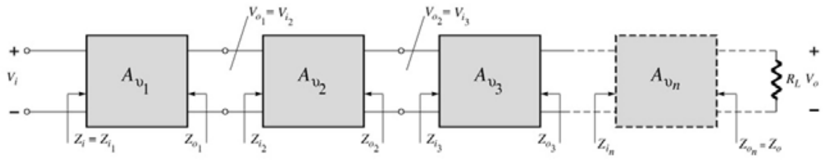
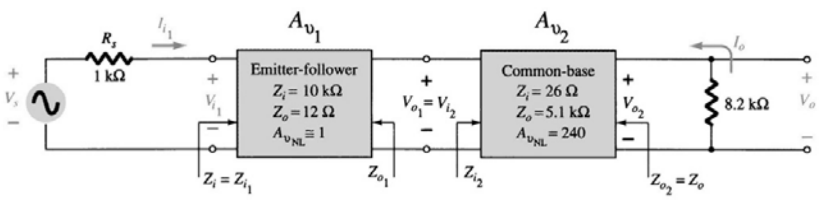
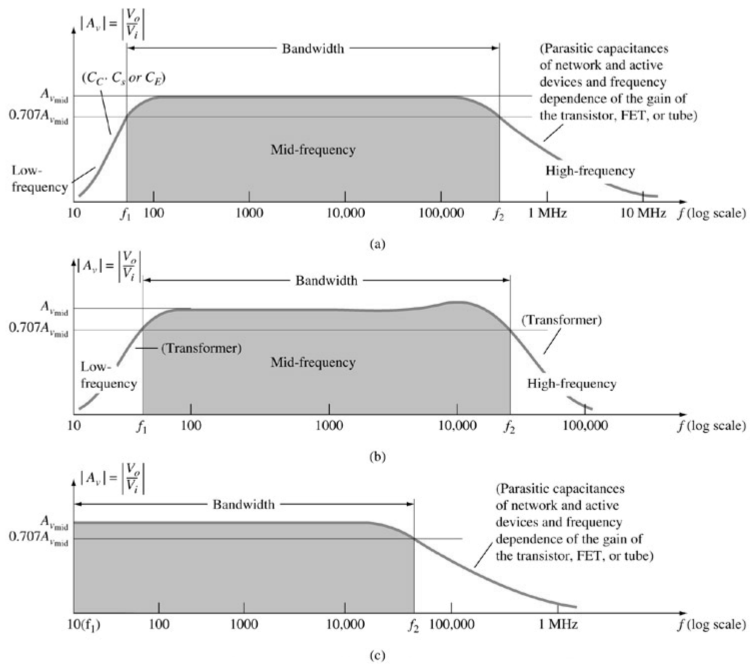
Multistage Amplifiers

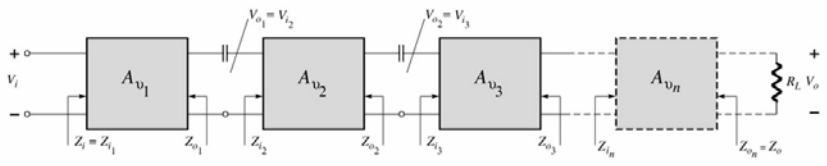
Cascade Connection







AC Coupled Multistage Amplifiers



The output of one amplifier is the input to the next amplifier.

Note the DC bias circuits **are isolated** from each other by the coupling capacitors.

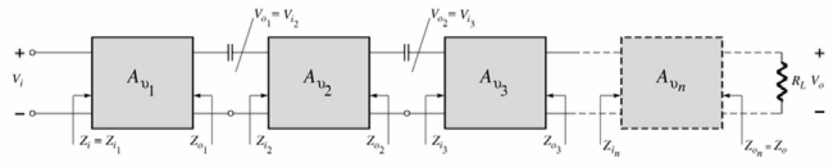
The DC calculations **are independent** of the cascading.
The AC calculations for gain and impedance are interdependent.

The overall gain:

$$A_v = A_{v1} \times \frac{Z_{i2}}{Z_{o1} + Z_{i2}} \times A_{v2} \times \cdots \frac{Z_{ik}}{Z_{ok-1} + Z_{ik}} \times A_{vk} \cdots \times \frac{Z_{in}}{Z_{on-1} + Z_{in}} \times A_{vn}$$

with $Z_i = Z_{i1}$ and $Z_o = Z_{on}$

AC Coupled Multistage Amplifiers



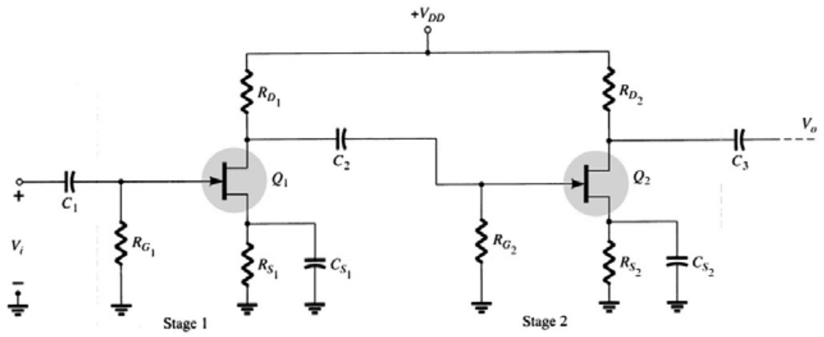
We can also express the overall gain as follows

$$A_v = A_{v_1}^* \times A_{v_2}^* \times \cdots A_{v_k}^* \cdots \times A_{v_n}$$

where

$$A_{v_k}^* = A_{v_k} \times \frac{Z_{i_{k+1}}}{Z_{o_k} + Z_{i_{k+1}}}$$

FET Cascade Amplifier

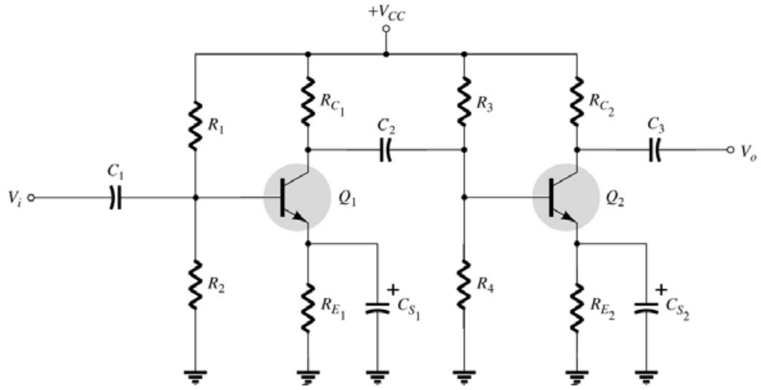


Voltage Gain: $A_v = A_{v_2} A_{v_1}^* = \left(-g_{m_2} R_{D_2}\right)\left[-g_{m_1}\left(R_{D_1} \parallel R_{G_2}\right)\right]$

Input Impedance: $Z_i = R_{G_1}$

Output Impedance: $Z_o = R_{D_2}$

BJT Cascade Amplifier



Voltage Gain: $A_v = A_{v_2} A^*_{v_1} = \left(-\frac{h_{fe_2} R_{C_2}}{h_{ie_2}} \right) \left(-\frac{h_{fe_1} \left[R_{C_1} \,||\, \left(R_3 \,||\, R_4 \,||\, h_{ie_2} \right) \right]}{h_{ie_1}} \right)$

Input Impedance: $Z_i = R_1 \,||\, R_2 \,||\, h_{ie_1}$

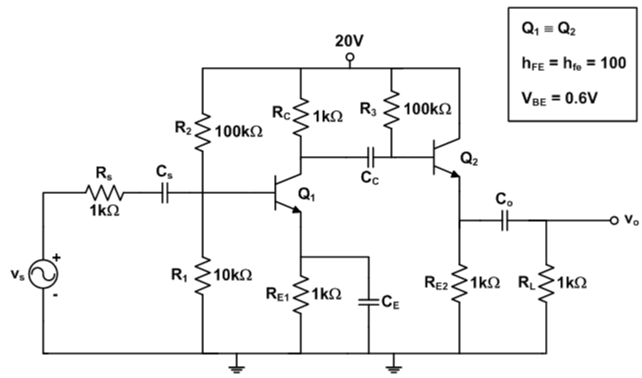
Output Impedance: $Z_o = R_{C2} \,||\, \frac{1}{h_{oe_2}}$

Combination of FET and BJT Cascade

A FET-BJT cascade is calculated in a similar fashion as a FET-FET or a BJT-BJT cascade.

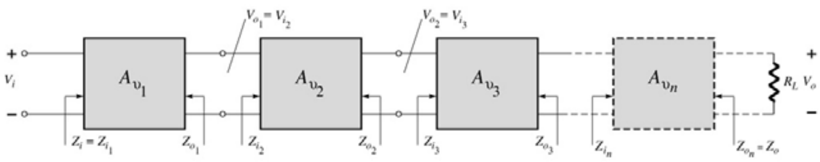
This combination provides a high gain from the BJT with the high input impedance from the FET.

Ex1:



a) Draw AC and DC load lines for both transistors.
b) Calculate the overall voltage gain $\mathbf{A_V = v_o / v_s}$.
c) Find $\mathbf{v_{s\,(max)}}$ which produces maximum undistorted output voltage.

DC Coupled Multistage Amplifiers



The output of one amplifier is the input to the next amplifier.

Note the DC bias circuits **are not isolated** from each other
The DC calculations **are not independent** of the cascading.

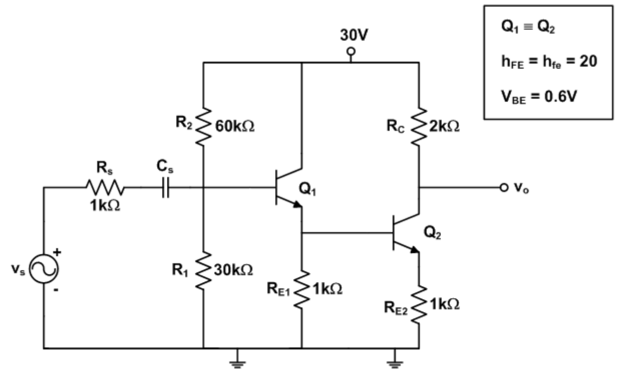
Used either to amplify very low frequency signals or to amplify DC signals

The overall gain:

$$A_v = A_{v_1} \times \frac{Z_{i_2}}{Z_{o_1} + Z_{i_2}} \times A_{v_2} \times \cdots \frac{Z_{i_k}}{Z_{o_{k-1}} + Z_{i_k}} \times A_{v_k} \cdots \times \frac{Z_{i_n}}{Z_{o_{n-1}} + Z_{i_n}} \times A_{v_n}$$

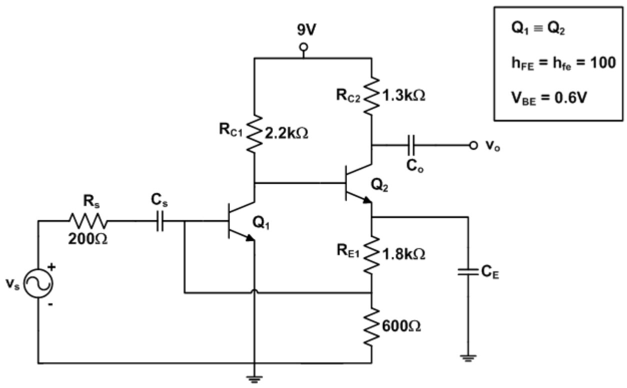
with $Z_i = Z_{i_1}$ and $Z_o = Z_{o_n}$

Ex2:



a) Draw AC and DC load lines for both transistors.
b) Calculate the overall voltage gain $\mathbf{A_V = v_o / v_s}$.
c) Find $\mathbf{v_{s\,(max)}}$ which produces maximum undistorted output voltage.

Ex3:



a) Draw AC and DC load lines for both transistors.
b) Calculate the overall voltage gain $\mathbf{A_V = v_o / v_s}$.
c) Find $\mathbf{v_{s\,(max)}}$ which produces maximum undistorted output voltage.

Ex4:

h_{fe} = 50 h_{fb} = -0.98

h_{ie} = 1.1kΩ h_{ib} = 21.6Ω

h_{oe} = 24μ A/V h_{ob} = 0.49μ A/V

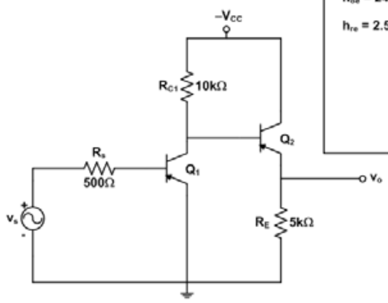
h_{re} = 2.5 10^{-4} h_{rb} = 2.59 10^{-4}

h_{fc} = 51

h_{ic} = 1.1kΩ

h_{oc} = 25μ A/V

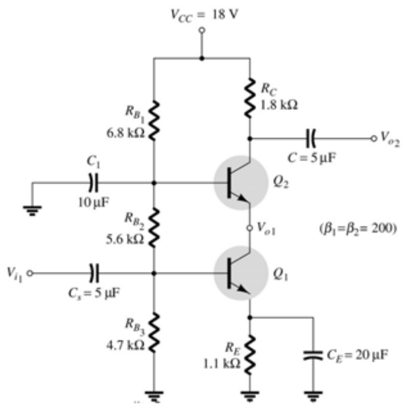
h_{rc} = 1



b) Calculate the overall voltage gain $\mathbf{A_V = v_o / v_s}$.

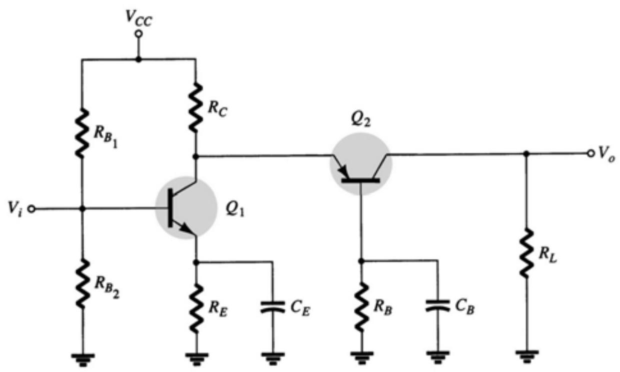
c) Find $\mathbf{R_o}$.

Cascode Connection

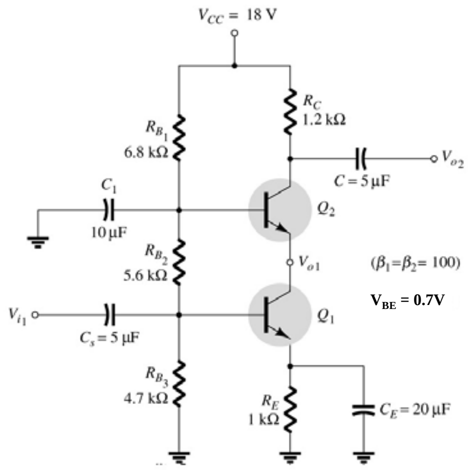


This is a CE – CB combination.
This arrangement provides high input impedance but a low voltage gain.
The low voltage gain reduces the Miller Input Capacitance therefore this combination works well in high frequency applications.

A more elaborate version of cascode amplifier



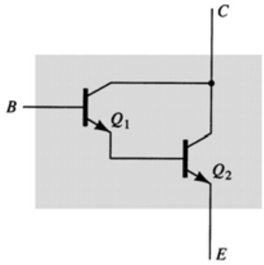
Ex5:



Consider the cascode amplifier above

a) Find the voltage gain $\mathbf{A_v = v_o/v_i}$
b) Find the input resistance $\mathbf{R_i}$
c) Find the output resistance $\mathbf{R_o}$

Darlington Connection



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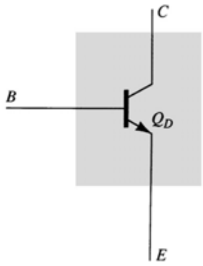
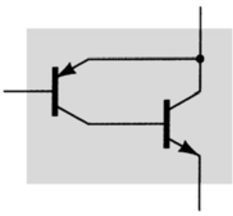


This combination provides large current gain, typically a few thousand.

It has a voltage gain of near 1, a low output impedance and a high input impedance.

Feedback Pair



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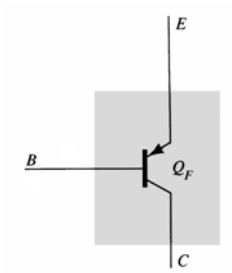

This is a two-transistor circuit that operates like a Darlington pair.
It has similar characteristics: high current gain, voltage gain of near 1, low output impedance and high input impedance.
Note: it is ***not the Darlington*** configuration:

Darlington: 2 npn BJTs
Feedback Pair: pnp driving an npn BJT