JFET

Resumo das Equações de Cálculo dos Amplificadores Básicos.

1.) Amplificador Fonte-Comum (CS):

$$I_D = IFTE\left(V_{DS} \geq V_{Dsat}, I_{Dp}, I_{Dt}\right)$$

$$I_{Dp} = \beta(V_{GS} - V_{To})^2(1 + \lambda V_{DS})$$

$$I_{Dt} = \beta(2(V_{GS} - V_{To}) - V_{DS})V_{DS}(1 + \lambda V_{DS})$$

$$V_G = IFTE\left(R_{G1} = \infty, IFTE(R_S \neq 0{,}0, -V_{GG}), \frac{R_{G2}V_{DD}}{R_{G1} + R_{G2}}\right)$$

$$R_G = IFTE(R_{G1} = \infty, R_{G2}, \frac{R_{G1}R_{G2}}{R_{G1} + R_{G2}})$$

$$V_{Dsat} = V_{GS} - V_{To}$$

$$V_{GS} = V_G - R_S I_D$$

$$V_{DS} = V_{DD} - (R_S + R_D)I_D$$

$$V_{DS\,x} = IFTE(V_{DS} \geq V_{Dsat}, \frac{\sqrt{(1 + 4\beta V_{DD}(R_S + R_D)(1 - \lambda V_{To}))} - 1}{2\beta(R_S + R_D)(1 - \lambda V_{To})}, inválido)$$

$$g_{mt} = 2\beta V_{DS}(1 + \lambda V_{DS}) \quad ; \quad g_{mp} = \frac{2I_D}{V_{GS} - V_{To}}$$

$$r_{dst} = \frac{1}{2\beta(1 + \lambda V_{DS})(V_{GS} - V_{To} - V_{DS}) + \lambda\beta V_{DS}[2(V_{GS} - V_{To}) - V_{DS}]}; r_{dsp} = IFTE\left(\lambda \neq 0, \frac{1 + \lambda V_{DS}}{\lambda I_D}, \infty\right)$$

$$g_m = IFTE\left(V_{DS} \geq V_{Dsat}, g_{mp}, g_{mt}\right) \quad ; \quad r_{ds} = IFTE\left(V_{DS} \geq V_{Dsat}, r_{dsp}, r_{dst}\right)$$

$$C_{gs} = \frac{C_{GS}}{\left(1 - \frac{V_{GS}}{P_B}\right)^m} \quad ; \quad C_{gd} = \frac{C_{GD}}{\left(1 - \frac{V_{GS} - V_{DS}}{P_B}\right)^m}$$

$$R_D^* = \frac{R_D R_L}{R_D + R_L} \quad ; \quad R_L^* = \frac{R_D^* r_{ds}}{R_D^* + r_{ds}} \quad ; \quad R_{S(AC)} = IFTE(C_S \neq 0{,}0, R_S)$$

$$p_G = \frac{1}{2\pi C_G(R_{ger} + R_i)} \quad ; \quad p_D = \frac{1}{2\pi C_D(R_o + R_L)}$$

$$Z_S = IFTE(C_S \neq 0, IFTE\left(R_S \neq 0, \frac{1}{2\pi C_S R_S}, 0\right), 0)$$

$$p_S = IFTE(C_S \neq 0, IFTE\left(R_S \neq 0, \frac{r_{ds} + R_D^* + R_S(1 + g_m r_{ds})}{2\pi C_S R_S(r_{ds} + R_D^*)}, 0\right), 0)$$

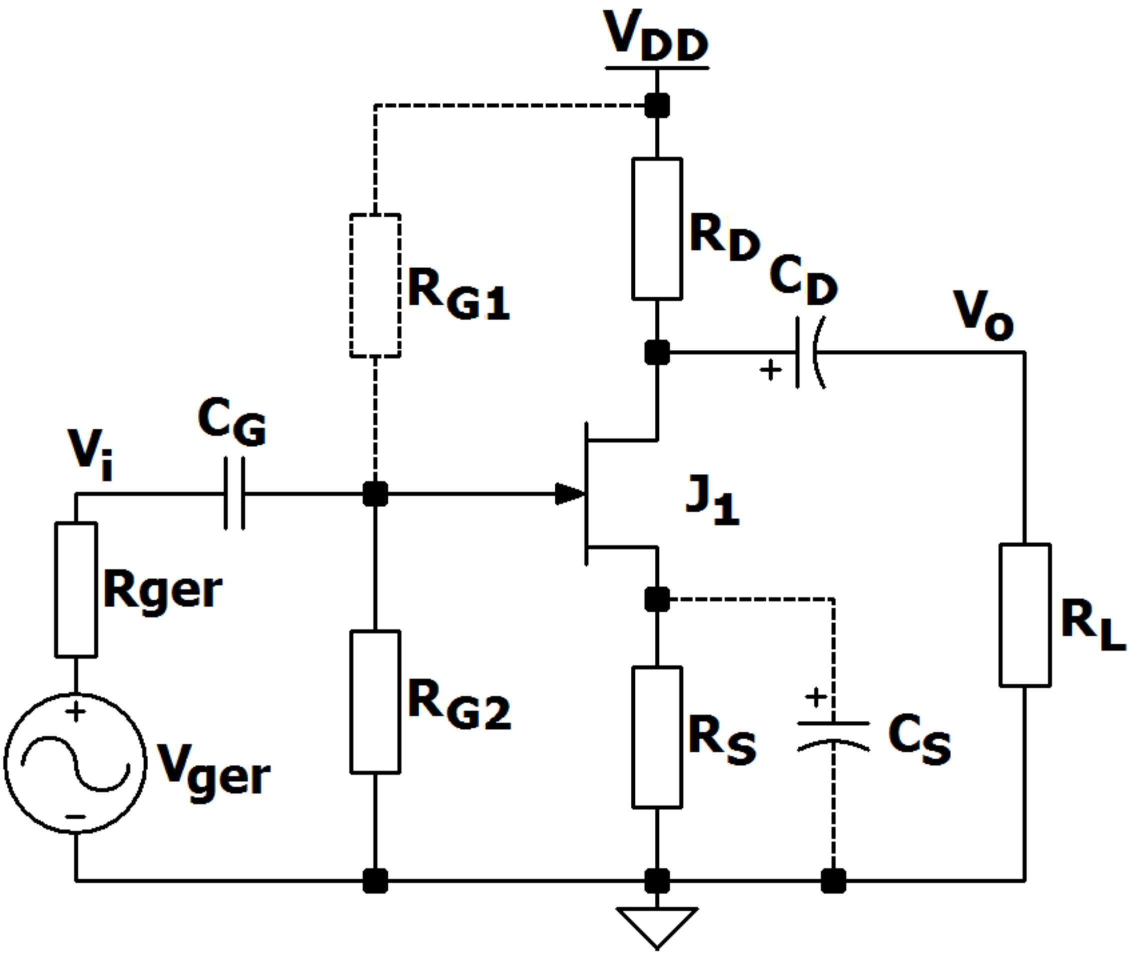

Figura 1 – Amplificador CS.

$$A_\vartheta = -\frac{g_m r_{ds} R_D^*}{r_{ds} + R_D^* + R_{S(AC)}(1 + g_m r_{ds})}$$

$$R_o = \frac{\left[r_{ds} + R_{S(AC)}(1 + g_m r_{ds})\right] R_D}{r_{ds} + R_D + R_{S(AC)}(1 + g_m r_{ds})}$$

$$R_i = R_G$$

$$f_{CA} = \frac{R_{ger} + R_G}{2\pi R_G \left\{\left[R_{ger} + \left(\frac{g_m R_{ger}}{1 + g_m R_{S(AC)}} + \frac{R_{ger} + R_G}{R_G}\right) R_L^*\right] C_{gd} + \frac{g_m R_L^* R_{ger} C_{gs}}{1 + g_m\left(R_L^* + R_{S(AC)}\right)}\right\}}$$

$$f_{CB} = IFTE\left(C_S \neq 0, \sqrt{p_G^2 + p_D^2 + p_S^2 - 2z_S^2}, \sqrt{\frac{p_G^2 + p_D^2 + \sqrt{p_G^4 + p_D^4 + 6p_G^2 p_D^2}}{2}}\right)$$

$$A_{\vartheta g} = \frac{R_i A_\vartheta}{R_i + R_{ger}}$$

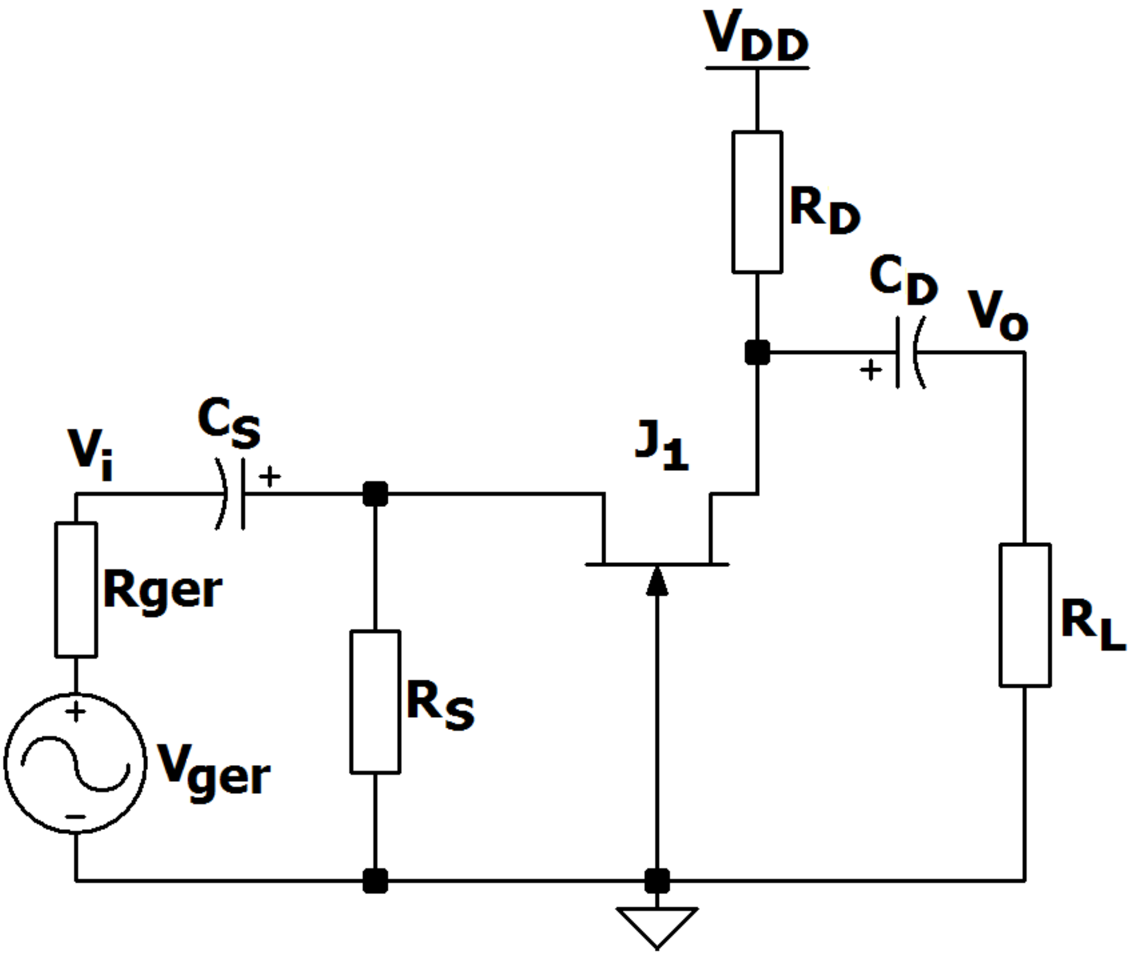

Figura 2 – Amplificador CG.

2.) Amplificador Porta-Comum (CG):

$$I_D = IFTE(V_{DS} \geq V_{Dsat}, I_{Dp}, I_{Dt})$$

$$I_{Dp} = \beta(V_{GS} - V_{To})^2(1 + \lambda V_{DS})$$

$$I_{Dt} = \beta(2(V_{GS} - V_{To}) - V_{DS})V_{DS}(1 + \lambda V_{DS})$$

$$V_{Dsat} = V_{GS} - V_{To}$$

$$V_{GS} = -R_S I_D$$

$$V_{DS} = V_{DD} - (R_S + R_D)I_D$$

$$g_{mt}=2\beta V_{DS}(1 + \lambda V_{DS}) \quad ; \quad g_{mp} = \frac{2I_D}{V_{GS}-V_{To}}$$

$$r_{dst} = \frac{1}{2\beta(1+\lambda V_{DS})(V_{GS}-V_{To}-V_{DS})+\lambda\beta V_{DS}[2(V_{GS}-V_{To})-V_{DS}]}; \; r_{dsp} = IFTE\left(\lambda \neq 0, \frac{1+\lambda V_{DS}}{\lambda I_D}, \infty\right)$$

$$g_m = IFTE(V_{DS} \geq V_{Dsat}, g_{mp}, g_{mt}) \quad ; \quad r_{ds} = IFTE(V_{DS} \geq V_{Dsat}, r_{dsp}, r_{dst})$$

$$C_{gs} = \frac{C_{GS}}{\left(1-\frac{V_{GS}}{P_B}\right)^m} \quad ; \quad C_{gd} = \frac{C_{GD}}{\left(1-\frac{V_{GS}-V_{DS}}{P_B}\right)^m}$$

$$R_D^* = \frac{R_D R_L}{R_D+R_L} \quad ; \quad R_L^* = \frac{R_D^* r_{ds}}{R_D^*+r_{ds}} \quad ; \quad R_S' = \frac{R_S R_{ger}}{R_S+R_{ger}}$$

$$p_i = IFTE(R_{ger} \neq 0, \frac{R_i+R_{ger}}{2\pi C_{gs} R_i R_{ger}}, 0) \quad ; \quad p_o = \frac{R_o+R_L}{2\pi C_{gd} R_o R_L}$$

$$p_S = \frac{1}{2\pi C_S(R_{ger}+R_i)} \quad ; \quad p_D = \frac{1}{2\pi C_D(R_o+R_L)}$$

$$A_\vartheta = \frac{(1+g_m r_{ds})R_D^*}{r_{ds}+R_D^*}$$

$$R_o = \frac{[r_{ds}+R_S'(1+g_m r_{ds})]R_D}{r_{ds}+R_D+R_S'(1+g_m r_{ds})}$$

$$R_i = \frac{(r_{ds}+R_D^*)R_S}{r_{ds}+R_D^*+R_S(1+g_m r_{ds})}$$

$$f_{CA} = IFTE(R_{ger} \neq 0, \sqrt{\frac{\sqrt{p_i^4+p_o^4+6p_i^2p_o^2}-p_i^2-p_o^2}{2}}, p_o)$$

$$f_{CB} = \sqrt{\frac{p_S^2+p_D^2+\sqrt{p_S^4+p_D^4+6p_S^2p_D^2}}{2}}$$

$$A_{\vartheta g} = \frac{R_i A_\vartheta}{R_i+R_{ger}}$$

3.) Amplificador Dreno-Comum (CD):

$$I_D = IFTE(V_{DS} \geq V_{Dsat}, I_{Dp}, I_{Dt})$$

$$I_{Dp} = \beta(V_{GS}-V_{To})^2(1+\lambda V_{DS})$$

$$I_{Dt} = \beta(2(V_{GS}-V_{To})-V_{DS})V_{DS}(1+\lambda V_{DS})$$

$$V_G = IFTE\left(R_{G1} = \infty, 0, \frac{R_{G2}V_{DD}}{R_{G1}+R_{G2}}\right)$$

$$R_G = IFTE(R_{G1} = \infty, R_{G2}, \frac{R_{G1}R_{G2}}{R_{G1}+R_{G2}})$$

$$V_{Dsat} = V_{GS} - V_{To}$$

$$V_{GS} = V_G - R_S I_D$$

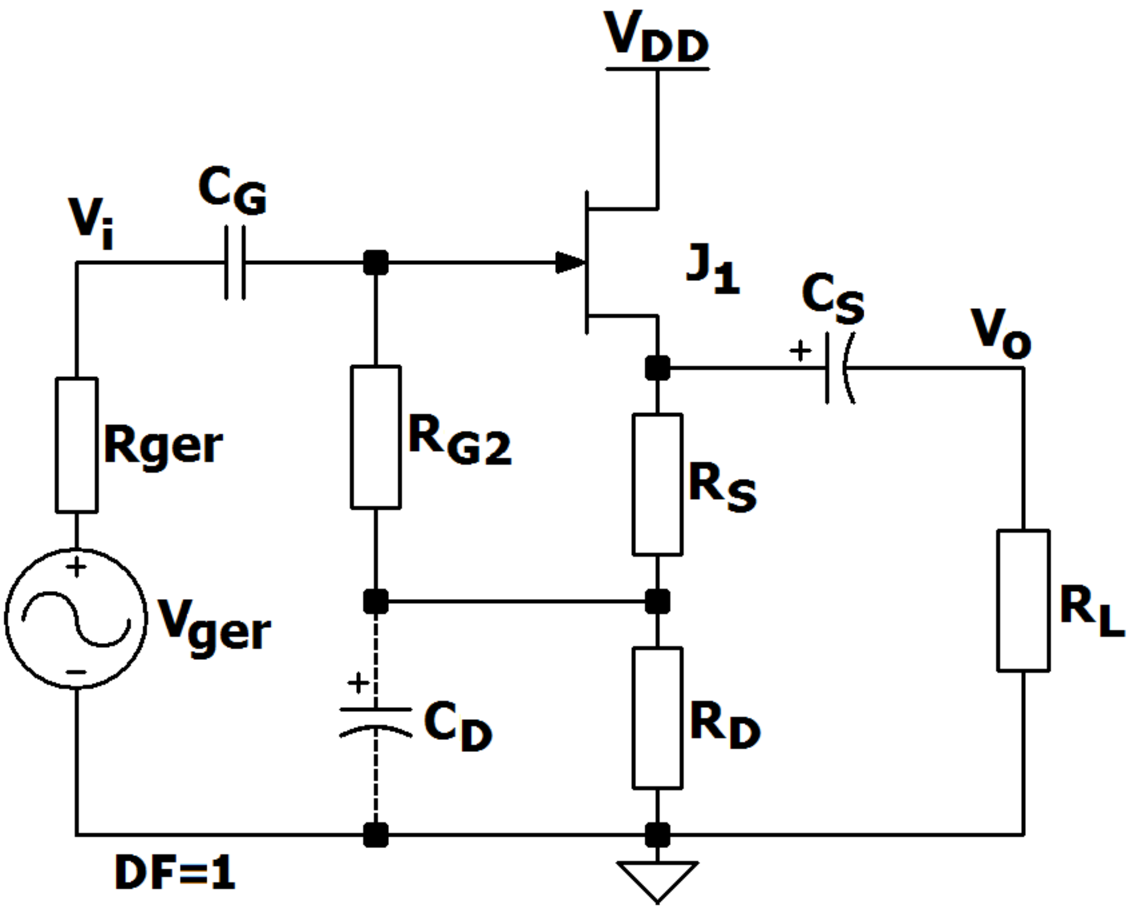

Figura 3a – Amplificador CD com Divisor de Fonte (DF=1).

$$V_{DS} = V_{DD} - (R_S + R_D)I_D$$

$$g_{mt}=2\beta V_{DS}(1+\lambda V_{DS}) \quad ; \quad g_{mp} = \frac{2I_D}{V_{GS}-V_{To}}$$

$$r_{dst} = \frac{1}{2\beta(1+\lambda V_{DS})(V_{GS}-V_{To}-V_{DS})+\lambda\beta V_{DS}[2(V_{GS}-V_{To})-V_{DS}]}; \; r_{dsp} = IFTE\left(\lambda \neq 0, \frac{1+\lambda V_{DS}}{\lambda I_D}, \infty\right)$$

$$g_m = IFTE(V_{DS} \geq V_{Dsat}, g_{mp}, g_{mt}) \quad ; \quad r_{ds} = IFTE(V_{DS} \geq V_{Dsat}, r_{dsp}, r_{dst})$$

$$C_{gs} = \frac{C_{GS}}{\left(1-\frac{V_{GS}}{P_B}\right)^m} \quad ; \quad C_{gd} = \frac{C_{GD}}{\left(1-\frac{V_{GS}-V_{DS}}{P_B}\right)^m}$$

$$R_S^* = \frac{R_S R_L}{R_S+R_L} \; ; \; R_{D(AC)} = IFTE(C_D \neq 0,0,R_D) \; ; \; P = (R_G + R_S)R_{D(AC)} + R_G R_S$$

$$P^* = (R_G^* + R_S)R_{D(AC)} + R_G^* R_S \quad ; \quad R_G^* = R_G + R_{ger}$$

$$A_{\vartheta 1} = \frac{g_m r_{ds} R_S^*}{r_{ds} + R_{D(AC)} + R_S^*(1 + g_m r_{ds})}$$

$$A_{\vartheta 2} = \frac{(R_{D(AC)} + P \times g_m) r_{ds} R_L}{[P + (R_G + R_{D(AC)})R_L] r_{ds} + (1 + g_m r_{ds}) P R_L}$$

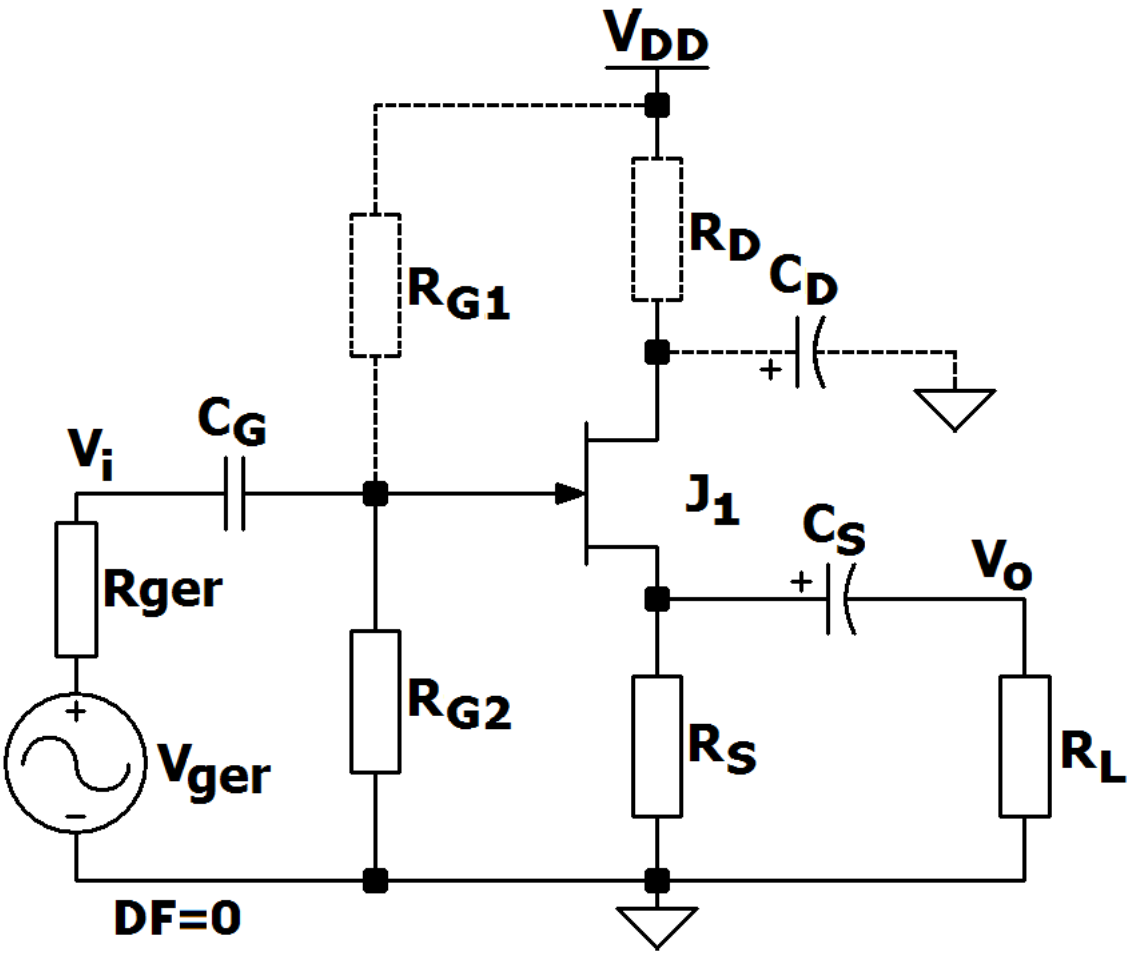

Figura 3b – Amplificador CD com Divisor de Porta (DF=0).

$$R_{i1} = IFTE(R_{G1} = \infty, R_{G2}, \frac{R_{G1}R_{G2}}{R_{G1} + R_{G2}})$$

$$R_{i2} = \frac{R_S R_{D(AC)} + \left(R_S + R_{D(AC)}\right)R_G}{R_S + (1 - A_\vartheta)R_{D(AC)}}$$

$$R_{o1} = \frac{\left(r_{ds} + R_{D(AC)}\right)R_S}{r_{ds} + R_{D(AC)} + (1 + g_m r_{ds})R_S}$$

$$R_{o2} = \frac{r_{ds} \times P^*}{\left(R_G^* + R_{D(AC)}\right)r_{ds} + (1 + g_m r_{ds})P^* - g_m r_{ds} R_{D(AC)} R_{ger}}$$

$$f_{CA1} = \frac{R_{ger} + R_i}{2\pi R_i R_{ger}\left[C_{gd}\left(1 + \frac{A_\vartheta R_{D(AC)}}{R_S}\right) + (1 - A_\vartheta)C_{gs}\right]}$$

$$f_{CA2} = \frac{R_{ger} + R_i}{2\pi R_i R_{ger}\left[C_{gd} + (1 - A_\vartheta)C_{gs}\right]}$$

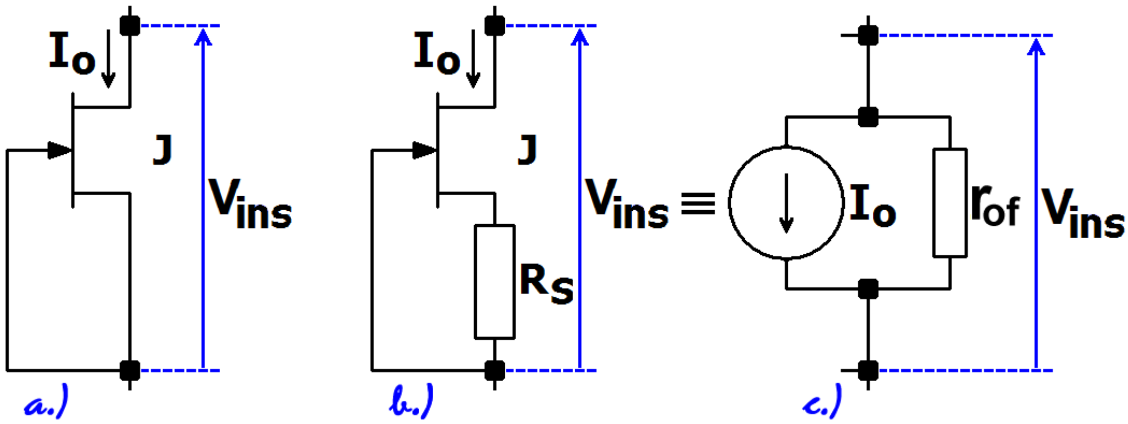

Figura 4 – Fonte de Corrente Simples: *a.)* Com $R_S = 0$ e $I_o = I_{DSS}$. *b.)* Com $R_S \neq 0$ e $I_o < I_{DSS}$. *c.)* Circuito Equivalente.

$$A_\vartheta = IFTE(DF = 0, A_{\vartheta 1}, A_{\vartheta 2})$$

$$R_i = IFTE(DF = 0, R_{i1}, R_{i2})$$

$$R_o = IFTE(DF = 0, R_{o1}, R_{o2})$$

$$f_{CA} = IFTE(R_{ger} \leq 1000, indefinida, IFTE(DF = 0, f_{CA1}, f_{CA2}))$$

$$f_{CB} = \sqrt{\frac{p_S^2 + p_G^2 + \sqrt{p_S^4 + p_G^4 + 6p_S^2 p_G^2}}{2}}$$

Onde: $p_S = \dfrac{1}{2\pi C_S (R_o + R_L)}$ e $p_G = \dfrac{1}{2\pi C_G (R_i + R_{ger})}$

Resumo das Equações de Cálculo das Fontes de Corrente Constante.

1.) Fonte de Corrente Simples (Fig. 4):

$$I_o = IFTE(V_{DS} \geq V_{Dsat}, I_{Dp}, I_{Dt})$$

$$I_{Dp} = \beta(V_{GS} - V_{To})^2(1 + \lambda V_{DS})$$

$$I_{Dt} = \beta(2(V_{GS} - V_{To}) - V_{DS})V_{DS}(1 + \lambda V_{DS})$$

$$V_{Dsat} = V_{GS} - V_{To}$$

$$V_{GS} = -R_S I_o$$

$$V_{DS} = V_{ins} + V_{GS}$$

$$g_{mt} = 2\beta V_{DS}(1 + \lambda V_{DS}) \quad ; \quad g_{mp} = \frac{2I_o}{V_{GS} - V_{To}}$$

$$r_{dst} = \frac{1}{2\beta(1+\lambda V_{DS})(V_{GS} - V_{To} - V_{DS}) + \lambda\beta V_{DS}[2(V_{GS} - V_{To}) - V_{DS}]}; \; r_{dsp} = IFTE\left(\lambda \neq 0, \frac{1+\lambda V_{DS}}{\lambda I_o}, \infty\right)$$

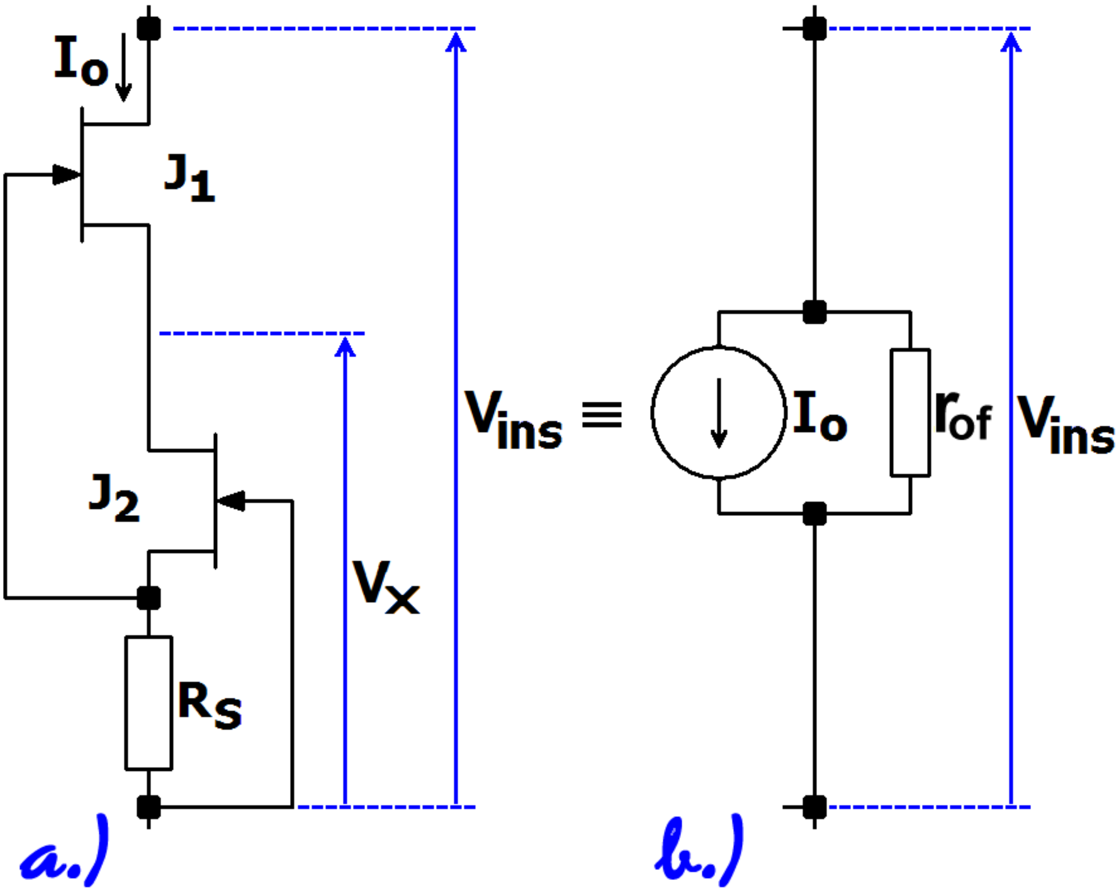

Figura 5 – *a.)* Fonte de Corrente Cascode I. *b.) Circuito Equivalente.*

$$g_m = IFTE\left(V_{DS} \geq V_{Dsat}, g_{mp}, g_{mt}\right) \quad ; \quad r_{ds} = IFTE\left(V_{DS} \geq V_{Dsat}, r_{dsp}, r_{dst}\right)$$

$$r_{of} = r_{ds} + R_S(1 + g_m r_{ds})$$

$$V_{ins(min)} = |V_{To}|$$

2.) Fonte de Corrente Cascode I (Fig. *5*):

$$I_o = \beta_1(-V_X + R_S I_o - V_{To1})^2[1 + \lambda_1(V_{ins} - V_X)]$$

$$V_X = \frac{I_o}{\lambda_2\beta_2(-R_S I_o - V_{To2})^2} - \frac{1}{\lambda_2} + R_S I_o$$

$$r_{of} = r_{ds1} + r_{ds2}(1 + g_{m1} r_{ds1}) + R_S[1 + g_{m2} r_{ds2}(1 + g_{m1} r_{ds1})]$$

$$V_{Dsat1} = V_{GS1} - V_{To1} \quad ; \quad V_{Dsat2} = V_{GS2} - V_{To2}$$

$$V_{GS1} = R_S I_o - V_X \ ; \ V_{GS2} = -R_S I_o \quad ; \quad V_{DS1} = V_{ins} - V_X \ ; \ V_{DS2} = V_X - R_S I_o$$

$$g_{m1} = \frac{2I_o}{V_{Dsat1}} \quad ; \quad g_{m2} = \frac{2I_o}{V_{Dsat2}} \quad ; \quad r_{ds1} = \frac{1+\lambda_1 V_{DS1}}{\lambda_1 I_o} \quad ; \quad r_{ds2} = \frac{1+\lambda_2 V_{DS2}}{\lambda_2 I_o}$$

$$teste = IFTE\left(V_X \leq |V_{To2}|, J_2err, IFTE(V_{ins} \leq |V_{To1}| + R_S I_o, J1err, OK)\right)$$

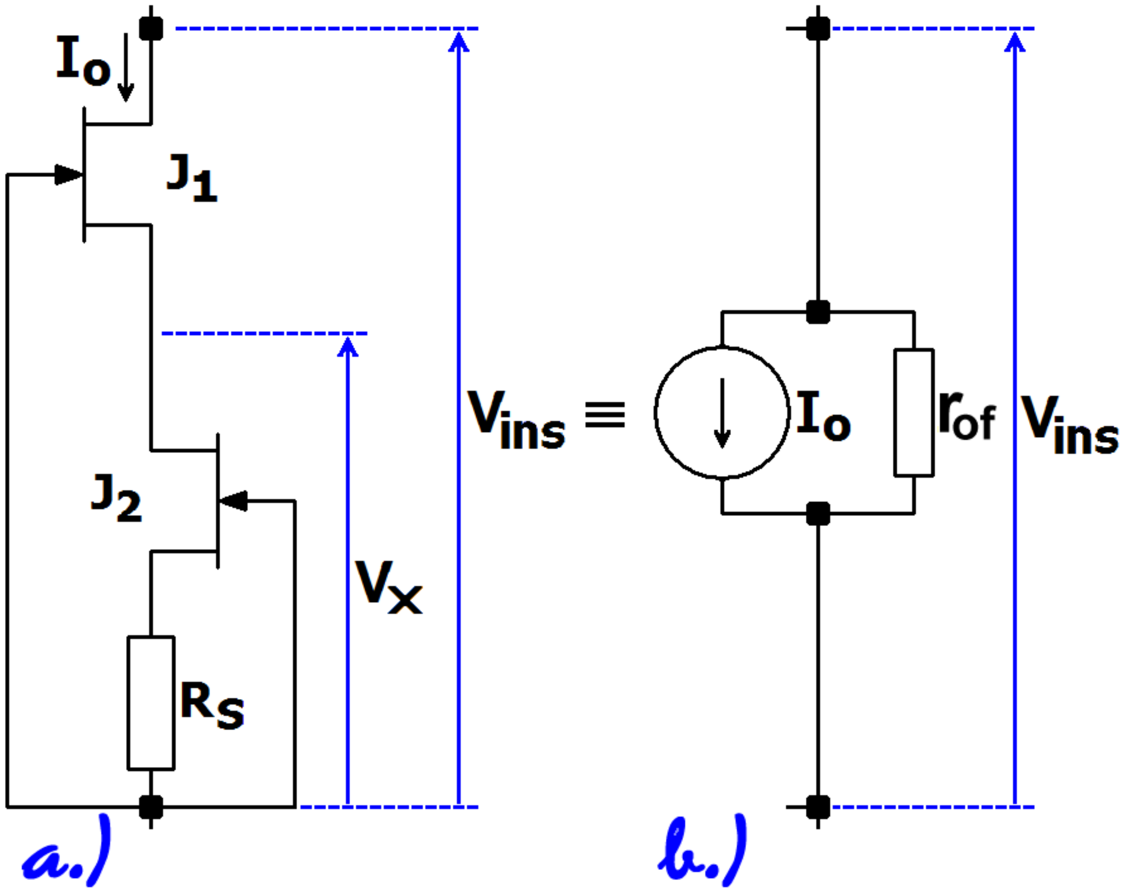

Figura 6 – *a.)* Fonte de Corrente Cascode II. *b.) Circuito Equivalente.*

3.) Fonte de Corrente Cascode II (Fig. *6*)

$$I_o = \beta_1(-V_X - V_{To1})^2[1 + \lambda_1(V_{ins} - V_X)]$$

$$V_X = \frac{I_o}{\lambda_2\beta_2(-R_S I_o - V_{To2})^2} - \frac{1}{\lambda_2} + R_S I_o$$

$$r_{of} = r_{ds1} + (1 + g_{m1}r_{ds1})[r_{ds2} + R_S(1 + g_{m2}r_{ds2})]$$

$$V_{Dsat1} = V_{GS1} - V_{To1} \quad ; \quad V_{Dsat2} = V_{GS2} - V_{To2}$$

$$V_{GS1} = -V_X \; ; \; V_{GS2} = -R_S I_o \quad ; \quad V_{DS1} = V_{ins} - V_X \; ; \; V_{DS2} = V_X - R_S I_o$$

$$g_{m1} = \frac{2I_o}{V_{Dsat1}} \quad ; \quad g_{m2} = \frac{2I_o}{V_{Dsat2}} \quad ; \quad r_{ds1} = \frac{1+\lambda_1 V_{DS1}}{\lambda_1 I_o} \quad ; \quad r_{ds2} = \frac{1+\lambda_2 V_{DS2}}{\lambda_2 I_o}$$

$$teste = IFTE\big(V_X \le |V_{To2}|, J_2 err, IFTE(V_{ins} \le |V_{To1}|, J1err, OK)\big)$$