source resistance. Multiple CE stages can be cascaded and CC stages inserted between them to reduce attenuation due to inter-stage loading.

General Feedback Structure



- The open-loop amplifier gain = A; thus $x_o = Ax_i$
- The sample x_f is related to x_o by the feedback factor ß

$$\left.\begin{array}{l} x_f = \beta x_o \\ x_i = x_s - x_f \end{array}\right\} \Rightarrow x_o = A(x_s - \beta x_o)$$

  - Implicit in the above description is that the source, the load, and the feedback network do not load the basic amplifier
- The gain of the feedback amplifier $A_f \equiv \frac{x_o}{x_s} = \frac{A}{1+A\beta}$
- The quantity Aß is called the loop gain
  - For the feedback to be negative, the loop gain Aß should be positive
  - That is, the feedback signal x_f should have the same sign as x_s, thus resulting in a smaller difference signal x_i
  - 1+ Aß: called he amount of feedback
  - The gain with feedback will be smaller than the open-loop gain A by the quantity 1+ Aß
- For Aß>>1, $A_f \approx 1/\beta$:the gain of the feedback amplifier (closed-loop gain) is almost entirely determined by the feedback network
  - The feedback network usually consists of passive components, which can be chosen to be as accurate as one wishes, the advantages

⇒Accurate, predictable, and stable gain should be apparent

- The feedback signal x_f

$$x_f = \frac{\beta A}{1+A\beta} x_s$$

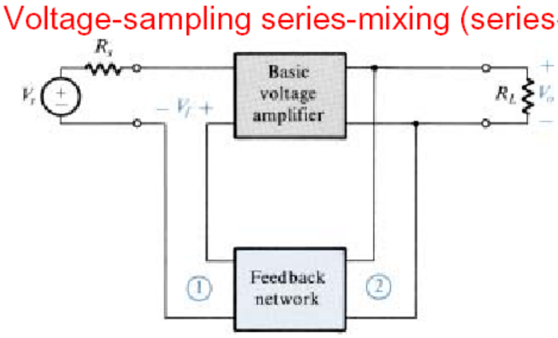
- For Aß>>1, then $x_f \approx x_s$
  - The signal x_i at the input of the basic amplifier is reduced to almost zero
- The difference between x_s and x_f, which is x_i, is sometimes referred to as the "error signal"
- The input differencing circuit is often also called a comparison circuit (mixer)
- Gain Desensitivity

$$A_f = \frac{A}{1+A\beta} \Rightarrow dA_f = \frac{dA}{(1+A\beta)^2} \Rightarrow \frac{dA_f}{A_f} = \frac{1}{1+A\beta}\frac{dA}{A}$$

1+Aß : desensitivity D

Feedback Topologies

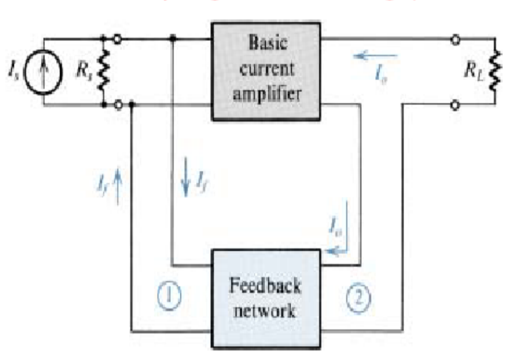
- Voltage-voltage feedback
  - Samples the output voltage and returns the feedback signal as a voltage
- Voltage-current feedback
  - Sense the output current to perform feedback
- Current-voltage feedback
  - Sense the output voltage and a proportional current is returned to the summing point at the input
- Current-current feedback
  - Sense the output current and a proportional current is returned to the summing point at the input
- Voltage amplifier
  - Amplifier an input voltage signal and provide an output voltage signal (voltage control voltage source)
  - High input impedance, low output impedance
  - Represent it in terms of a Th'evenin equivalent circuit
  - The feedback network should sample the output voltage, and the feedback signal x_f should be a voltage that can mixed with the source voltage in series
  - Voltage-sampling series-mixing (series-shunt feedback) topology



$R_{if} \uparrow$ than R_i

$R_{of} \downarrow$ than R_o

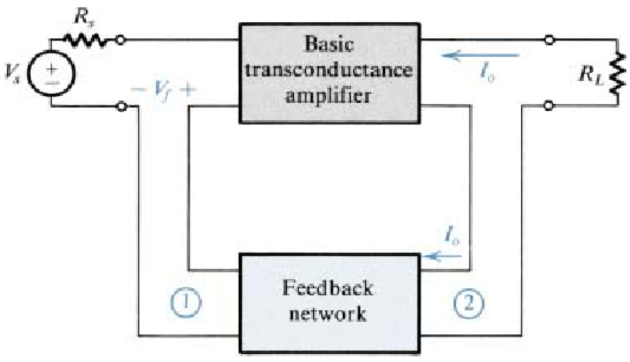
- Current amplifier
  - Low input impedance, high output impedance
  - Represent it in terms of a Norton equivalent
  - The feedback signal should be in current form so that it may be mixed in shunt with the source current
  - Current-sampling shunt-mixing (shunt-series feedback) topology



$R_{if} \downarrow$ than R_i

$R_{of} \uparrow$ than R_o

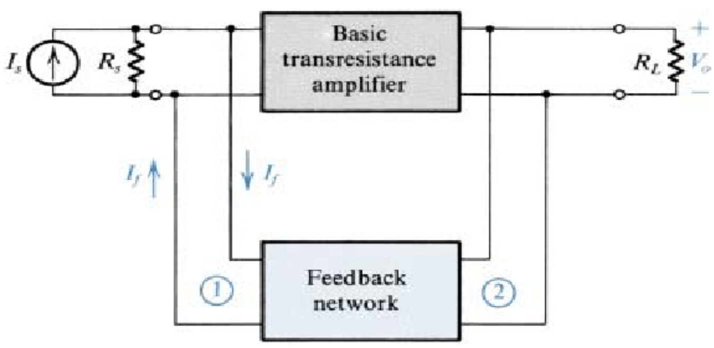
- Transconductance amplifiers
  - Input signal is a voltage and the output signal is a current
  - High input impedance, high output impedance
  - Represent it in terms of a Th'evenin equivalent circuit
  - Current-sampling series-mixing (series-series feedback) topology



$R_{if} \uparrow$ than R_i

$R_{of} \uparrow$ than R_o

- Transresistance amplifiers
  - Input signal is a current and the output signal is a voltage
  - Low input impedance, Low output impedance
  - Represent it in terms of a Norton equivalent
  - Voltage-sampling shunt-mixing (shunt-shunt feedback) topology



$R_{if} \downarrow$ than R_i

$R_{of} \downarrow$ than R_o

PROCEDURE

Cascaded Amplifier

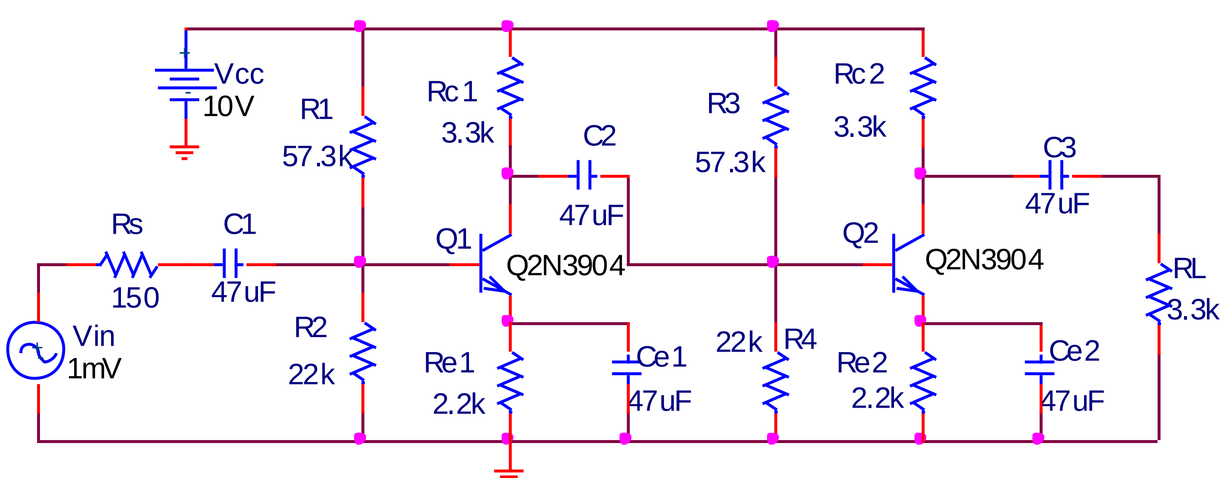


Fig.1. Circuit for Small signal analysis using BJT

1.1. Draw the circuit shown in Fig. 1 in PSpice schematics.

1.2. Here, Vin is variable frequency AC source (Having **Part Name** of **VAC**). Set its amplitude to 1 mV, keeping other parameters (e.g. Vdc) to zero value.

1.3. Select AC Sweep from **Setup Analysis**. Select sweep from 10 Hz to 1 MHz (or higher or lower, ensuring that you observe both the cut-off frequencies) in Decade mode, with 20 Pts/decade.

1.4. Run the simulation.

1.5. Observe the voltage gain ($A_V = v_o/v_i$) and phase shift between v_o and v_i at different frequencies.

1.6. Normalize the voltage gain $A_{VN} = A_V/A_{Vmax}$

1.7. Plot the voltage gain (in dB) vs. frequency (f) [$A_{VdB} = 20\log_{10}(A_{VN})$]

1.8. Determine the -3dB (cut-off) frequencies from the plot. Also note the phase difference between v_o and v_i at –3dB frequencies.

1.9. At mid-band frequency, note the voltage gain (A_V), current gain (A_I), input resistance (R_i) and output resistance (R_o) of the configuration.

1.10. Find the h- parameters of the given CE configuration using the data taken in step 9.

1.11. Compare the results with that of Single-stage amplifier studied in previous simulation. Also compare the gain-bandwidth product (GB) of single-stage and cascaded amplifiers. (GB=BW*A_V, where BW=f_{HC}-f_{LC} & $A_V = v_o/v_i$)

FEEDBACK AMPLIFIERS

Voltage-Series Feedback

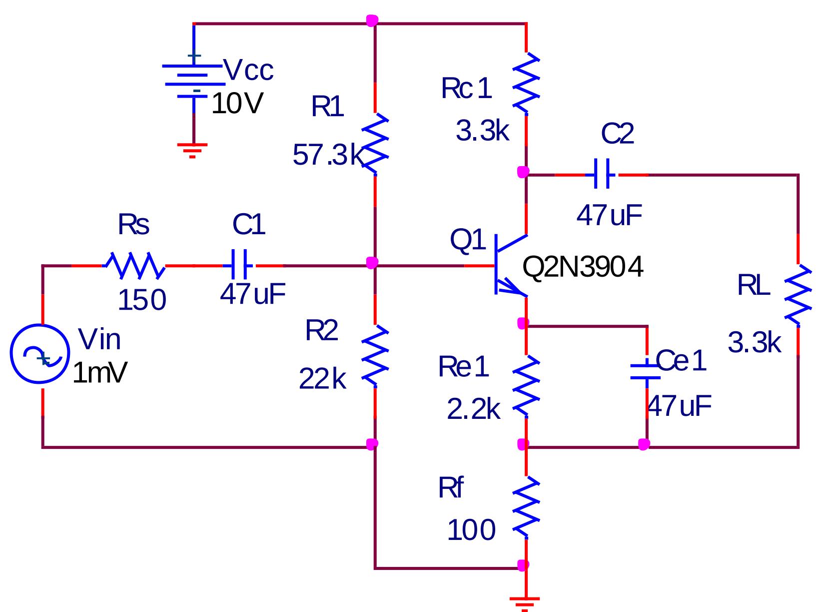


Fig.2. Voltage-series feedback amplifier

Draw the circuit shown in Fig. 2 in PSpice schematics.

Here, Vin is variable frequency AC source (Having **Part Name** of **VAC**). Set its amplitude to 1 mV, keeping other parameters (e.g. Vdc) to zero value.

Select AC Sweep from **Setup Analysis**. Select sweep from 10 Hz to 1 MHz (or higher or lower, ensuring that you observe both the cut-off frequencies) in Decade mode, with 20 Pts/decade.

Run the simulation.

Observe the voltage gain ($A_V = v_o/v_i$) at different frequencies.

At mid-band frequency, note the voltage gain (A_V), current gain (A_I), input resistance (R_i) and output resistance (R_o) of the configuration.

Compare the results with that of single stage amplifier (without feedback) studied in previous simulation. Hence, find the desensitivity (D) of the amplifier.

Verify the values measured in step 6, with theoretical values obtained from without feedback single-stage amplifier's *preserved values* modified using D. [see theory for details]

Current-Series Feedback

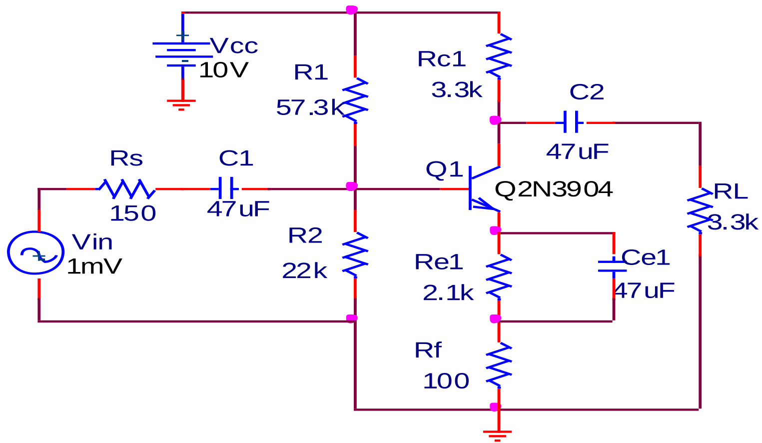


Fig.3. **Current-series feedback amplifier**

3.1. Draw the circuit shown in Fig. 2 in PSpice schematics.

3.2. Here, Vin is variable frequency AC source (Having **Part Name** of **VAC**). Set its amplitude to 1 mV, keeping other parameters (e.g. Vdc) to zero value.

3.3. Select AC Sweep from **Setup Analysis**. Select sweep from 10 Hz to 1 MHz (or higher or lower, ensuring that you observe both the cut-off frequencies) in Decade mode, with 20 Pts/decade.

3.4. Run the simulation.

3.5. Observe the voltage gain ($A_V=v_o/v_i$) at different frequencies.

3.6. At mid-band frequency, note the voltage gain (A_V), current gain (A_I), input resistance (R_i) and output resistance (R_o) of the configuration.

3.7. Compare the results with that of single stage amplifier (without feedback) studied in previous simulation. Hence, find the desensitivity (D) of the amplifier.

3.8. Verify the values measured in step 6, with theoretical values obtained from without feedback single-stage amplifier's *preserved values* modified using D. [see theory for details].

Voltage-Shunt Feedback

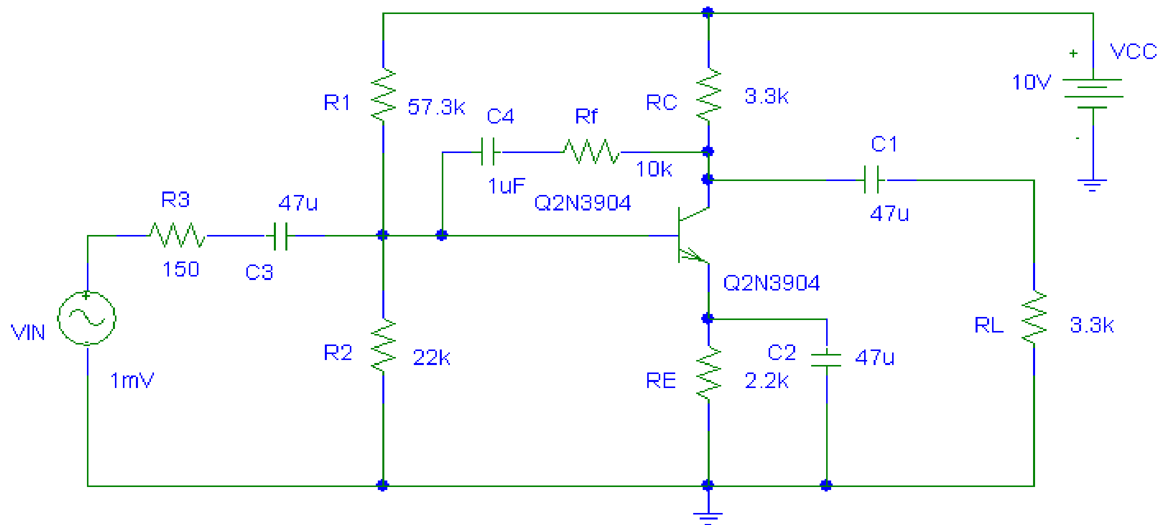


Fig.4. Voltage-shunt feedback amplifier

4.1. Draw the circuit shown in Fig. 2 in PSpice schematics.

4.2. Here, Vin is variable frequency AC source (Having **Part Name** of **VAC**). Set its amplitude to 1 mV, keeping other parameters (e.g. Vdc) to zero value.

4.3. Select AC Sweep from **Setup Analysis**. Select sweep from 10 Hz to 1 MHz (or higher or lower, ensuring that you observe both the cut-off frequencies) in Decade mode, with 20 Pts/decade.

4.4. Run the simulation.

4.5. Observe the voltage gain (A_V=v_o/v_i) at different frequencies.

4.6. At mid-band frequency, note the voltage gain (A_V), current gain (A_I), input resistance (R_i) and output resistance (R_o) of the configuration.

4.7. Compare the results with that of single stage amplifier (without feedback) studied in previous simulation. Hence, find the desensitivity (D) of the amplifier.

4.8. Verify the values measured in step 6, with theoretical values obtained from without feedback single-stage amplifier's *preserved values* modified using D. [see theory for details]

Current-Shunt Feedback

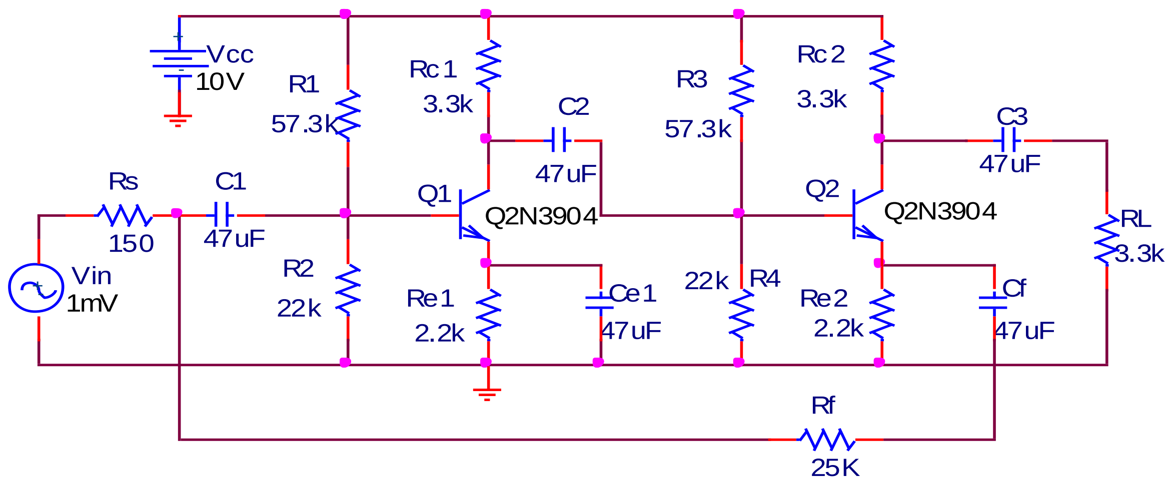


Fig.5. Current-shunt feedback amplifier

5.1. Draw the circuit shown in Fig. 2 in PSpice schematics.

5.2. Here, Vin is variable frequency AC source (Having **Part Name** of **VAC**). Set its amplitude to 1 mV, keeping other parameters (e.g. Vdc) to zero value.

5.3. Select AC Sweep from **Setup Analysis**. Select sweep from 10 Hz to 1 MHz (or higher or lower, ensuring that you observe both the cut-off frequencies) in Decade mode, with 20 Pts/decade.

5.4. Run the simulation.

5.5. Observe the voltage gain (A_V=v_o/v_i) at different frequencies.

5.6. At mid-band frequency, note the voltage gain (A_V), current gain (A_I), input resistance (R_i) and output resistance (R_o) of the configuration.

5.7. Compare the results with that of single stage amplifier (without feedback) studied in previous simulation. Hence, find the desensitivity (D) of the amplifier.

5.8. Verify the values measured in step 6, with theoretical values obtained from without feedback single-stage amplifier's *preserved values* modified using D. [see theory for details]