CÔNG THỨC BJT DC

TABLE A

BJT Bias Configurations

Type	Configuration	Pertinent Equations
Fixed-bias	${}^{\circ}V_{CC}$ ${}^{\circ}R_{B}$ ${}^{\circ}R_{C}$	$I_B = \frac{V_{CC} - V_{BE}}{R_B}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C R_C$
Emitter-bias	Q_{CC} R_B R_C R_E	$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $R_i = (\beta + 1)R_E$ $V_{CE} = V_{CC} - I_C (R_C + R_E)$
Voltage-divider bias	$ \begin{array}{c} $	EXACT: $R_{Th} = R_1 R_2, E_{Th} = \frac{R_2 V_{CC}}{R_1 + R_2}$ APPROXIMATE: $\beta R_E \ge 10 R_2$ $I_B = \frac{E_{Th} - V_{BE}}{R_{Th} + (\beta + 1) R_E}$ $I_C = \beta I_B, I_E = (\beta + 1) I_B$ $V_{CE} = V_{CC} - I_C (R_C + R_E)$ $I_C = V_{CC} - I_C (R_C + R_E)$ $I_C = V_{CC} - I_C (R_C + R_E)$ $I_C = V_{CC} - I_C (R_C + R_E)$
Collector-feedback	ρ V_{CC} R_C R_C R_C	$I_B = \frac{V_{CC} - V_{BE}}{R_F + \beta(R_C + R_E)}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{CC} - I_C (R_C + R_E)$
Emitter-follower	R_B R_E $-V_{EE}$	$I_B = \frac{V_{EE} - V_{BE}}{R_B + (\beta + 1)R_E}$ $I_C = \beta I_B, I_E = (\beta + 1)I_B$ $V_{CE} = V_{EE} - I_E R_E$
Common-base	R_E R_C V_{EE} V_{CC}	$I_E = \frac{V_{EE} - V_{BE}}{R_E}$ $I_B = \frac{I_E}{\beta + 1}, I_C = \beta I_B$ $V_{CE} = V_{EE} + V_{CC} - I_E(R_C + R_E)$ $V_{CB} = V_{CC} - I_C R_C$

Unloaded BJT Transistor Amplifiers

Configuration Z_i Z_o A_v A_i				
Fixed-bias:	Medium (1 k Ω)	Medium $(2 k\Omega)$	High (-200)	High (100)
$\begin{array}{c c} & & & & & & & & & & & & & & & & \\ & & & & & & & & & & & & & & \\ & & & & & & & & & & & & \\ & & & & & & & & & & & \\ & & & & & & & & & & \\ & & & & & & & & & & \\ & & & & & & & & & & \\ & & & & & & & & & \\ & & & & & & & & & \\ & & & & & & & & & \\ & & & & & & & & & \\ & & & & & & & & \\ & & & & & & & & \\ & & & & & & & & \\ & & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ & & \\ & & & \\ & & \\ & & & \\ & \\ & \\ & & \\$	$= \begin{bmatrix} R_B \ \beta r_e \end{bmatrix}$ $\cong \begin{bmatrix} \beta r_e \end{bmatrix}$ $(R_B \ge 10 \beta r_e)$	$= \begin{bmatrix} R_C \ r_o \end{bmatrix}$ $\cong \begin{bmatrix} R_C \end{bmatrix}$ $(r_o \ge 10R_C)$	$= \boxed{-\frac{(R_C \ r_o)}{r_e}}$ $\cong \boxed{-\frac{R_C}{r_e}}$ $(r_o \ge 10R_C)$	$= \frac{\beta R_B r_o}{(r_o + R_C)(R_B + \beta r_e)}$ $\cong \beta$ $(r_o \ge 10R_C, R_B \ge 10\beta r_e)$
Voltage-divider bias: $R_1 \qquad V_{CC}$ $R_1 \qquad V_{CC}$ $R_2 \qquad R_E \qquad C_E$	Medium (1 k Ω) $= R_1 R_2 \beta r_e$ High (100 k Ω)	Medium $(2 \text{ k}\Omega)$ $= \boxed{R_C \ r_o}$ $\cong \boxed{R_C}$ $(r_o \ge 10R_C)$	High (-200) $= \frac{-\frac{R_C \ r_o}{r_e}}{\frac{-\frac{R_C}{r_e}}{r_e}}$ $\approx \frac{-\frac{R_C}{r_e}}{r_e}$ $(r_o \ge 10R_C)$	High (50) $= \frac{\beta(R_1 R_2) r_o}{(r_o + R_C)(R_1 R_2 + \beta r_e)}$ $\cong \frac{\beta(R_1 R_2)}{R_1 R_2 + \beta r_e}$ $(r_o \ge 10R_C)$ High (50)
Unbypassed emitter bias: R_B I_o R_C V_{CC} V_{CC} V_{CC} V_{CC}	High $(100 \mathrm{k}\Omega)$ $= \boxed{R_B \ Z_b}$ $Z_b \cong \beta(r_e + R_E)$ $\cong \boxed{R_B \ \beta R_E}$ $(R_E \gg r_e)$	Medium $(2 k\Omega)$ $= \boxed{R_C}$ (any level of r_o)	Low (-5) $= \boxed{-\frac{R_C}{r_e + R_E}}$ $\cong \boxed{-\frac{R_C}{R_E}}$ $(R_E \gg r_e)$	High (50) $\cong \boxed{-\frac{\beta R_B}{R_B + Z_b}}$
Emitter- follower: $V_{i} = I_{o} $	High $(100 \text{ k}\Omega)$ $= \boxed{R_B \ Z_b}$ $Z_b \cong \beta(r_e + R_E)$ $\cong \boxed{R_B \ \beta R_E}$ $(R_E \gg r_e)$	Low (20Ω) $= \boxed{R_E \ r_e}$ $\cong \boxed{r_e}$ $(R_E \gg r_e)$	$Low (\cong 1)$ $= \boxed{\frac{R_E}{R_E + r_e}}$ $\cong \boxed{1}$	$ \text{High } (-50) $ $ \cong \boxed{ -\frac{\beta R_B}{R_B + Z_b} } $
Common-base: $\begin{array}{c c} I_i \\ \downarrow \\ V_i \\ \hline Z_i \\ \hline \end{array} \begin{array}{c} R_E \\ \hline Z_o \\ V_o \end{array} \begin{array}{c} V_{CC} \\ \hline \end{array}$	Low (20 Ω) $= \boxed{R_E \ r_e}$ $\cong \boxed{r_e}$ $(R_E \gg r_e)$	$ Medium (2 k\Omega) $ $= \boxed{R_C} $	High (200) $\cong \boxed{\frac{R_C}{r_e}}$	Low (−1) ≅
Collector feedback: $R_{F} \stackrel{\circ}{\bigvee} R_{C}$ $Z_{o} V_{o}$	Medium (1 k Ω) $= \frac{r_e}{\frac{1}{\beta} + \frac{R_C}{R_F}}$ $(r_o \ge 10R_C)$	Medium $(2 \text{ k}\Omega)$ $\cong \boxed{R_C R_F}$ $(r_o \ge 10R_C)$	High (-200) $\cong \boxed{-\frac{R_C}{r_e}}$ $(r_o \ge 10R_C)$ $(R_F \gg R_C)$	High (50) $= \frac{\beta R_F}{R_F + \beta R_C}$ $\cong \frac{R_F}{R_C}$

Configuration	$A_{v_L} = V_o/V_i$	Z_i	Z_o
V_{CC} R_B	$\frac{-(R_L \ R_C)}{r_e}$	$R_B \ \beta r_e$	R_C
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Including r_o : $-\frac{(R_L R_C r_o)}{r_e}$	$R_B \ eta r_e$	$R_C \ r_o$
R_1 R_C	$\frac{-(R_L \ R_C)}{r_e}$	$R_1 \ R_2 \ \beta r_e$	R_C
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Including r_o : $\frac{-(R_L R_C r_o)}{r_e}$	$R_1 \ R_2 \ \beta r_e$	$R_C \ r_o$
R_s	≅ 1	$R'_E = R_L R_E$ $R_1 R_2 \beta(r_e + R'_E)$	$R'_{s} = R_{s} R_{1} R_{2}$ $R_{E} \left(\frac{R'_{s}}{\beta} + r_{e}\right)$
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Including r_o : $\cong 1$	$R_1 \ R_2 \ \beta(r_e + R_E')$	$R_E \ \left(\frac{R_s'}{\beta} + r_e \right)$
$R_s \rightarrow V_i \rightarrow V_o$	$\cong \frac{-(R_L R_C)}{r_e}$	$R_E \ r_e$	R_C
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Including r_o : $\cong \frac{-(R_L R_C r_o)}{r_e}$	$R_E \ r_e$	$R_C \ r_o$
V_{CC} R_1 R_C	$\frac{-(R_L \ R_C)}{R_E}$	$R_1 \ R_2 \ \beta(r_e + R_E)$	R_C
$\begin{array}{c c} R_s & V_i \\ V_s & & Z_i \\ \end{array} \begin{array}{c c} R_2 & R_E \end{array}$	Including r_o : $\frac{-(R_L R_C)}{R_E}$	$R_1 \ R_2 \ \beta(r_e + R_e)$	$\cong R_C$

BJT Transistor Amplifiers Including the Effect of Rs and RL

DST Transision implifiers including the Lifect of K _s and K _L			
Configuration	$A_{\nu_L} = V_o/V_i$	Z_i	Z_o
R_{s} V_{i} Q R_{s} V_{i} Q	$\frac{-(R_L \ R_C)}{R_{E_1}}$	$R_B \ \beta(r_e + R_{E_1})$	R_C
$\begin{array}{c c} + & & \\ V_s & & \\ \hline \end{array}$ R_{E_2} C_E	Including r_o : $\frac{-(R_L R_C)}{R_{E_t}}$	$R_B \ \beta(r_e + R_E)$	$\cong R_C$
R_{F}	$\frac{-(R_L \ R_C)}{r_e}$	$eta r_e \ rac{R_F}{ A_v }$	R_C
$ \begin{array}{c c} & & & \\ & &$	Including r_o : $\frac{-(R_L R_C r_o)}{r_e}$	$eta r_e \ rac{R_F}{ A_v }$	$R_C \ R_F\ r_o$
V_{CC} R_F R_C R_C	$\frac{-(R_L R_C)}{R_E}$	$eta R_E \ rac{R_F}{ A_ u }$	$\cong R_C R_F$
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	Including r_o : $\cong \frac{-(R_L R_C)}{R_E}$	$\cong \beta R_E \ \frac{R_F}{ A_v }$	$\cong R_C R_F$

$$V_{BE} \cong 0.7 \text{ V}, \qquad I_E = (\beta + 1)I_B \cong I_C, \qquad I_C = \beta I_B$$
 Voltage-divider bias:

Fixed bias:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}, \qquad I_C = \beta I_B$$

Emitter stabilized:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + (\beta + 1)R_E}, \qquad R_i = (\beta + 1)R_E$$

DC bias with voltage feedback:

$$I_B = \frac{V_{CC} - V_{BE}}{R_B + \beta (R_C + R_E)}, \qquad I_C' \cong I_C \cong I_E$$

Common base:

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}, \quad I_C \cong I_E$$

Exact:
$$R_{\text{Th}} = R_1 \| R_2$$
, $E_{\text{Th}} = V_{R_2} = \frac{R_2 V_{CC}}{R_1 + R_2}$, $I_B = \frac{E_{\text{Th}} - V_{BE}}{R_{\text{Th}} + (\beta + 1)R_E}$

Approximate: Test $\beta R_E \ge 10R_2$

$$V_B = \frac{R_2 V_{CC}}{R_1 + R_2}, \quad V_E = V_B - V_{BE}, \quad I_E = \frac{V_E}{R_E} \cong I_C$$

Transistor switching networks:

$$\frac{V_{CC} - V_{BE}}{R_B + \beta(R_C + R_E)}, \quad I'_C \cong I_E \qquad I_{C_{\text{sat}}} = \frac{V_{CC}}{R_C}, \quad I_B > \frac{I_{C_{\text{sat}}}}{\beta_{\text{dc}}}, \quad R_{\text{sat}} = \frac{V_{CE_{\text{sat}}}}{I_{C_{\text{sat}}}},$$

$$I_E = \frac{V_{EE} - V_{BE}}{R_E}, \quad I_C \cong I_E \qquad t_{\text{on}} = t_r + t_d, \quad t_{\text{off}} = t_s + t_f$$

	Field Effect Transistors			
Type	Symbol and Basic Relationships	Transfer Curve	Input Resistance and Capacitance	
JFET (n-channel)	$I_G = 0 \text{ A}, I_D = I_S$ $G \qquad \qquad D$ I_{DSS} V_P $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$R_i > 100 \mathrm{M}\Omega$ C_i : (1 - 10) pF	
MOSFET depletion type (n-channel)	$I_G = 0 \text{ A}, I_D = I_S$ $G \qquad D$ I_{DSS} V_P $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$	I_D I_D I_D I_{DSS} I_{DSS	$R_i > 10^{10} \Omega$ C_i : (1 - 10) pF	
MOSFET enhancement type (n-channel)	$I_G = 0 \text{ A}, I_D = I_S$ O O O $I_D = k (V_{GS} - V_{GS \text{ (Th)}})^2$ $k = \frac{I_{D(\text{on})}}{(V_{GS(\text{on})} - V_{GS \text{ (Th)}})^2}$	I_{D} $I_{D(\text{on})}$ $V_{GS(\text{Th})} V_{GS(\text{on})} V_{GS}$	$R_i > 10^{10} \Omega$ C_i : (1 - 10) pF	
MESFET depletion type (n-channel)	$I_G = 0 \text{ A}, I_D = I_S$ $G \longrightarrow S$ $I_D = I_{DSS} \left(1 - \frac{V_{GS}}{V_P}\right)^2$ $I_G = 0 \text{ A}, I_D = I_S$	$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	$R_i > 10^{12} \Omega$ C_i : (1 - 5) pF	
MESFET enhancement type (n-channel)	$I_D = k (V_{GS} - V_{GS \text{ (Th)}})^2$ $k = \frac{I_{D(\text{on})}}{(V_{GS(\text{on})} - V_{GS \text{ (Th)}})^2}$	$I_{D(\text{on})}$ $I_{D(\text{on})}$ $V_{GS(\text{Th})}$ $V_{GS(\text{on})}$ V_{GS}	$R_i > 10^{12} \Omega$ C_{i} : (1 - 5) pF	

Type	Configuration	Pertinent Equations	Graphical Solution
JFET Fixed-bias	V_{GG}	$V_{GS_Q} = -V_{GG}$ $V_{DS} = V_{DD} - I_D R_S$	$\begin{array}{c c} I_D \\ I_{DSS} \\ \hline V_P \ V_{GG} \ 0 & V_{GS} \end{array}$
JFET Self-bias	R_G	$V_{GS} = -I_D R_S$ $V_{DS} = V_{DD} - I_D (R_D + R_S)$	$Q\text{-point} = \begin{array}{c c} I_D & & & \\ I_{DSS} & & & \\ \hline V_{P1V'_{GS}} & 0 & & V_{GS} \end{array}$
JFET Voltage-divider bias	R_1 R_D R_S	$V_{G} = \frac{R_{2}V_{DD}}{R_{1} + R_{2}}$ $V_{GS} = V_{G} - I_{D}R_{S}$ $V_{DS} = V_{DD} - I_{D}(R_{D} + R_{S})$	$\begin{array}{c c} I_D & \\ I_{DSS} & \\ \hline V_P & 0 & V_G & V_{GS} \end{array}$
JFET Common-gate	$\{R_D \}_{R_D}$ $\{R_S \}_{V_{SS}}$	$V_{GS} = V_{SS} - I_D R_S$ $V_{DS} = V_{DD} + V_{SS} - I_D (R_D + R_S)$	$\begin{array}{c c} I_D \\ I_{DSS} \\ \hline V_P & 0 & V_{SS} V_{GS} \end{array}$
	R_D	$V_{GS} = -I_D R_S$ $V_D = V_{DD}$ $V_S = I_D R_S$ $V_{DS} = V_{DD} - I_S R_S$	$Q\text{-point} - I_{DSS}$ $-I'_{D}$ $V_{P} \mid V'_{GS} \mid 0 \qquad V_{GS}$
JFET Special case $(V_{GS_Q} = 0 \text{ V})$	$V_{GG} \stackrel{QV_{DD}}{\rightleftharpoons}$	$V_{GS_Q} = 0 \text{ V}$ $I_{D_Q} = I_{DSS}$	$Q\text{-point} = I_{DSS}$ $V_{GSQ} = 0 \text{ V}$ $V_{P} = 0 V_{GS}$
Depletion-type MOSFET Fixed-bias (and MESFETs)	$R_G = R_S$	$V_{GS_Q} = +V_{GG}$ $V_{DS} = V_{DD} - I_D R_S$	I_{DSS} Q -point V_{P} 0 V_{GG} V_{GS}
Depletion-type MOSFET Voltage-divider bias (and MESFETs)	R_1 R_2 R_S	$V_{G} = \frac{R_{2}V_{DD}}{R_{1} + R_{2}}$ $V_{GS} = V_{G} - I_{S}R_{S}$ $V_{DS} = V_{DD} - I_{D}(R_{D} + R_{S})$	V_G V_P V_P V_G V_G V_G
Enhancement type MOSFET Feedback configuration (and MESFETs)	$R_G ightharpoonup R_D$	$V_{GS} = V_{DS}$ $V_{GS} = V_{DD} - I_D R_D$	$I_{D(\text{on})} - I_{D}$ $Q\text{-point}$ $0 V_{GS(\text{Th})} V_{GS(\text{on})} V_{DD} V_{GS}$
Enhancement type MOSFET Voltage-divider bias (and MESFETs)	R_1 R_2 R_S	$V_G = \frac{R_2 V_{DD}}{R_1 + R_2}$ $V_{GS} = V_G - I_D R_S$	$\begin{array}{c c} V_G \\ \hline R_S \end{array} \qquad \begin{array}{c c} I_D \\ \hline O \end{array} \qquad \begin{array}{c c} Q\text{-point} \\ \hline V_{GS(\text{Th})} & V_G & V_{GS} \end{array}$

 Z_i , Z_o , and A_v for various FET configurations $A_{v} = \frac{V_{o}}{V_{i}}$ Z_o Configuration Z_i Fixed-bias [JFET or D-MOSFET] Medium (2 k Ω) Medium (-10) High $(10 \, \text{M}\Omega)$ $R_D \| r_d$ $-g_m(r_d || R_D)$ R_D $-g_m R_D$ $(r_d \ge 10 R_D)$ $(r_d \ge 10 R_D)$ Self-bias bypassed R_S [JFET or D-MOSFET] $+V_{DD}$ Medium (2 k Ω) Medium (-10) High (10 $M\Omega$) $R_D \| r_d$ $-g_m(r_d || R_D)$ R_G R_D $-g_m R_D$ $(r_d \ge 10 R_D)$ $(r_d \ge 10 R_D)$ Self-bias unbypassed R_S [JFET or D-MOSFET] Low (-2) $g_m R_D$ High $(10 \,\mathrm{M}\Omega)$ = R_D $g_m R_D$ $r_d \ge 10 R_D \text{ or } r_d = \infty \Omega$ \simeq $1 + g_m R_S$ $[r_d \ge 10 (R_D + R_S)]$ Voltage-divider bias [JFET or D-MOSFET] $+V_{DD}$

High $(10 \, M\Omega)$

 $R_1 \| R_2$

Medium (2 k Ω)

 $R_D \| r_d$

 $(r_d \ge 10 R_D)$

 R_D

Medium (-10)

 $-g_m(r_d || R_D)$

 $(r_d \ge 10 R_D)$

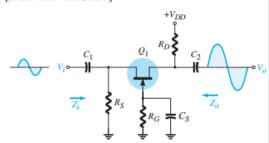
 $-g_m R_D$

(Continued)

 $A_{v} = \frac{V_{o}}{V_{i}}$

Common-gate

[JFET or D-MOSFET]



Configuration

Low (1 kΩ)

$$= R_S \| \left[\frac{r_d + R_D}{1 + g_m r_d} \right]$$

$$\cong R_S \| \frac{1}{g_m} \|_{COMM}$$

 Z_i

Medium (2 k Ω)

 Z_o

$$= \begin{bmatrix} R_D \| r_d \end{bmatrix}$$

$$\cong \begin{bmatrix} R_D \end{bmatrix}_{(R_d \ge 10 R_D)}$$

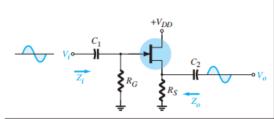
Medium (+10)

$$= \frac{g_m R_D + \frac{R_D}{r_d}}{1 + \frac{R_D}{r_d}}$$

$$\cong \boxed{g_m R_D}$$

$$\equiv g_m R_D$$
 $(r_d \ge 10 RD)$

Source-follower [JFET or D-MOSFET]



High (10 M Ω)

$$=$$
 R_G

Low $(100 k\Omega)$

$$= \boxed{r_d \|R_S\| 1/g_m}$$

$$\cong \boxed{R_S \|1/g_m\}_{r_d \ge 10R_S}}$$

Low (<1)

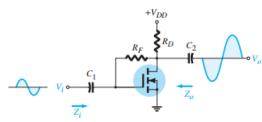
$$= \frac{g_m(r_d || R_S)}{1 + g_m(r_d || R_S)}$$

$$\cong \frac{g_m R_S}{1 + g_m R_S}$$

$$(r_d \ge 10 R_S)$$

Drain-feedback bias

E-MOSFET



Medium (1 MΩ)

$$= \frac{R_F + r_d \| R_D}{1 + g_m (r_d \| R_D)}$$

$$\approx \frac{R_F}{1 + g_m R_D}$$
(2008)

Medium (2 kΩ)

$$= \begin{bmatrix} R_F \| r_d \| R_D \end{bmatrix}$$

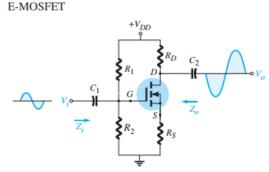
$$\cong \begin{bmatrix} R_D \end{bmatrix}_{(R_F, r_d \ge 10R_D)}$$

Medium (-10)

$$= \begin{bmatrix} -g_m(R_F || r_d || R_D) \\ \\ = \end{bmatrix}$$

$$\cong \begin{bmatrix} -g_m R_D \\ \\ \\ (R_F, r_d \ge 10R_D) \end{bmatrix}$$

Voltage-divider bias



Medium (1 MΩ)

$$= \boxed{R_1 \| R_2}$$

Medium (2 k Ω)

$$= \begin{bmatrix} R_D \| r_d \end{bmatrix}$$

$$\cong \begin{bmatrix} R_D \end{bmatrix}_{(r_d \ge 10R)}$$

Medium (-10)

$$= \boxed{-g_m(r_d || R_D)}$$

$$\cong \boxed{-g_m R_D}$$

Equations

$$g_m = y_{fs} = \frac{\Delta I_D}{\Delta V_{GS}}$$

$$g_{m0} = \frac{2I_{DSS}}{|V_P|}$$

$$g_m = g_{m0} \left[1 - \frac{V_{GS}}{V_P} \right]$$

$$g_m = g_{m0} \sqrt{\frac{I_D}{I_{DSS}}}$$

$$r_d = \frac{1}{y_{os}} = \frac{\Delta V_{DS}}{\Delta I_D} \bigg|_{VG_S = \text{constant}}$$

Effect of load impedance:

$$A_{\nu_L} = \frac{V_o}{V_i} = \frac{R_L}{R_L + R_o} A_{\nu_{\rm NL}}, \qquad A_{i_L} = \frac{I_o}{I_i} = -A_{\nu_L} \frac{Z_i}{R_L} \label{eq:alpha_local_problem}$$

Effect of source impedance:

$$V_i = \frac{R_i V_s}{R_i + R_s}, \qquad A_{v_s} = \frac{V_o}{V_s} = \frac{R_i}{R_i + R_s} A_{v_{\rm NL}}$$

$$I_s = \frac{V_s}{R_s + R_i}$$

Combined effect of load and source impedance:

$$A_{\nu_L} = \frac{V_o}{V_i} = \frac{R_L}{R_L + R_o} A_{\nu_{\rm NL}}, \qquad A_{\nu_s} = \frac{V_o}{V_s} = \frac{R_i}{R_i + R_s} \cdot \frac{R_L}{R_L + R_o} A_{\nu_{\rm NL}}$$

$$A_{i_L} = \frac{I_o}{I_i} = -A_{v_L} \frac{R_i}{R_L}, \qquad A_{i_s} = \frac{I_o}{I_s} = -A_{v_s} \frac{R_s + R_i}{R_L}$$

Configuration	$A_{v_L} = V_o \ V_i$	Z_i	Z_o
V_{DD} $R_{Sig} = V_{O}$ V_{O}	$-g_m(R_D R_L)$	R_G	R_D
V_{s} Z_{i} R_{G} R_{S} R_{S} R_{L}	Including r_d : $-g_m(R_D R_L r_d)$	R_G	$R_D \ r_d$
V_{DD} $R_{Sig} = V_i$ V_o	$\frac{-g_m(R_D R_L)}{1+g_mR_S}$	R_G	$\frac{R_D}{1 + g_m R_S}$
V_s Z_i R_G R_S R_L	Including r_d :	R_G	$\cong \frac{R_D}{1 + g_m R_S}$
$R_{\text{sig}} = V_{i}$	$-g_m(R_D R_L)$	$R_1 \ R_2$	R_D
V_{1} V_{2} V_{3} V_{4} V_{5} V_{5	Including r_d : $-g_m(R_D R_L r_d)$	$R_1 \ R_2$	$R_D \ r_d;$
R_{sig}	$\frac{g_m(R_S R_L)}{1 + g_m(R_S R_L)}$	R_G	$R_S \parallel 1/g_m$
V_{s} \downarrow \downarrow R_{G} \downarrow R_{S} \downarrow \downarrow R_{L} \downarrow	Including r_d : $= \frac{g_m r_d(R_S R_L)}{r_d + R_D + g_m r_d(R_S R_L)}$	R_G	$\frac{R_S}{1 + \frac{g_m r_d R_S}{r_d + R_D}}$
V_s $V_{DD} \equiv V_{DD}$ $V_{DD} = V_{DD}$	$g_m(R_D R_L)$ Including r_d : $\cong g_m(R_D R_L)$	$Z_{i} = \frac{R_{S}}{1 + g_{m}R_{S}}$ $Z_{i} = \frac{R_{S}}{1 + \frac{g_{m}r_{d}R_{S}}{r_{d} + R_{D} R_{L}}}$	R_D $R_D \ r_d$