Universidad
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Session 22
Multistage Amplifiers

Electronic Components and Circuits

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Multistage Amplifiers

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- Multistage Amplifiers analysis methodology.
- Multistage Amplifier example
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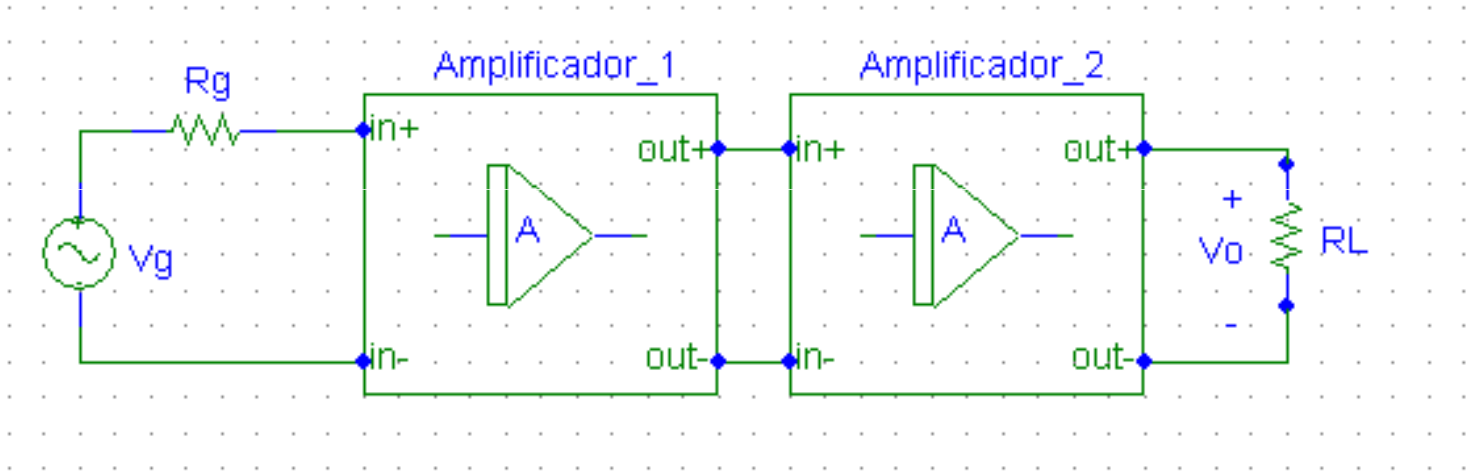
The need for Multistage Amplifiers
Single-stage Amplifiers Characteristics

Scheme	Rin	Rout	Av	Ai(sc)
CE	$R_b // r_\pi \approx r_\pi$	$R_c // r_o$	✸ $-g_m(r_o // R_c // R_L)$	$-g_m R_{in} \approx -\beta_o$
CE-RE	✸ $R_b // [r_\pi + (1+\beta_o)R_e]$	R_c	✸ $-\dfrac{\beta_o(R_c // R_L)}{r_\pi + (1+\beta_o)\cdot R_e}$	$-\beta_o \dfrac{R_b + R_{ib}}{R_b} \approx -\beta_o$
CC	✸ $R_b // [r_\pi + (1+\beta_o)\cdot R_{EM}]$	✸ $\dfrac{r_\pi + (R_b // R_g)}{1+\beta_o}$	$\dfrac{(1+\beta_o)\cdot R_{EM}}{r_\pi + (1+\beta_o)\cdot R_{EM}} \approx 1$	$(1+\beta_o)\dfrac{R_b + R_{ib}}{R_b}$
CB	$\dfrac{r_\pi}{1+\beta_o} \approx \dfrac{1}{g_m}$ ✸	R_c	$+g_m(R_c // R_L)$	$\dfrac{\beta_o}{(1+\beta_o)} = \alpha$

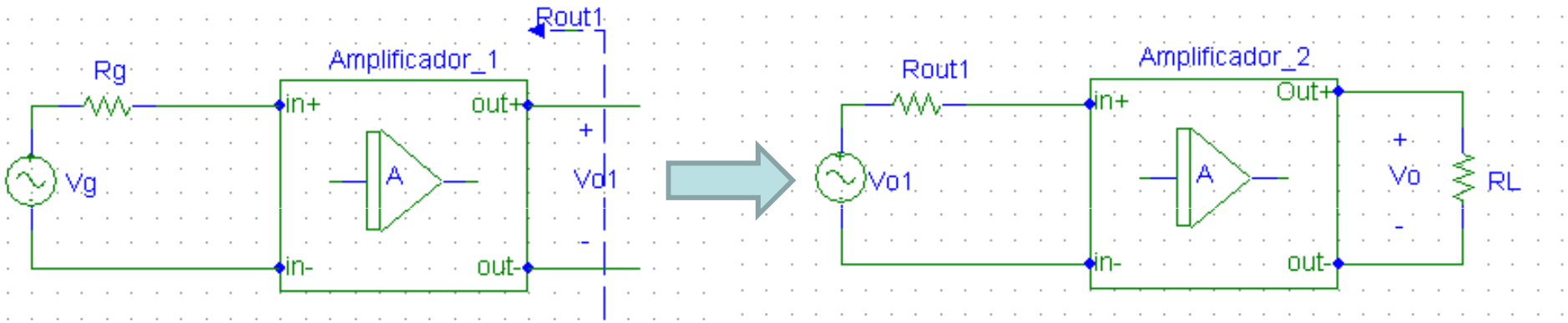
$$G_v = A_v \frac{R_{in}}{R_g + R_{in}} \qquad G_v\Big|_{EC}^{máx} \approx -g_m r_o = -\frac{V_A}{V_T} \qquad G_v\Big|_{CC}^{máx} \approx 1$$

Multiestage Amplifiers



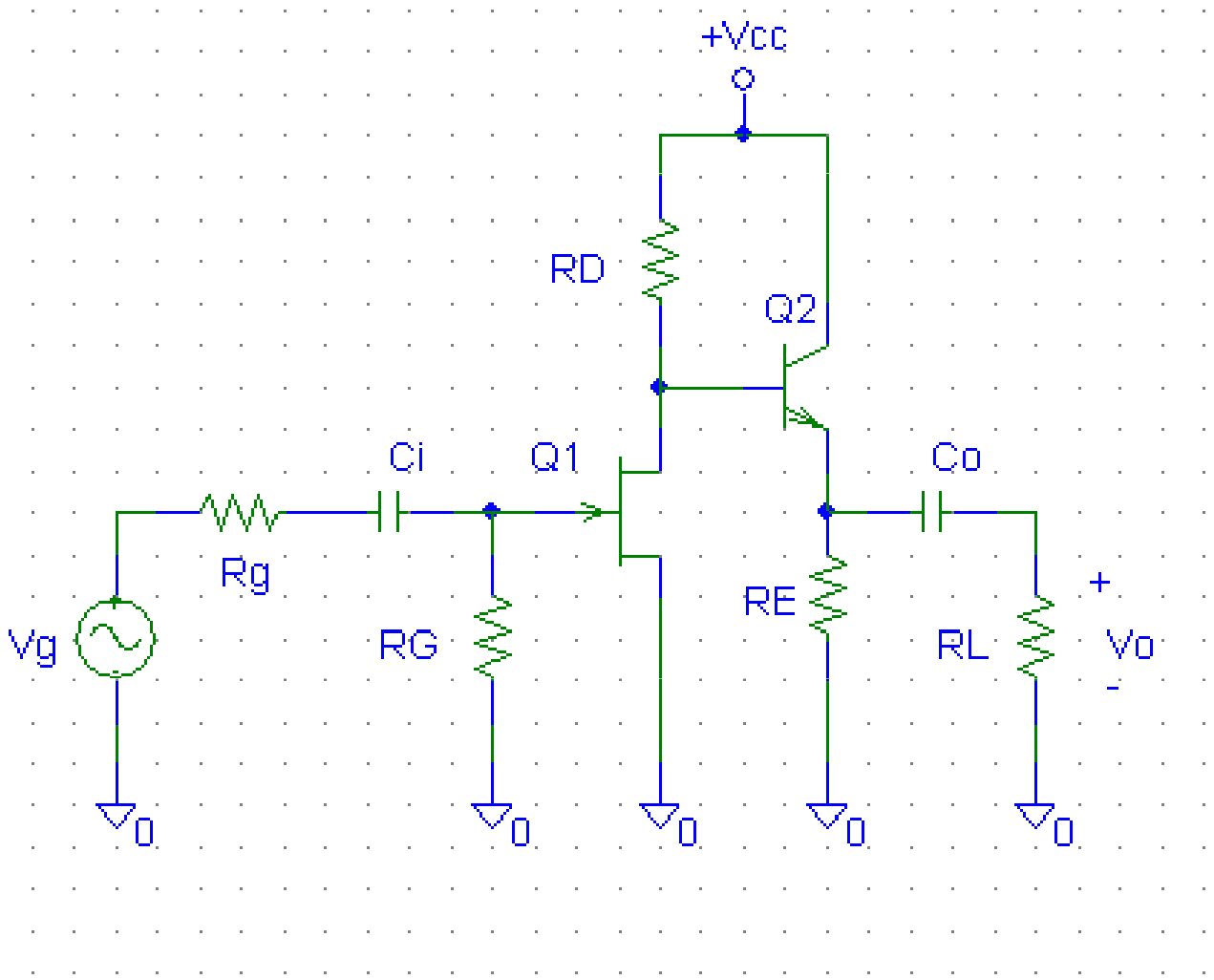
- All analog integrated circuits (IC) are made of several amplification stages, usually DC coupled, each of them with a specific objective.
- The first stage (input stage) fixes the input impedance. There is at least one gain stage and finally the output stage fixes the output impedance and delivers the output current to the load.

Methodology

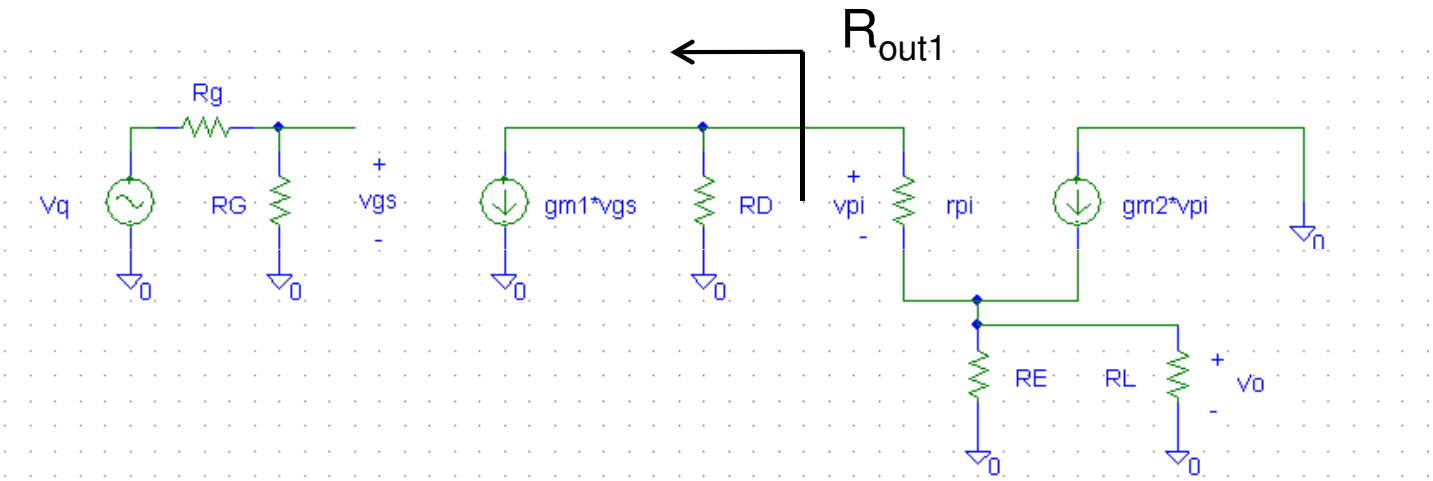


- We start with the determination of the characteristics of the first stage (isolated). The parameters needed are the output voltage (function of Vg) and the output impedance (Rout1).
- The following step includes driving the second stage with the first stage's output voltage using Rout1 as the new generator impedance. With this new scheme, the characteristics for the second stage are determined (output voltage and output impedance).
- Repeat the process for all the stages.

Example (I)



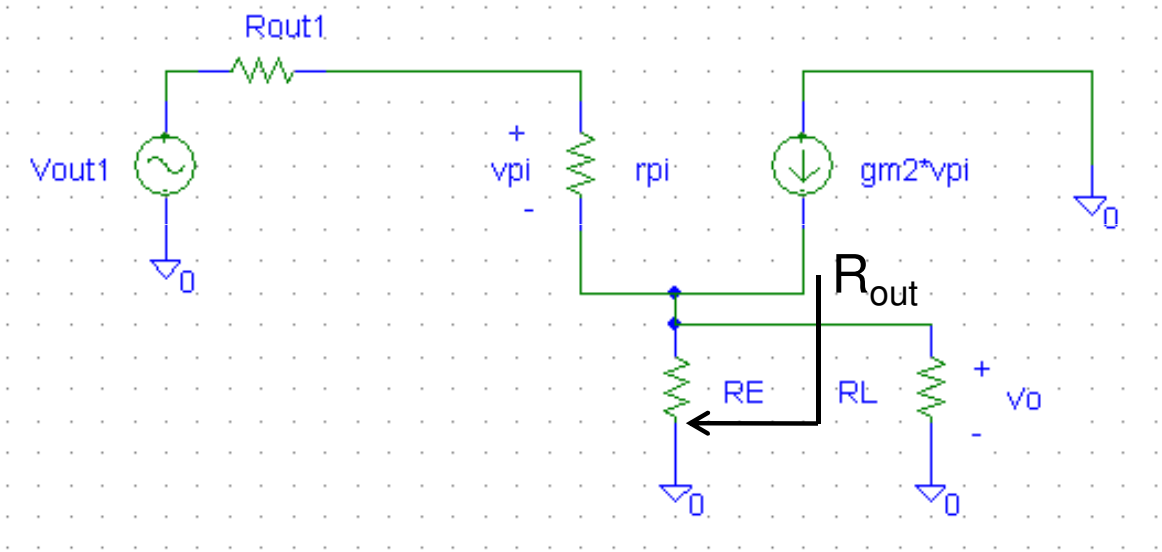
Example (II)



$$R_{out1} = R_D$$

$$V_{out1} = -\frac{R_G}{R_g + R_G} g_{m1} R_D V_g$$

Example (III)



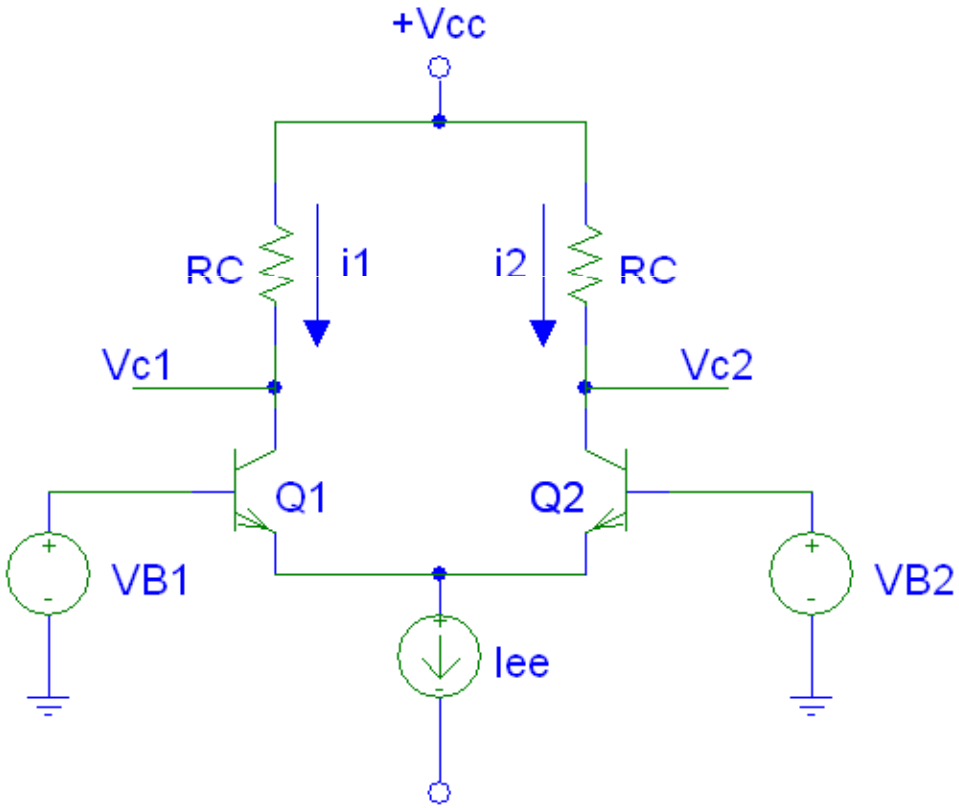
$$R_{out} = R_E \,//\, \frac{r_\pi + R_{out1}}{1+\beta_0}$$

$$V_o = \frac{(1+\beta_0)R_E \,//\, R_L}{R_{out1} + r_\pi + (1+\beta_0)R_E \,//\, R_L} V_{out1}$$

Differential Amplifier

- Fundamental Circuit in Analog Electronics (as well as digital electronics).
- It allows differential signal amplification as well as direct coupling between stages (without coupling capacitors). Circuits with DC gain possible.
- Fundamental part of operational amplifiers (used in the lab).

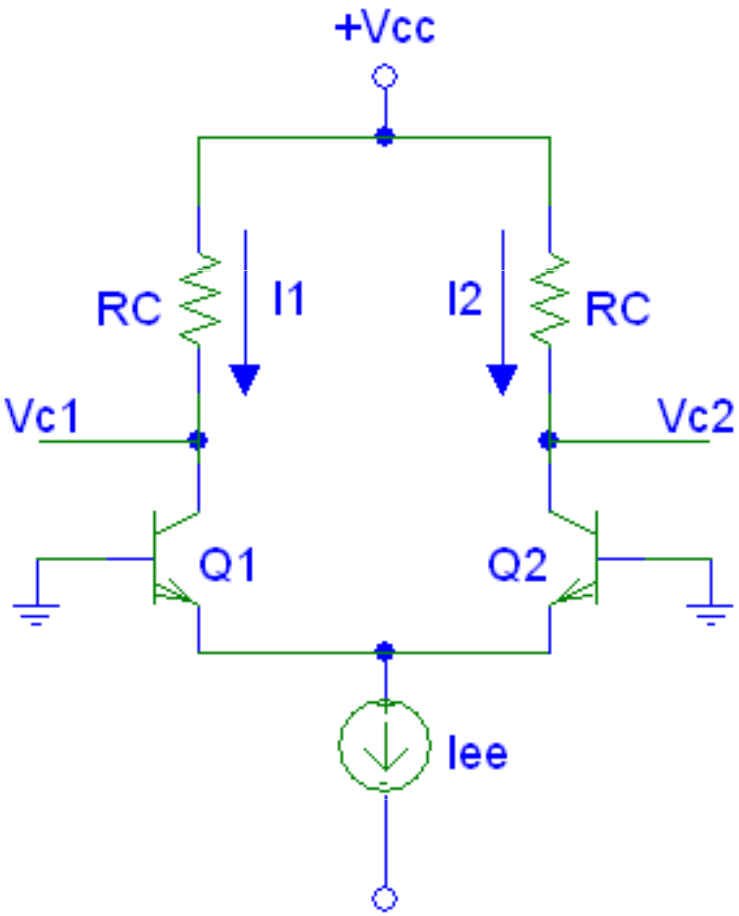
Differential Amplifier



$$v_{id} = v_{B1} - v_{B2}$$

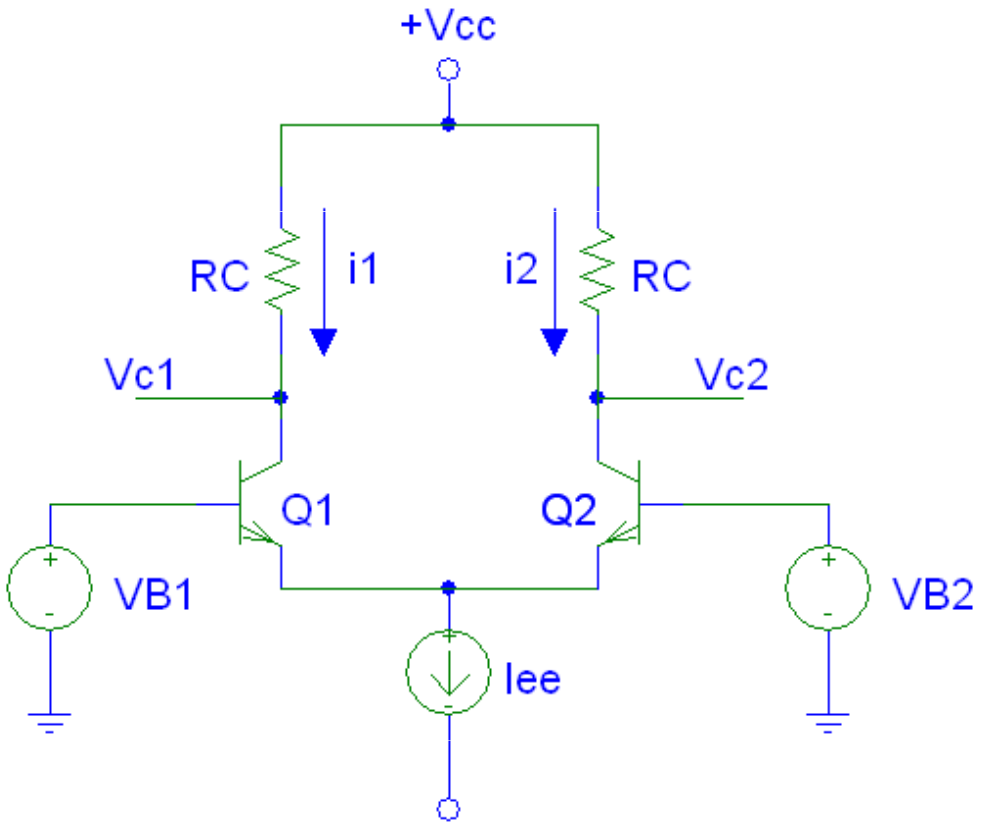
$$v_c = \frac{v_{B1} + v_{B2}}{2}$$

DC analysis of the Differential Amplifier



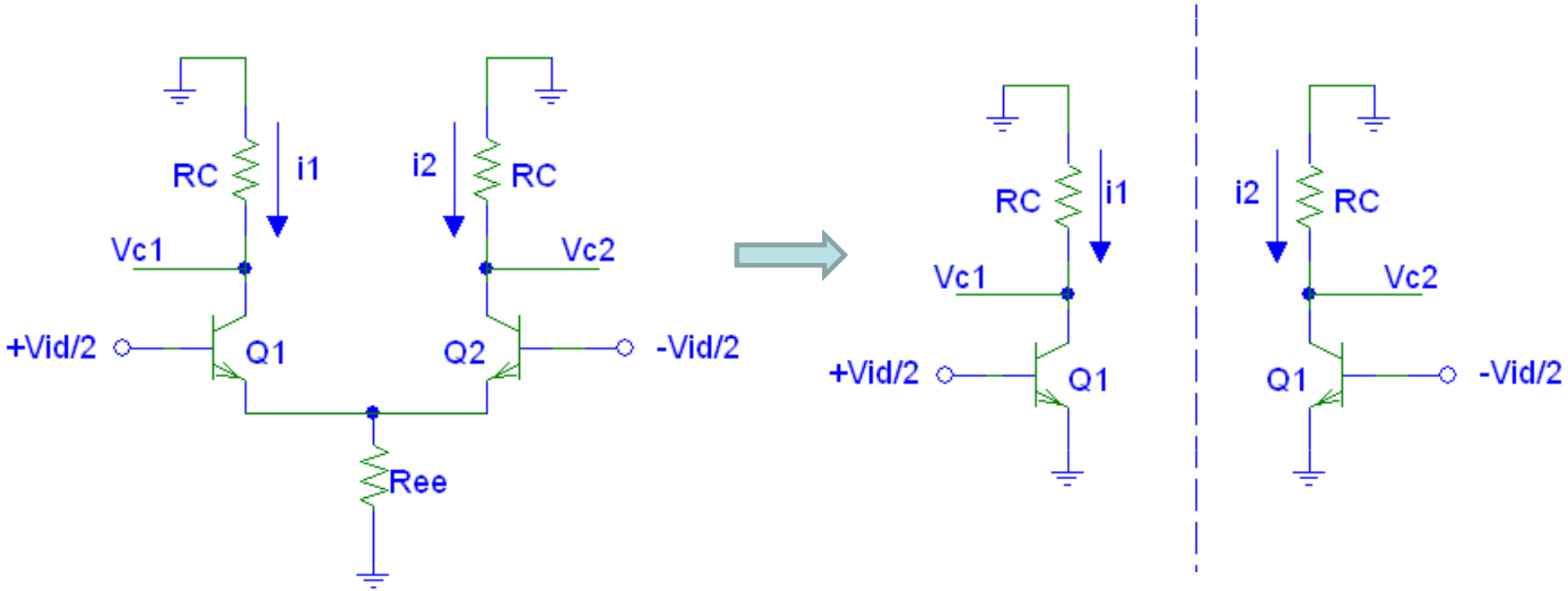
$$I_{C1} = I_{C2} = \frac{I_{ee}}{2}$$

Small-signal Analysis of the Differential Amplifier

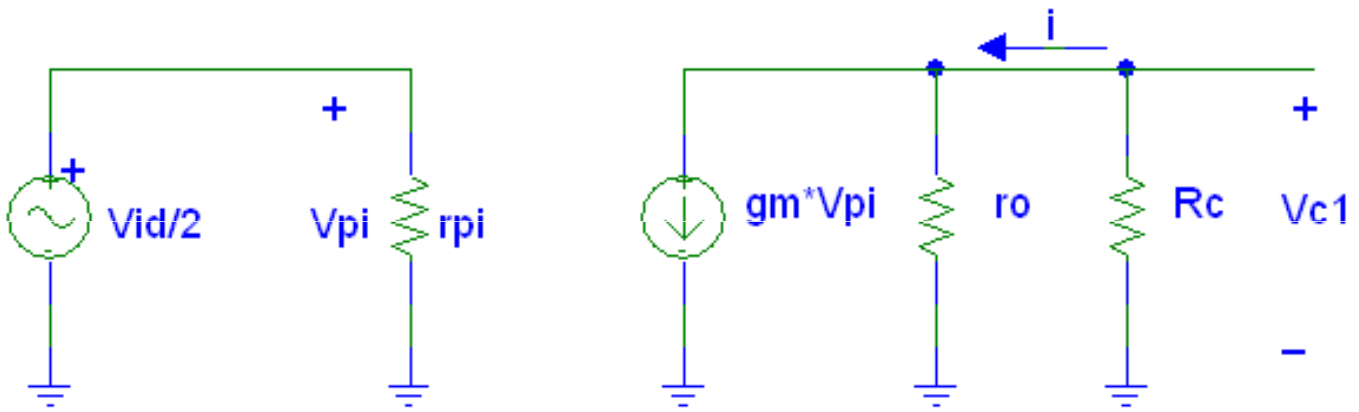


$$v_{c1} = A\,v_{B1} + B\,v_{B2} \quad \Rightarrow \quad v_{c1} = A_{DM}\,v_{id} + A_{CM}\,v_{c}$$

Differential Amplifier Small Signal Analysis Differential Mode (I)



Differential Amplifier Small Signal Analysis Differential Mode (II)

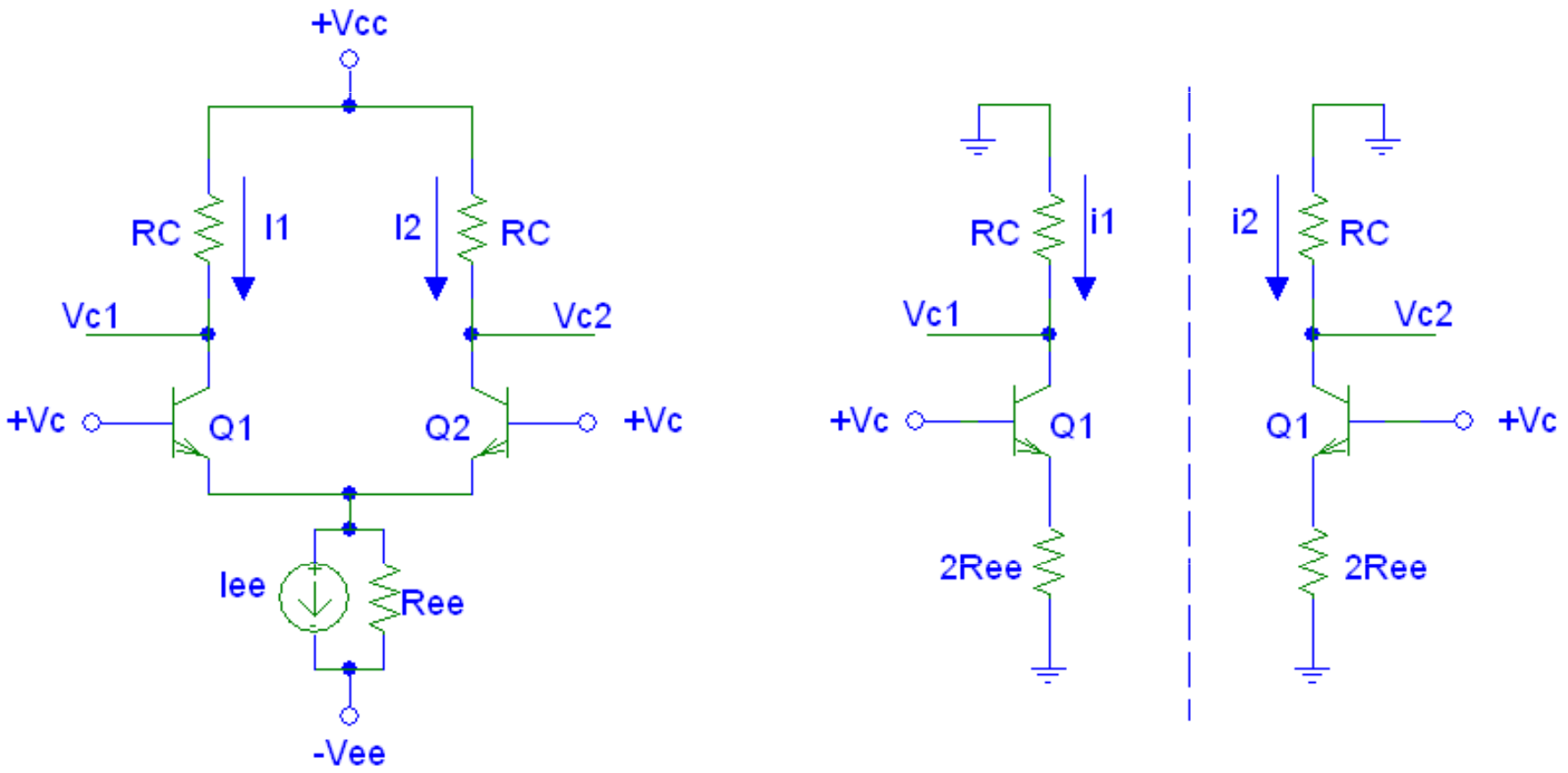


- The output can be the signal that appears between both collectors (differential output):

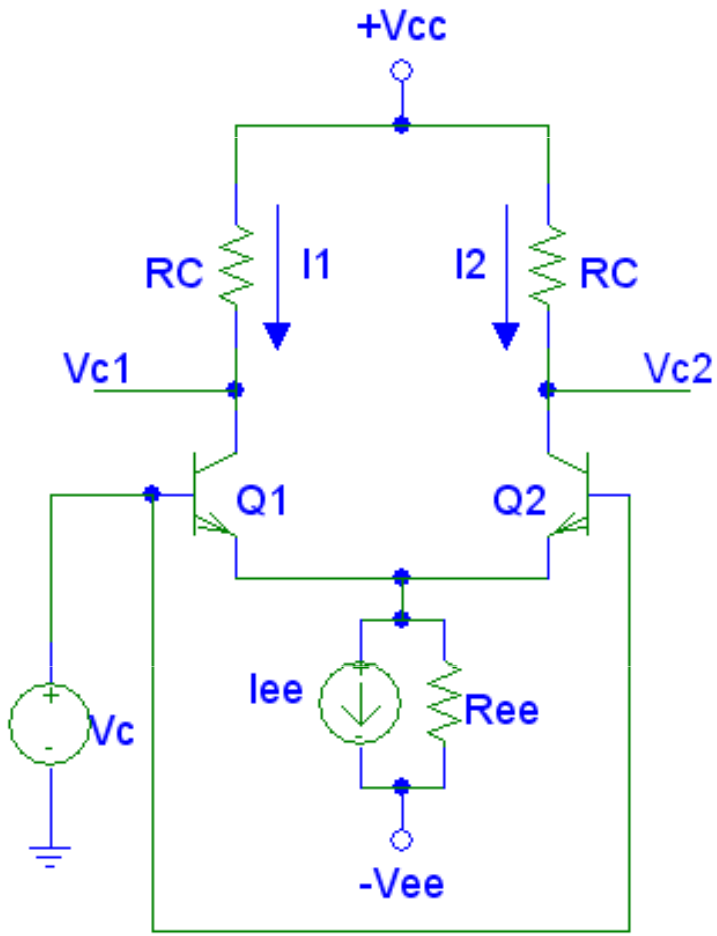
$$v_o = v_{c1} - v_{c2}$$

- Or directly the voltage of one of them referenced to ground (single-ended output)

Differential Amplifier Small Signal Analysis Common Mode (I)



Differential Amplifier Small Signal Analysis Common Mode (II)



Differential Amplifier
Final Considerations (I)

- Common-mode rejection ratio (CMRR):

$$CMRR = \frac{A_{DM}}{A_{CM}}$$

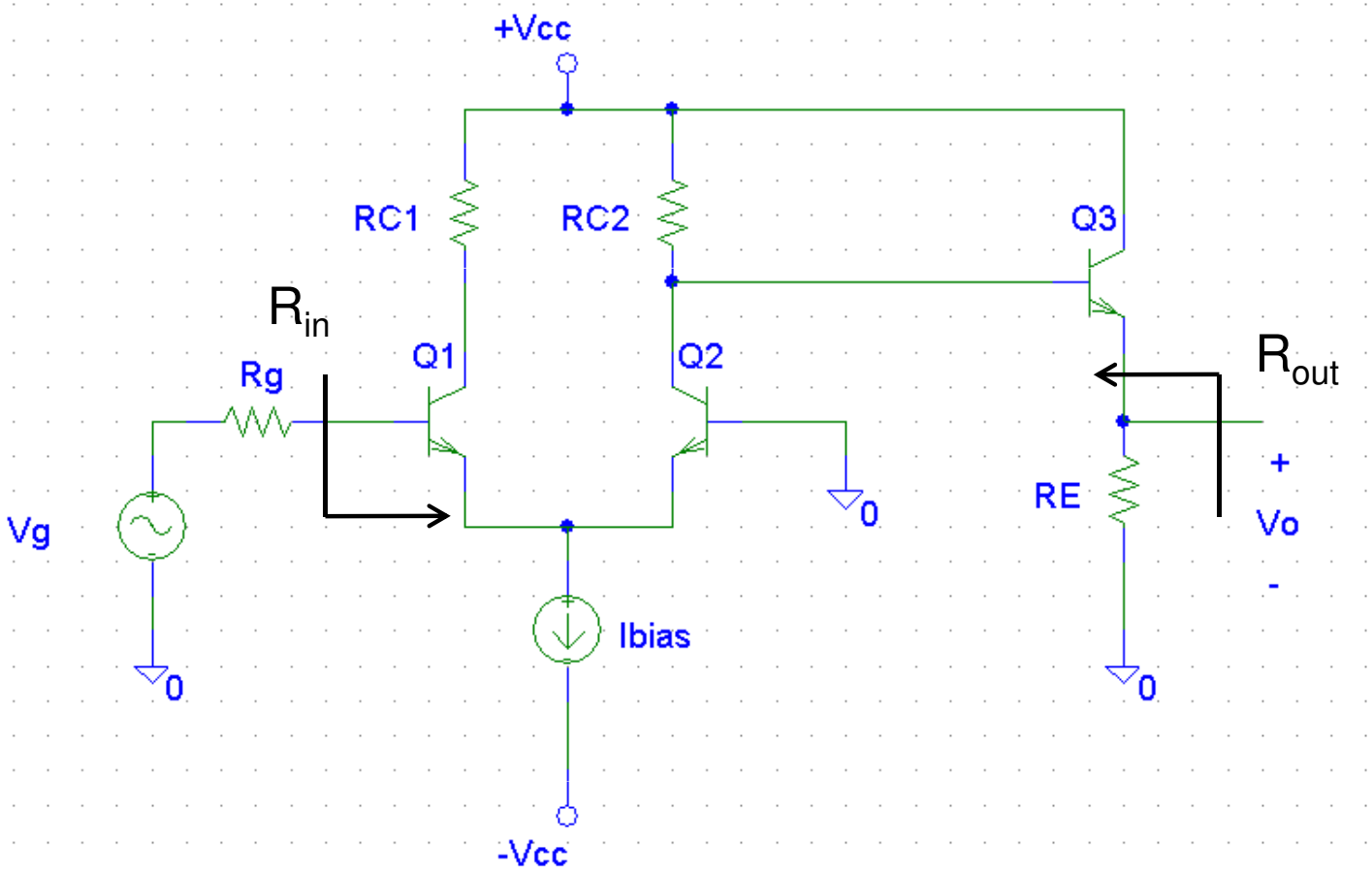
- This way:

$$v_o = A_{DM}\left(v_{id} + \frac{v_c}{CMRR}\right)$$

Differential Amplifier
Final Considerations (II)

- The determination of the different impedances associated to the equivalent circuits are left as an exercise for the students.
- The determination of the frequency response will be covered in the proposed exercise

Proposed Exercise



V_{cc} = 15 V
I_{bias}= 1 mA
$R_{C1} = R_{C2}$ = 10 kΩ R_E = 560 Ω R_g = 50 Ω
BJTs: $\beta_0 = \beta_F$ =250 , V_T = 25 mV, V_{BE}=0.6V, C_π=2 pF, C_μ=0.7 pF