LOM3221 – LABORATÓRIO DE ELETRÔNICA
AULA 8

Prof. Dr. Emerson G. Melo

Sumário

- Projeto de Amplificador Classe AB.
- Experimento

Projeto de Amplificador Classe AB

- Objetivo: Dimensionar o amplificador de potência classe AB para atender aos seguintes requisitos:

$P_{oAC} = 500\ \text{mWrms}$

$V_s = 100\ \text{mVrms}$

$R_L = 33\ \Omega$

$R_S = 50\ \Omega$

$f_L = 300\ \text{Hz}$

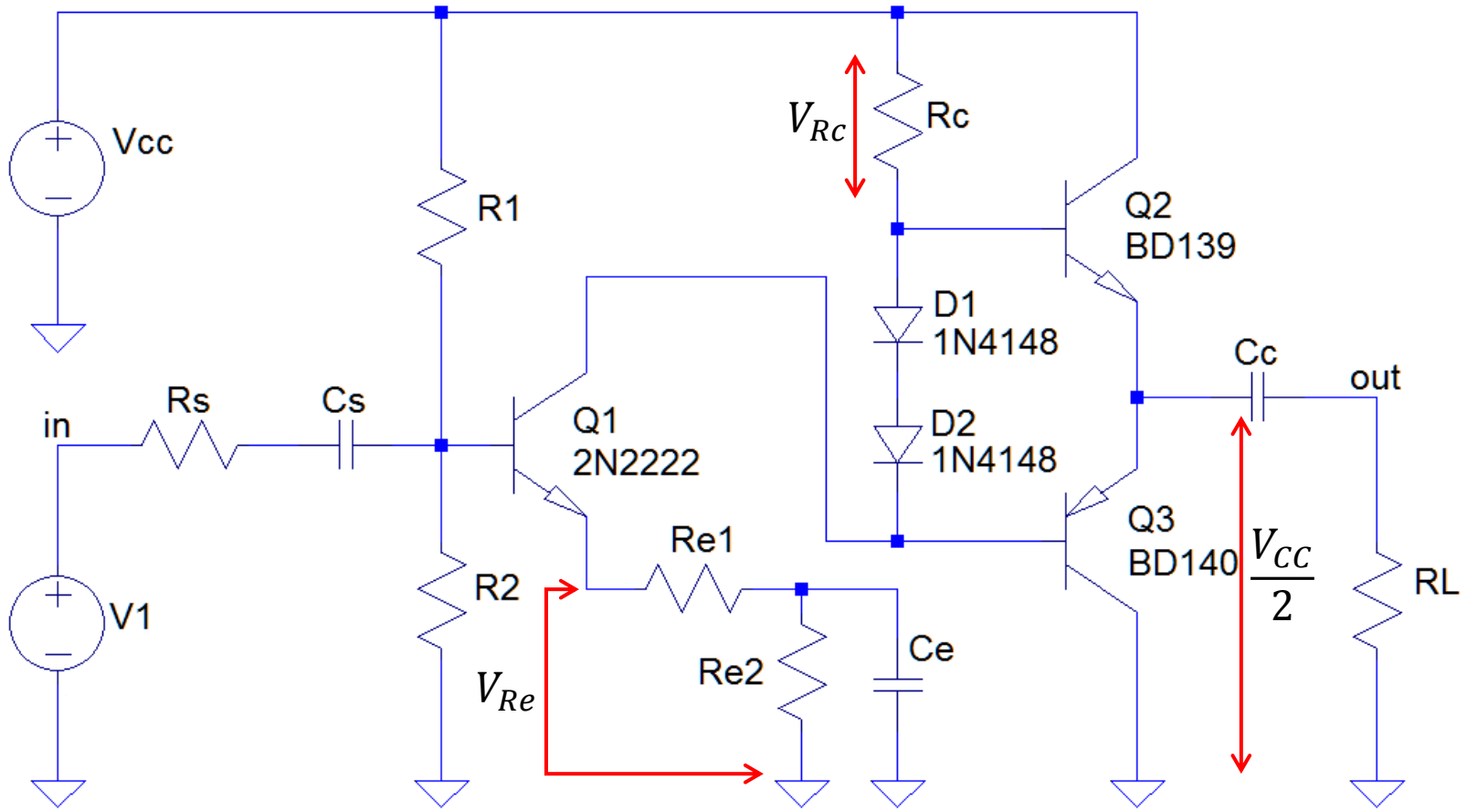
Considerações:

$V_{R_E} \geq 1\ \text{V}$

$V_{R_C} \geq 1\ \text{V}$

$\beta_{Q1} = 200$

$\beta_{Q2} = \beta_{Q3} = 185$



Projeto de Amplificador Classe AB

❑1 – Calcular o ganho de tensão.

$P_{oAC} = 500\ \text{mWrms}$
$V_s = 100\ \text{mVrms}$
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300\ \text{Hz}$
$V_{R_E} \geq 1\ \text{V}$
$V_{R_C} \geq 1\ \text{V}$
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$$A_{vs} = -\frac{V_L}{V_s}$$

$$P_{oAC} = \frac{{V_L}^2}{R_L} \qquad V_L = \sqrt{P_{oAC} R_L} = \sqrt{500\ \text{mW} \times 33\ \Omega} = 4\ \text{V}$$

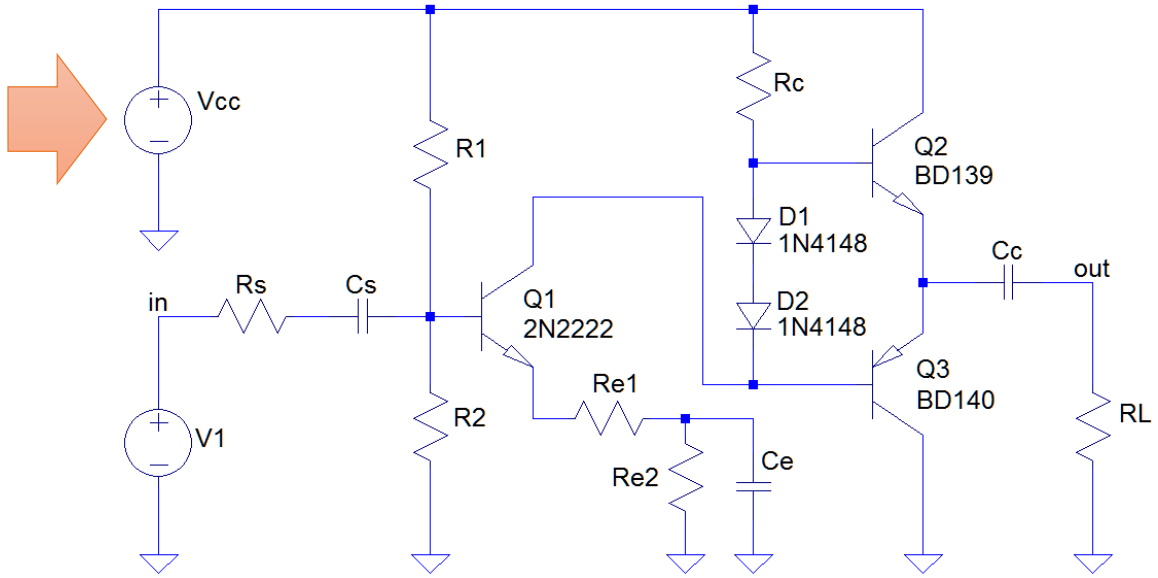
$$A_{vs} = -\frac{4\ \text{V}}{0{,}1\ V} = -40$$

Projeto de Amplificador Classe AB

❑2 – Estimar a tensão de alimentação.

$P_{oAC} = 500\ \text{mWrms}$
$V_s = 100\ \text{mVrms}$
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300\ \text{Hz}$
$V_{R_E} \geq 1\ \text{V}$
$V_{R_C} \geq 1\ \text{V}$
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$



$$V_{CC\,\text{min}} = V_{R_E\text{min}} + V_{BE\,\text{Q3}} + V_{L(\text{pp})} + V_{BE\,\text{Q1}} + V_{R_C\text{min}}$$

$$V_{L(\text{p})} = \sqrt{2}V_{L(\text{RMS})} = \sqrt{2} \times 4\text{V} = 5{,}66\ \text{V}$$

$$V_{CC\,\text{min}} = 1\ \text{V} + 0{,}7\ \text{V} + 2 \times 5{,}66\ \text{V} + 0{,}7\ \text{V} + 1\ \text{V} = 14{,}72\ \text{V}$$

$$V_{CC} = 15\ \text{V}$$

Projeto de Amplificador Classe AB

❑3 – Calcular R_C.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15$ V

$$R_C = \frac{V_{R_C}}{I_{B_{Q2}}}$$

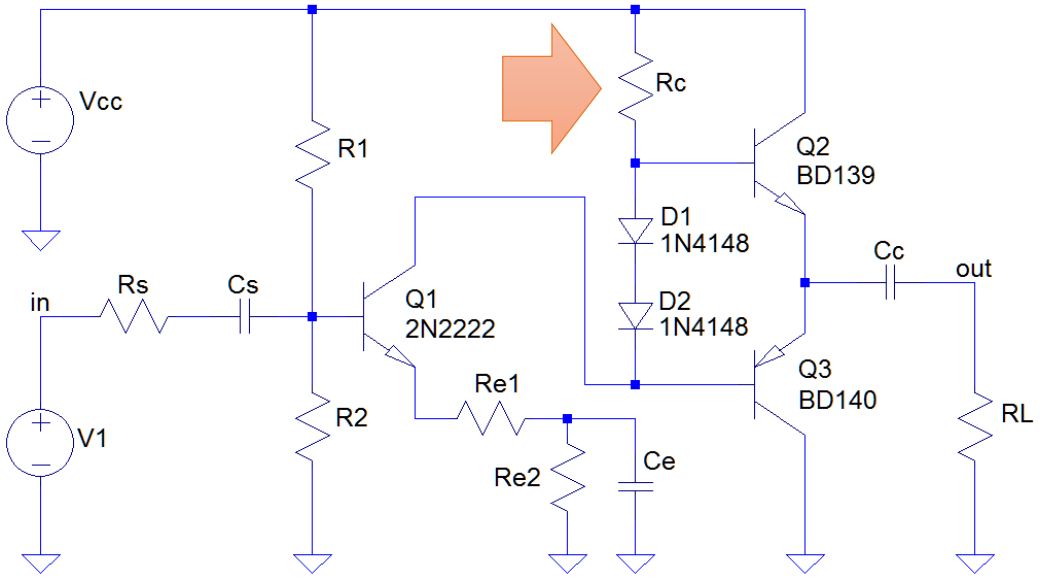
$$V_{R_C} = V_{CC} - \left(V_{L(\mathrm{p})} + \frac{V_{CC}}{2} + V_{BE_{Q2}}\right)$$

$$V_{R_C} = 15 - (5{,}66 + 7{,}5 + 0{,}7) = 1{,}143\ \mathrm{V}$$

$$I_{B_{Q2}} = \frac{I_{L(\mathrm{p})}}{\beta_{Q2}} \qquad I_{L(\mathrm{p})} = \frac{V_{L(\mathrm{p})}}{R_L} = \frac{5{,}66\ \mathrm{V}}{33\ \Omega} = 176{,}8\ \mathrm{mA}$$

$$I_{B_{Q2}} = \frac{176{,}8\ \mathrm{mA}}{185} = 955\ \mu\mathrm{A}$$

$$R_C = \frac{1{,}143\ \mathrm{V}}{955\ \mu\mathrm{A}} = 1{,}19\ \mathrm{k}\Omega$$



Projeto de Amplificador Classe AB

❑4 – Calcular R_{E1} e R_{E2}.

$P_{oAC} = 500\ \text{mWrms}$
$V_s = 100\ \text{mVrms}$
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300\ \text{Hz}$
$V_{R_E} \geq 1\ \text{V}$
$V_{R_C} \geq 1\ \text{V}$
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15\ \text{V}$
$R_C = 1{,}19\ \text{k}\Omega$

$$R_E = R_{E1} + R_{E2} = \frac{V_{R_E}}{I_{R_{CQ}}}$$

$$I_{R_{CQ}} = \frac{V_{CC} - \left(\frac{V_{CC}}{2} + V_{BE_{Q2}}\right)}{R_C} = \frac{15 - (7{,}5 + 0{,}7)}{1190} = 5{,}7\ \text{mA}$$

$$R_{E1} + R_{E2} = \frac{1\ \text{V}}{5{,}7\ \text{mA}} = 176\ \Omega$$

$$A_{vs} \cong -\frac{R_C \parallel \beta_{Q2} R_L}{(R_{E1} + r_e)}$$

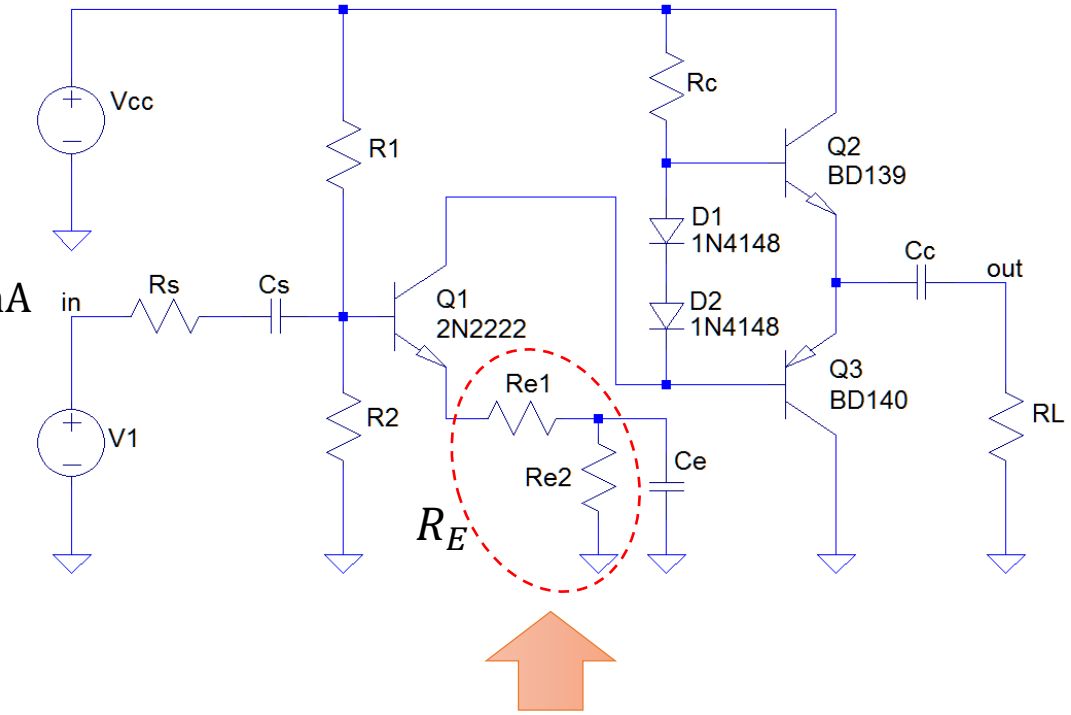
$$R_{E1} = -\frac{R_C \parallel \beta_{Q2} R_L}{A_{vs}} - r_e$$

$$r_e = \frac{26\ mV}{I_E}$$

$$r_e = \frac{26\ mV}{5{,}7\ \text{mA}} = 4{,}57\ \Omega$$

$$R_{E1} = \frac{1{,}19\ \text{k}\Omega \parallel 185 \times 33\ \Omega}{40} - 4{,}57\ \Omega = 20{,}3\ \Omega$$

$$R_{E2} = R_E - R_{E1} = 176\ \Omega - 20{,}3\ \Omega = 155{,}6\ \Omega$$



Projeto de Amplificador Classe AB

❑5 – Calcular R_1 e R_2.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

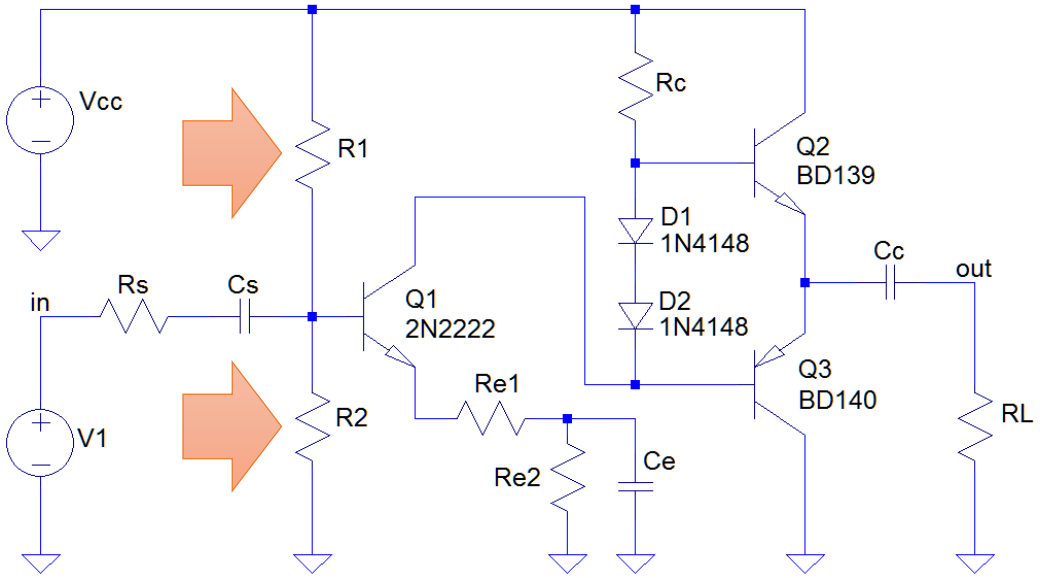
$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$

$$R_1 = \frac{V_{CC} - (V_{R_E} + V_{BE_{Q1}})}{10\left(I_{R_{CQ}}/\beta_{Q1}\right)}$$

$$R_1 = \frac{15\text{ V} - (1\text{ V} + 0{,}7\text{ V})}{10(5{,}7\text{ mA}/200)} = 43{,}3\text{ kΩ}$$

$$R_2 = \frac{V_{R_E} + V_{BE_{Q1}}}{10\left(I_{R_{CQ}}/\beta_{Q1}\right)}$$

$$R_2 = \frac{1\text{ V} + 0{,}7\text{ V}}{10(5{,}7\text{ mA}/200)} = 5{,}53\text{ kΩ}$$



Projeto de Amplificador Classe AB

❑6 – Calcular C_S, C_E e C_C.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ

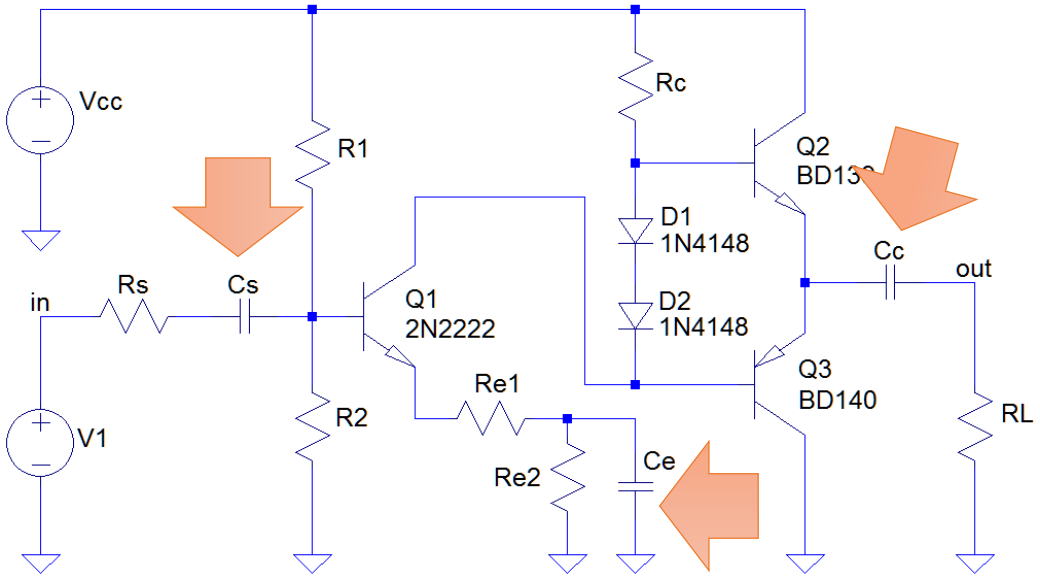
Adotar : $X_C \leq 0{,}1R_j$

$$Z_i = R' \parallel \beta_{Q1}(R_{E1} + r_e) = 2{,}37\ \text{k}\Omega$$

$$C_S \geq \frac{1}{2\pi f_L \times 0{,}1(R_S + Z_i)} = 2{,}18\ \mu\text{F}$$

$$C_E \geq \frac{1}{2\pi f_L \times 0{,}1R_{E2}} = 34\ \mu\text{F}$$

$$C_C \geq \frac{1}{2\pi f_L \times 0{,}1R_L} = 166\ \mu\text{F}$$

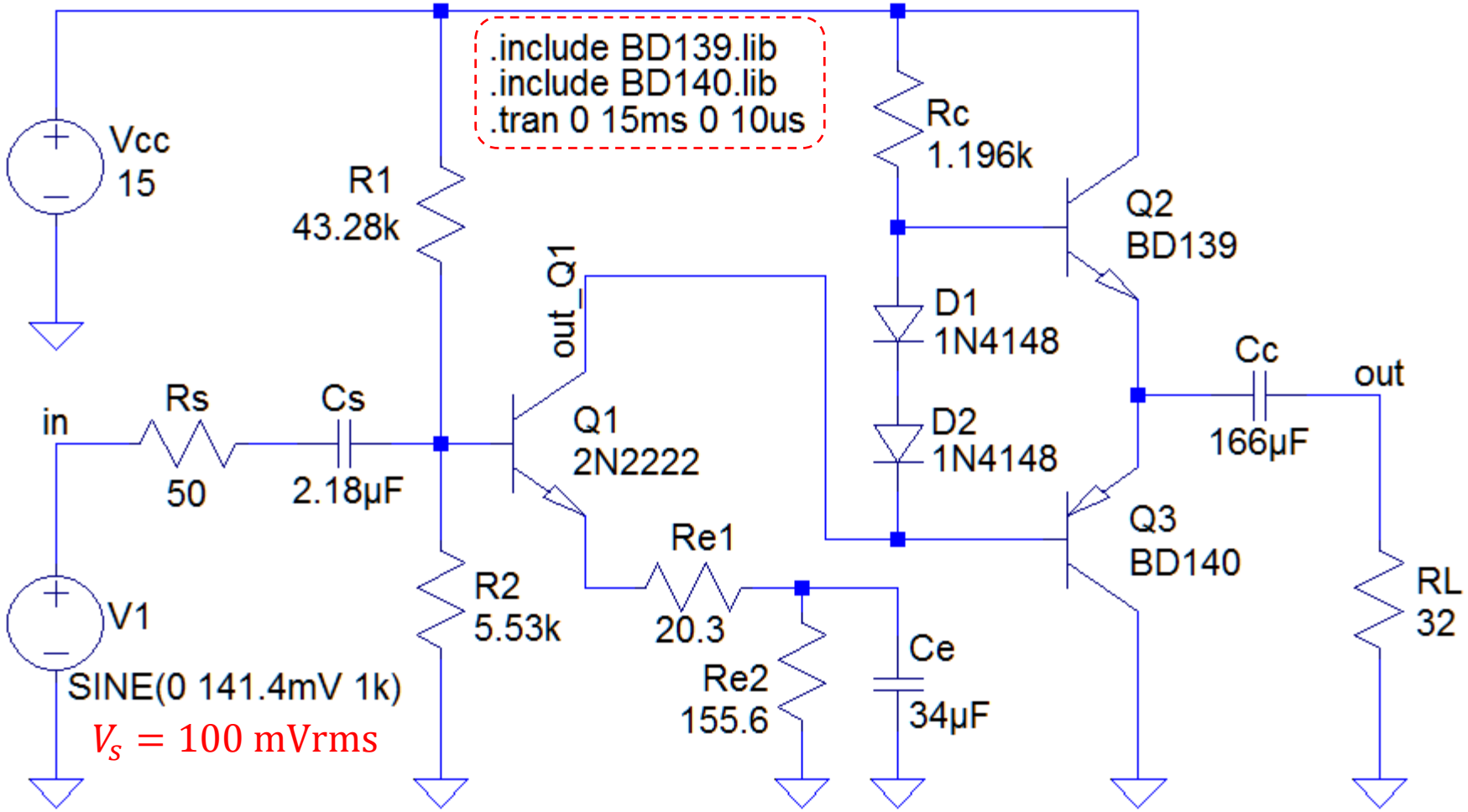


Projeto de Amplificador Classe AB

❑7 – Medir o sinal de saída através de simulação no LTspice.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ
$C_S = 2{,}18$ µF
$C_E = 34$ µF
$C_C = 166$ µF

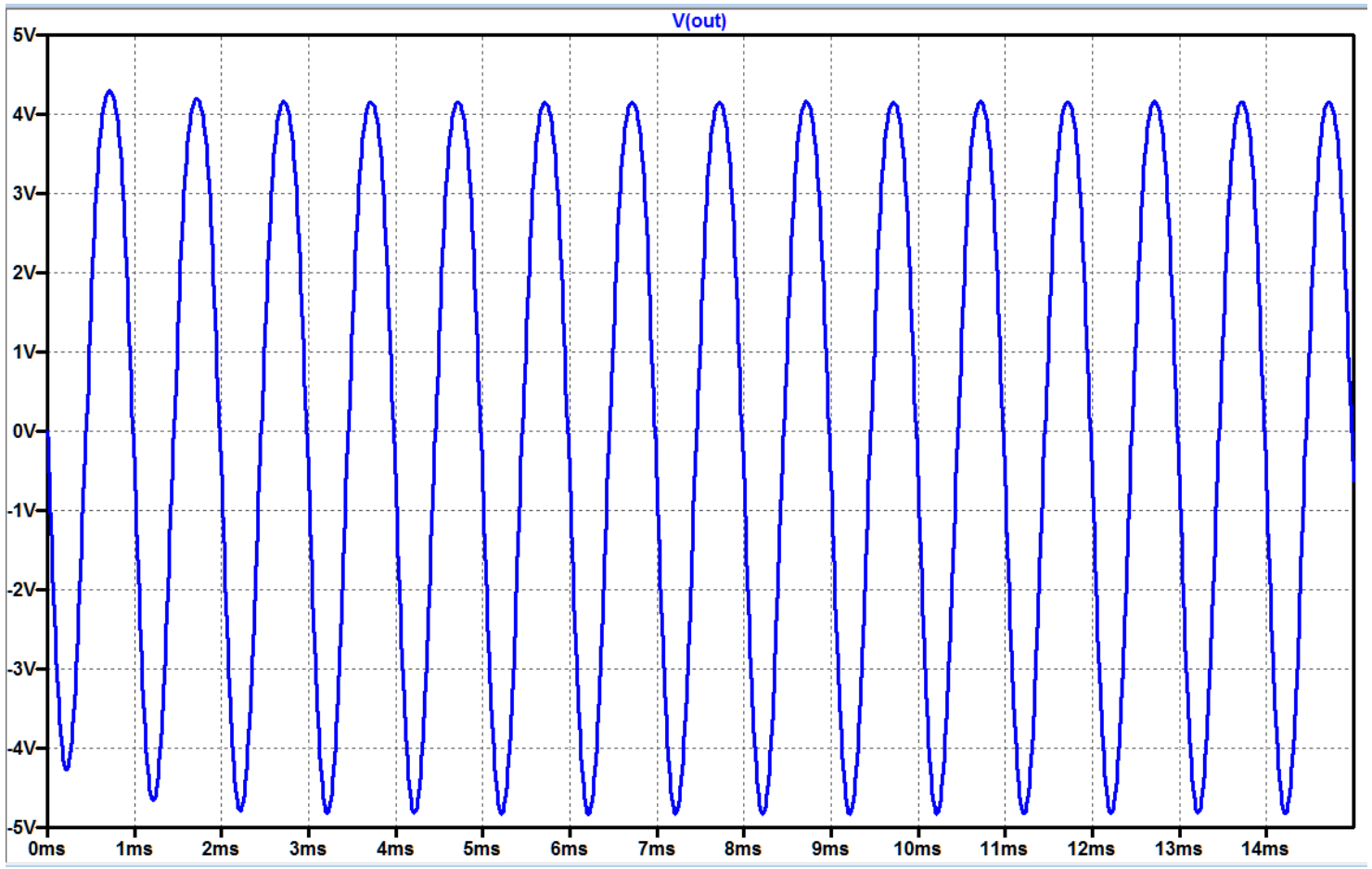


Projeto de Amplificador Classe AB

❑7 – Medir o sinal de saída através de simulação no LTspice.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ
$C_S = 2{,}18$ µF
$C_E = 34$ µF
$C_C = 166$ µF



$$V_L = 9\ \text{Vpp}$$

$$A_{vs} = -\frac{9\ \text{Vpp}}{2\sqrt{2} \times 100\ \text{mVrms}}$$

$$A_{vs} = -31{,}8$$

Projeto de Amplificador Classe AB

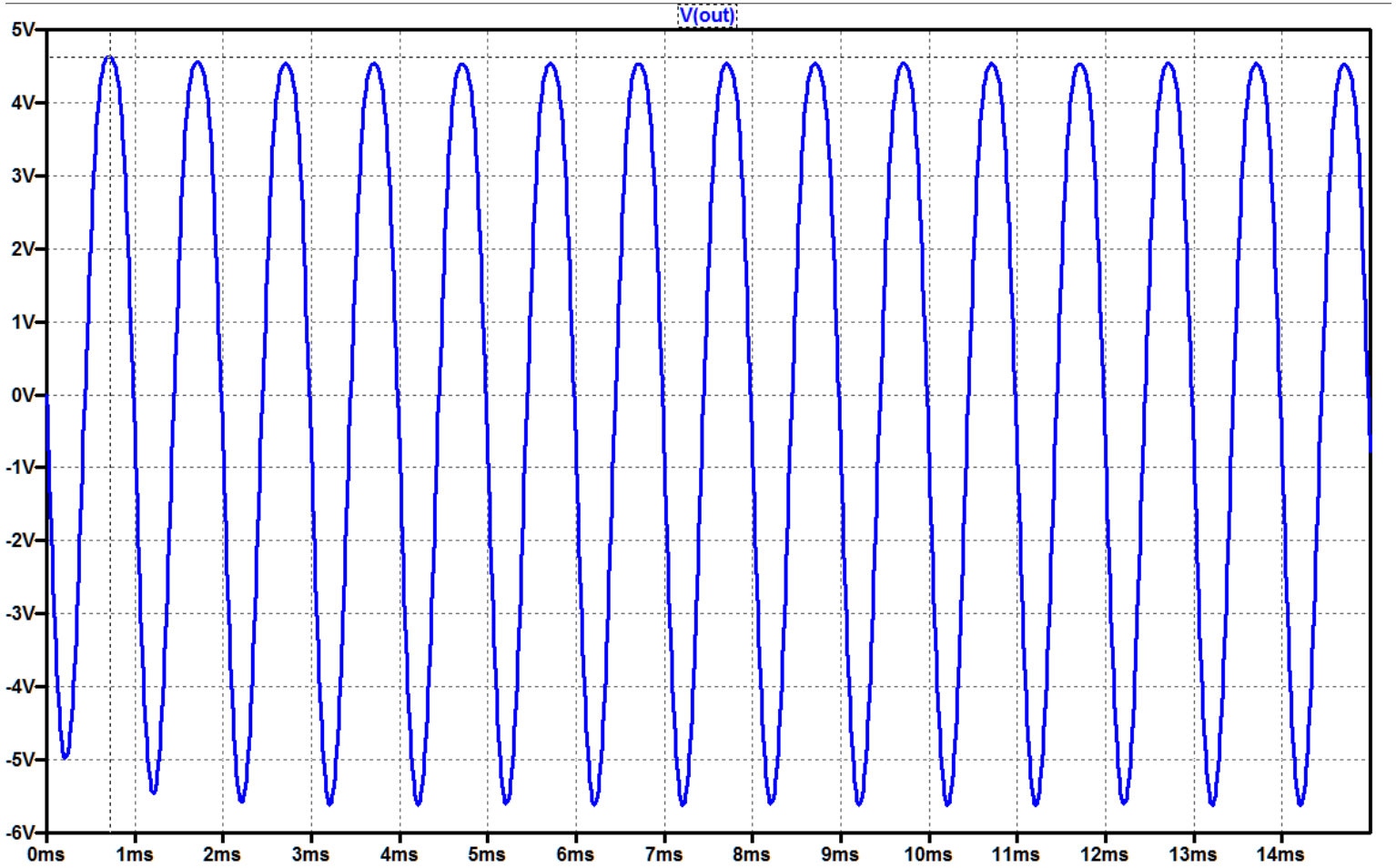
❑8 – Corrigir o valor de R_{E1}.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$$R_{E1} \cong \frac{-31{,}8}{-40} \times 20{,}3\ \Omega$$

$$R_{E1} \cong 16{,}15\ \Omega$$

$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ
$C_S = 2{,}18$ µF
$C_E = 34$ µF
$C_C = 166$ µF



$A_{vs} = -36$

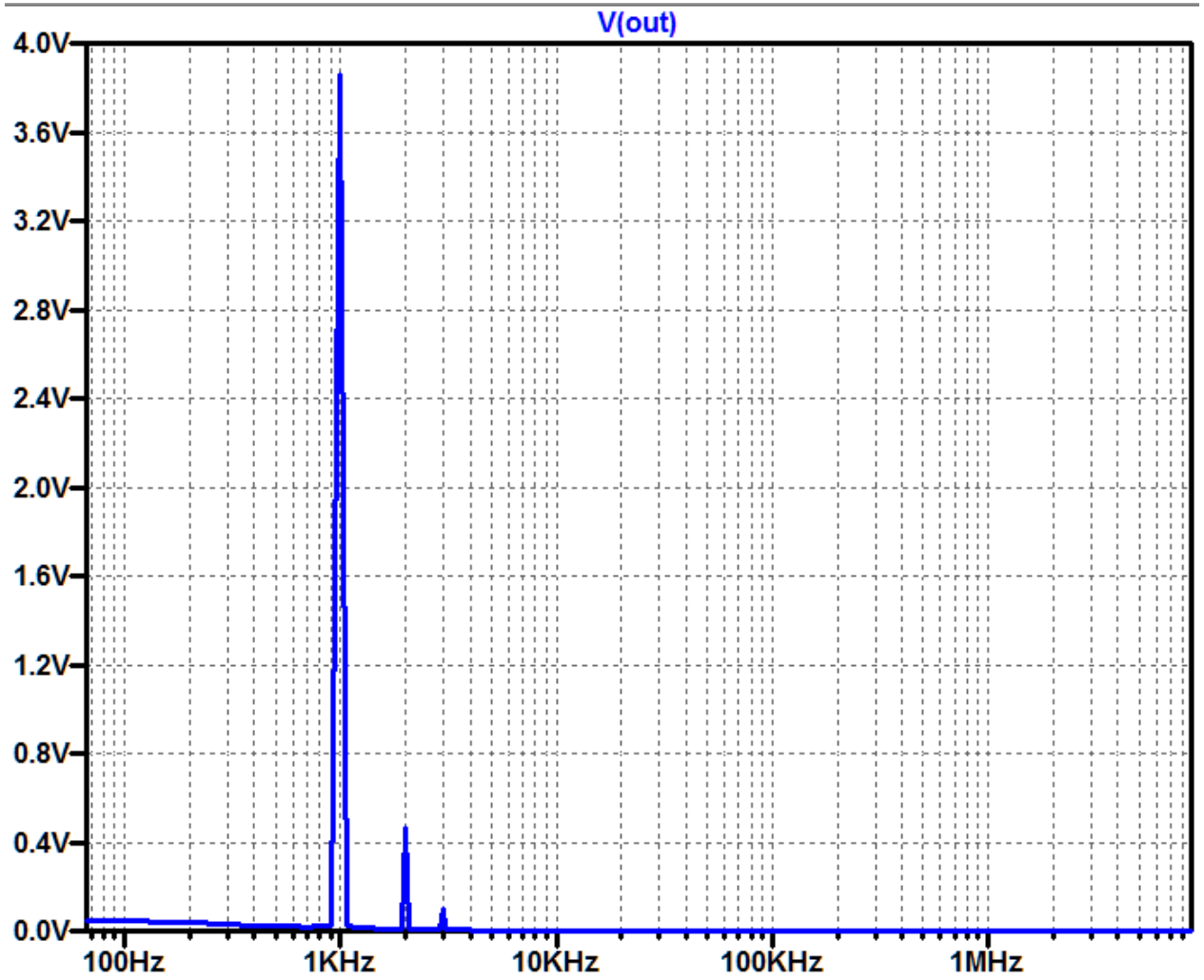
Emerson G. Melo – Departamento de Engenharia de Materiais - Polo Urbo-Industrial, Gleba AI-6, Lorena, SP 12612-550, Brasil

Projeto de Amplificador Classe AB

❑9 – Analisar a distorção harmônica.

$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

$A_{vs} = -40$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ
$C_S = 2{,}18$ µF
$C_E = 34$ µF
$C_C = 166$ µF



Emerson G. Melo – Departamento de Engenharia de Materiais - Polo Urbo-Industrial, Gleba AI-6, Lorena, SP 12612-550, Brasil

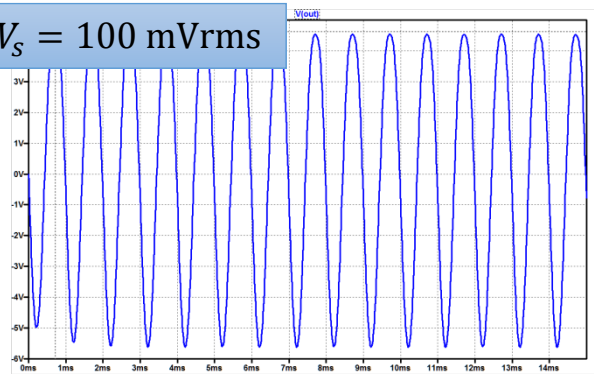
Projeto de Amplificador Classe AB

❑9 – Analisar a distorção harmônica total.

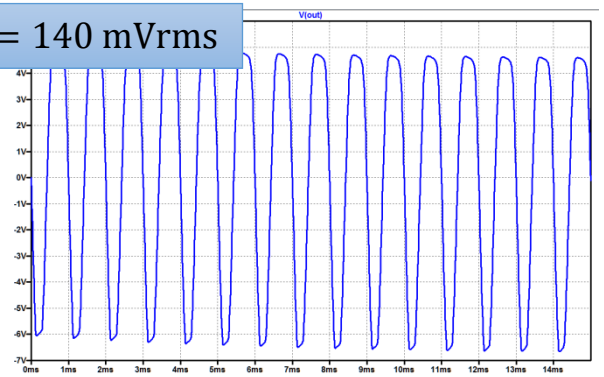
$P_{oAC} = 500$ mWrms
$V_s = 100$ mVrms
$R_L = 33\ \Omega$
$R_S = 50\ \Omega$
$f_L = 300$ Hz
$V_{R_E} \geq 1$ V
$V_{R_C} \geq 1$ V
$\beta_{Q1} = 200$
$\beta_{Q2} = \beta_{Q3} = 185$

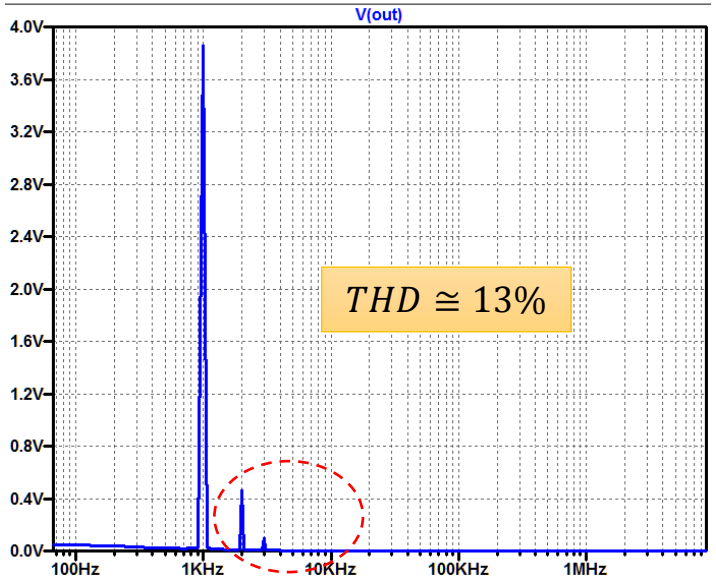
$A_{vs} = -40(-36)$
$V_{CC} = 15$ V
$R_C = 1{,}19$ kΩ
$R_{E1} = 20{,}3\ \Omega$
$R_{E2} = 155{,}6\ \Omega$
$R_1 = 43{,}3$ kΩ
$R_2 = 5{,}53$ kΩ
$C_S = 2{,}18$ µF
$C_E = 34$ µF
$C_C = 166$ µF

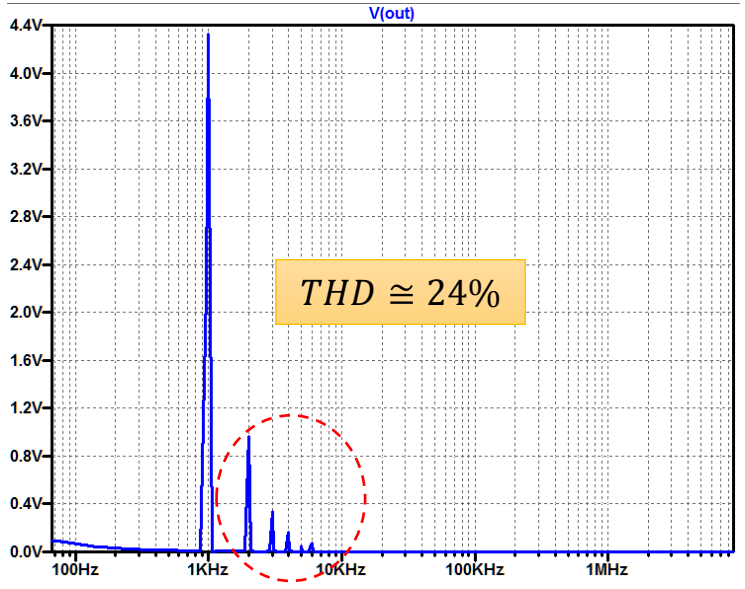
$V_s = 100$ mVrms



$V_s = 140$ mVrms







Experimento 1: Amplificador Classe AB

- Dimensionar o amplificador de potência classe AB para atender aos seguintes requisitos:

$P_{oAC} = 700\ \text{mWrms}$

$V_s = 100\ \text{mVrms}$

$R_L = 16\ \Omega$

$R_S = 50\ \Omega$

$f_L = 200\ \text{Hz}$

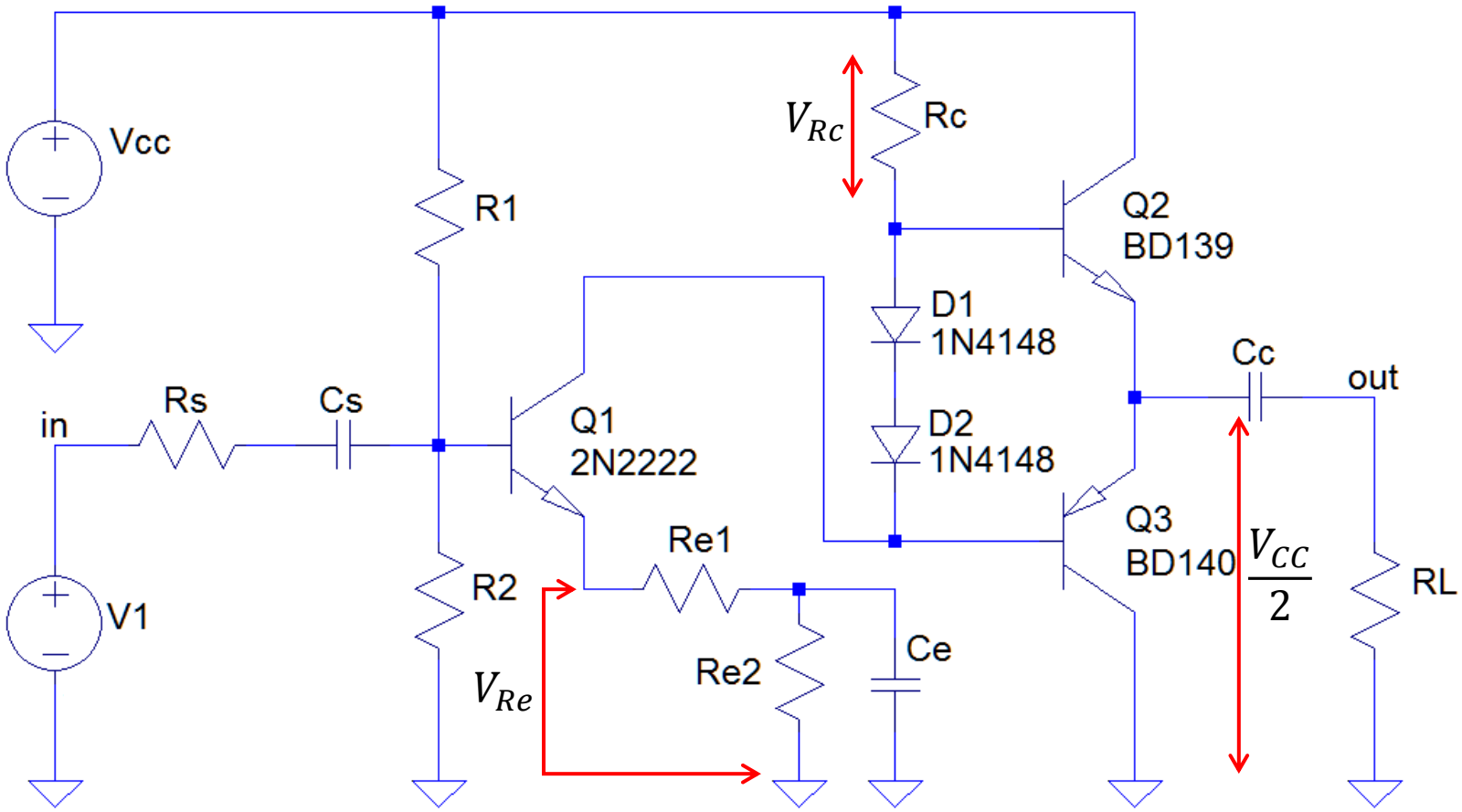
Considerações:

$V_{Re} \geq 1\ \text{V}$

$V_{Rc} \geq 1\ \text{V}$

$\beta_{Q1} = 200$

$\beta_{Q2} = \beta_{Q3} = 185$



Experimento 2: Amplificador Classe AB

- Calcular a Eficiência e a THD para um sinais de entrada com amplitudes de 50 mVrms e 150 mVrms:

$P_{oAC} = 700$ mWrms

$V_s = 100$ mVrms

$R_L = 16\ \Omega$

$R_S = 50\ \Omega$

$f_L = 200$ Hz

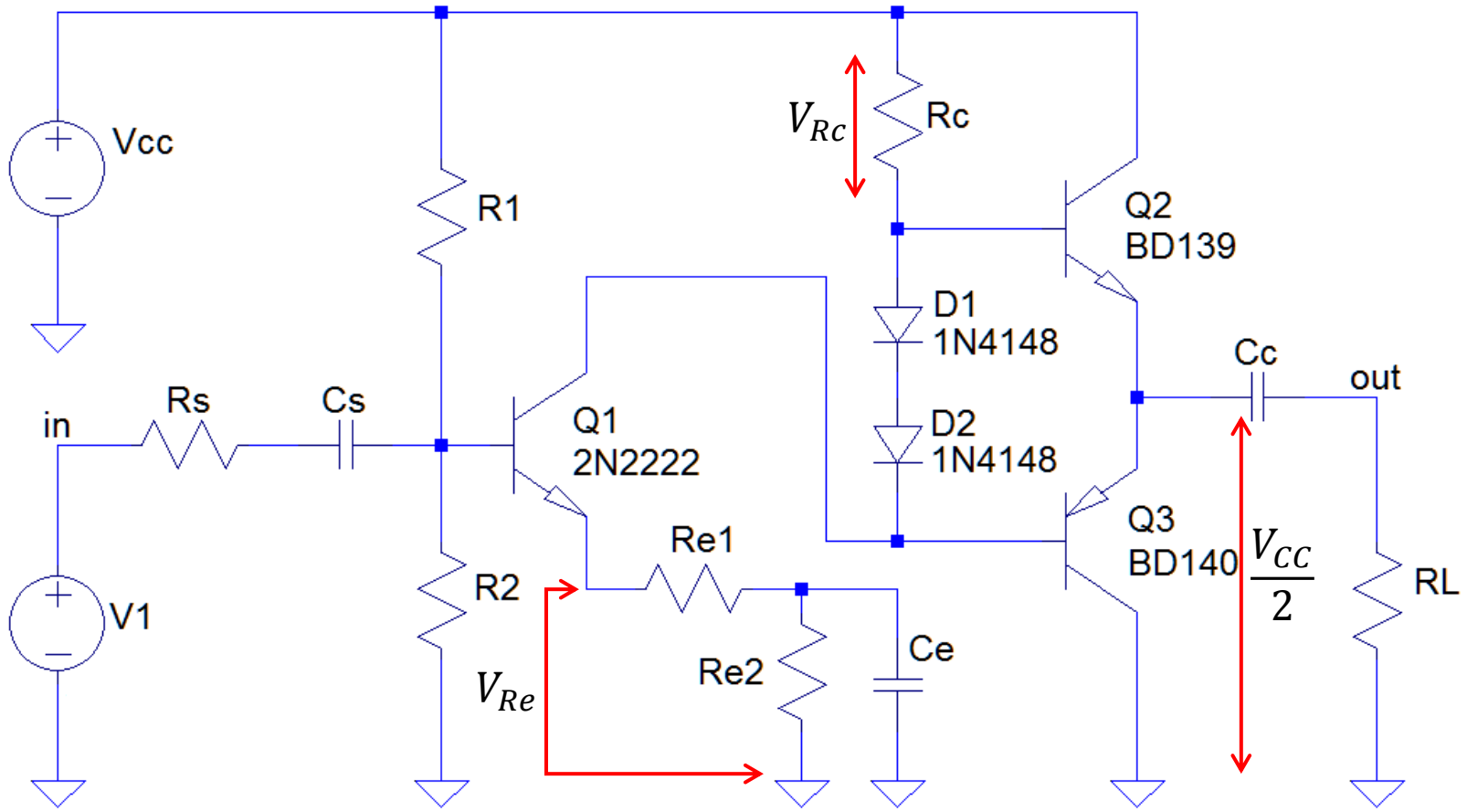
Considerações:

$V_{Re} \geq 1$ V

$V_{Rc} \geq 1$ V

$\beta_{Q1} = 200$

$\beta_{Q2} = \beta_{Q3} = 185$



Referências

- Boylestad, Robert L.; Nashelsky, Louis “Dispositivos Eletrônicos e Teoria de Circuitos”, 6 ed., Rio de Janeiro, LTC (1998
- Boylestad, Robert L.; Nashelsky, Louis “Electronic Devices and Circuit Theory”, 11 ed., Boston, Pearson (2013).