Configuration	Z_i	Z_o	A_{v}	A_l
Fixed-bias:	Medium (1 kΩ)	Medium (2 kΩ)	High (-200)	High (100)
$R_{B} \bigvee_{l} R_{C} \bigvee_{l} R_{C}$	$= R_B \ \beta r_e \ $ $\equiv \beta r_e$	$= R_C \ r_o $ $\cong R_C$	$= \frac{ R_C r_o }{r_e}$	$= \frac{\beta R_B r_o}{(r_o + R_C)(R_B + \beta r_e)}$
$\frac{1}{V_i}$ $\frac{1}{Z_i}$ $\frac{1}{Z_o}$ $\frac{1}{V_o}$	$(R_B \ge 10\beta r_e)$	$(r_o \ge 10R_C)$	$\cong \frac{R_C}{r_e}$	$ (r_o \ge 10R_C, R_B \ge 10\beta r_e) $
Voltage-divider	Medium (1 kΩ)	Medium (2 kΩ)	$(r_o \ge 10R_C)$ High (-200)	
bias:				High (50)
$\begin{array}{c c} & & & \\ & & & \\ & & & \\ & & & \\ & & & \\ \end{array}$	$= \left[R_1 \ R_2 \ \beta r_e \right]$	$= R_C \ r_o \ $ $\cong R_C$	$= \left[\frac{-\frac{R_C \ r_o}{r_e}}{r_e} \right]$	$= \frac{\beta(R_1 R_2) r_o}{(r_o + R_C)(R_1 R_2 + \beta r_e)}$
$\begin{array}{c c} & Z_{o} \\ \hline V_{i} & Z_{i} \\ \hline \end{array}$ $\begin{array}{c c} & Z_{o} \\ \hline \end{array}$ $\begin{array}{c c} & V_{o} \\ \hline \end{array}$		$(r_o \ge 10R_C)$		$\cong \frac{\beta(R_1 R_2)}{R_1 R_2 + \beta r_e}$ $(r_o \ge 10R_C)$
Unbypassed	High (100 kΩ)	Medium (2 kΩ)	Low (-5)	High (50)
emitter bias: $I_o \downarrow R_C$	$= \boxed{R_B \ Z_b}$ $Z_b \cong \beta(r_e + R_E)$	$= \boxed{R_C}$ (any level of r_o)	$= \boxed{-\frac{R_C}{r_e + R_E}}$	$\cong \boxed{ \frac{\beta R_B}{R_B + Z_b}}$
$\begin{array}{c c} & \downarrow \\ & \downarrow \\ $	$\cong R_B \ \beta R_E \ $ $(R_E \gg r_e)$		$\cong \boxed{\frac{R_C}{R_E}}$ $(R_E \gg r_e)$	6
Emitter- follower:	High (100 kΩ)	Low (20 Ω)	Low (≅1)	High (-50)
follower: $\begin{array}{c c} I_i & R_B \end{array}$	$= \begin{bmatrix} R_B \ Z_b \end{bmatrix}$ $Z_b \cong \beta(r_e + R_E)$	$= \begin{bmatrix} R_E \ r_e \end{bmatrix}$ $\cong \boxed{r_e}$	$= \frac{R_E}{R_E + r_e}$ ≈ 1	$\cong \left[-\frac{\beta R_B}{R_B + Z_b} \right]$
$ \begin{array}{c c} V_i & \\ \hline Z_i & \\ \hline \end{array} $ $I_o \downarrow \underbrace{R_E + V_o}_{Z_o V_o}$	$\cong R_B \ \beta R_E \ $ $(R_E \gg r_e)$	$(R_E \gg r_e)$		
Common-base:	Low (20 Ω)	Medium (2 kΩ)	High (200)	Low (-1)
$ \begin{array}{c c} I_{o} \\ \downarrow \\ V_{i} \\ \hline Z_{i} \end{array} $ $ \begin{array}{c c} R_{E} \\ \hline V_{EE} \end{array} $ $ \begin{array}{c c} I_{o} \\ \hline Z_{o} \\ V_{o} \end{array} $	$= R_E \ r_e \ $ $\approx r_e$	$=$ R_C	$\cong \frac{R_C}{r_e}$	≅ -1
_ 0	$(R_E \gg r_e)$	Madiene (01.0)	1E-1 (200)	11:-L (50)
Collector feedback: V_{CC} R_F $I_o \downarrow R_C$	Medium (1 k Ω) $= \frac{r_e}{\frac{1}{\beta} + \frac{R_C}{R_F}}$	Medium $(2 \text{ k}\Omega)$ $\cong \boxed{R_C \ R_F}$ $(r_o \ge 10R_C)$	$ \text{High } (-200) $ $ \cong \boxed{-\frac{R_C}{r_e}} $	$= \frac{\beta R_F}{R_F + \beta R_C}$
$ \begin{array}{c c} & I_{i} \\ \hline & V_{i} \\ \hline & Z_{o} \end{array} $	$(r_o \ge 10R_C)$	_	$(r_o \ge 10R_C) (R_F \gg R_C)$	$\cong \frac{R_F}{R_C}$

TABLE 5.2BJT Transistor Amplifiers Including the Effect of R_s and R_L

Configuration	$A_{v_L} = V_o/V_i$	\mathbf{Z}_{i}	Z _o
V_{CC}	$\frac{-(R_L R_C)}{r_e}$	$R_B \ oldsymbol{eta} r_e$	R _C
$\begin{array}{c c} R_{s} & V_{o} \\ V_{s} & \overline{Z_{i}} \end{array}$	Including r_o : $\frac{(R_L R_C r_o)}{r_e}$	$R_B \ oldsymbol{eta} r_e$	$R_C \ r_o$
V_{CC} R_1 R_C	$\frac{-(R_L \ R_C)}{r_c}$	$R_1 \ R_2 \ \beta r_e$	R_C
$ \begin{array}{c c} R_s & V_i \\ \hline V_s & \hline \end{array} $ $ \begin{array}{c c} R_s & V_i \\ \hline Z_i & R_2 \\ \hline \end{array} $ $ \begin{array}{c c} R_E & C_E \\ \hline \end{array} $	Including r_o : $\frac{-(R_L R_C r_o)}{r_e}$	$R_1 \ R_2 \ \beta r_e$	$R_C \ r_o$
R_1 R_C	≅ 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_a : $\cong 1$	$R_1 \ R_2 \ \beta(r_e + R_E')$	$R_E \ \left(\frac{R_s'}{\beta} + r_e \right)$
$R_1 \cup V_1 \cap \dots \cap V_n \cap $	$\cong \frac{-(R_L \ R_C)}{r_e}$	$R_E \ r_e$	R_C
$ \begin{array}{c c} \downarrow \\ V_s \\ \hline \end{array} $ $ \begin{array}{c c} \downarrow \\ \overline{Z}_i \\ \hline \end{array} $ $ \begin{array}{c c} \downarrow \\ V_{CC} \\ \hline \end{array} $ $ \begin{array}{c c} \downarrow \\ \overline{Z}_o \\ \end{array} $ $ \begin{array}{c c} \downarrow \\ R_L \\ \end{array} $	Including r_o : $\cong \frac{-(R_L \ R_C\ r_o)}{r_e}$	$R_E \mid r_e$	$R_C \ r_o$
R_{C}	$\frac{-(R_L \ R_C)}{R_E}$	$R_1 \ R_2 \ \beta(r_e + R_E)$	R_C
$\begin{array}{c c} & & & & & & & & & & & & & & & & & & &$	Including r_o : $\frac{-(R_L R_C)}{R_E}$	$R_1 \ R_2 \ \beta(r_e + R_e)$	$\approx R_C$

Configuration	$A_{v_L} = V_o/V_l$	Z_l	Z_o
$\begin{array}{c c} V_{CC} \\ R_3 & V_i \\ V_3 & Z_i \\ \end{array}$ $\begin{array}{c c} R_{E1} & R_{C} \\ \end{array}$ $\begin{array}{c c} R_{L} & R_{L} \\ \end{array}$	$\frac{-(R_L \ R_C)}{R_{E_1}}$	$R_B \ \beta(r_e + R_{E_1})$	R_C
	Including r_o : $\frac{-(R_L R_C)}{R_{E_s}}$	$R_B \ \beta(r_e + R_E)$	$\cong R_C$
V_{CC} R_F R_C	$\frac{-(R_L \ R_C)}{r_e}$	$\beta r_e \ \frac{R_F}{ A_v }$	R_C
$\begin{array}{c c} & & & \\ & & & &$	Including r_o : $\frac{-(R_L \ R_C\ r_o)}{r_e}$	$eta r_e \ rac{R_F}{ A_v }$	$R_C \ R_F \ r_o$
R_F	$\frac{-(R_L \ R_C)}{R_E}$	$eta R_E \ rac{R_F}{ A_v }$	$\cong R_C R_F$
$\begin{array}{c c} R_{s} & V_{i} \\ \downarrow V_{s} & \downarrow Z_{i} \end{array}$ $\begin{array}{c c} R_{E} & \downarrow R_{L} \end{array}$	Including r_o : $\cong \frac{-(R_L \ R_C)}{R_E}$	$\cong \beta R_E \ \frac{R_F}{ A_v }$	$\equiv R_C \ R_F$

packaged system relates to the actual amplifier or network. The system of Fig. 5.61 is called a two-port system because there are two sets of terminals—one at the input and the other at the output. At this point it is particularly important to realize that

the data surrounding a packaged system is the no-load data.

This should be fairly obvious because the load has not been applied, nor does it come with the load attached to the package.

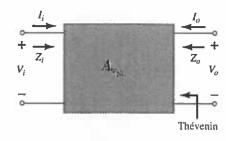


FIG. 5.61
Two-port system.

TABLE 8.1 Z_i , Z_o , and A_v for various FET configurations

Configuration	Z _i	Z_o	$A_v = \frac{V_o}{V_i}$
Fixed-bias [JFET or D-MOSFET] $V_{i} \stackrel{V_{i}}{=} V_{GG}$ $V_{i} \stackrel{V_{i}}{=} V_{GG}$	$V_{g} = \boxed{R_{G}}$	Medium $(2 k\Omega)$ $= R_D r_d$ $\approx R_D _{(r_d \approx 10 R_D)}$	Medium (-10) $= -g_m(r_d R_D)$ $\equiv -g_m R_D _{(r_d \ge 10 R_D)}$
Self-bias bypassed R_S [JFET or D-MOSFET] $V_i \circ \begin{array}{c} & & & & & & & & & & & \\ & & & & & & & $	$V_o = \boxed{R_G}$	Medium $(2 k\Omega)$ $= R_D \ r_d \ _{(r_d \approx 10 R_D)}$	Medium (-10) $= \left[-g_m(r_d R_D) \right]$ $\equiv \left[-g_m R_D \right]_{(r_d \ge 10 R_D)}$
Self-bias unbypassed R_S [JFET or D-MOSFET] $V_i \circ \overline{Z_i}$ $R_G \circ \overline{Z_o}$ $R_S \circ \overline{Z_o}$	High (10 M Ω) $= R_G$	$= \frac{\left[1 + g_m R_S + \frac{R_S}{r_d}\right] R_D}{\left[1 + g_m R_S + \frac{R_S}{r_d} + \frac{R_D}{r_d}\right]}$ $= R_D$ $r_d \approx 10 R_D \text{ or } r_d = 20$	Low (-2) $= \frac{g_m R_D}{1 + g_m R_S + \frac{R_D + R_S}{r_d}}$ $= \frac{g_m R_D}{1 + g_m R_S}$ $[r_j \ge 10 (R_D + R_S)]$
Voltage-divider bias [JFET or D-MOSFET] $V_{i} \circ \begin{array}{c} & & & \\ & & \\ & & & \\ & & & \\ & & & \\ & & & \\ &$	$V_{\sigma} = \boxed{R_1 \ R_2}$	Medium $(2 k\Omega)$ $= R_D r_d$ $= R_D r_{d \ge 10 R_D}$	Medium (-10) $= \boxed{-g_m(r_d R_D)}$ $\cong \boxed{-g_m R_D} \qquad \qquad$

Configuration	Z_i	Zo	$A_{\scriptscriptstyle ec {\scriptscriptstyle \Psi}} = rac{V_{o}}{V_{i}}$
Common-gate [JFET or D-MOSFET] $V_{i} \circ V_{o} \circ V_{o}$ $Z_{i} \circ V_{o} \circ V_{o}$	Low (1 k Ω) $= R_S \left\ \frac{r_d + R_D}{1 + g_m r_d} \right\ $ $\approx R_S \left\ \frac{1}{g_m} \right\ _{(r_d \ge 10 R_D)}$	Medium (2 k Ω) $= R_D \ r_d \ _{(R_d \approx 10 R_D)}$ $\cong R_D$	Medium (+10) $= \frac{g_m R_D + \frac{R_D}{r_d}}{1 + \frac{R_D}{r_d}}$ $\cong g_m R_D$ $r_{d = 10 RD}$
Source-follower [JFET or D-MOSFET] $V_i \circ \overline{Z_i} = R_G \circ V_o$	High (10 M Ω) $= \boxed{R_G}$	Low (100 k Ω) $= r_d \ R_S\ 1/g_m$ $\cong R_S \ 1/g_m\ _{(r_d=10R_3)}$	Low (<1) $= \frac{g_m(r_d R_S)}{1 + g_m(r_d R_S)}$ $\cong \frac{g_m R_S}{1 + g_m R_S}$ $(r_d = 10 R_S)$
Drain-feedback bias E-MOSFET $ \begin{array}{c c} & & & & & & \\ & & & & & & \\ & & & & & $	Medium (1 M Ω) $= \frac{R_F + r_d \ R_D}{1 + g_m(r_d \ R_D)}$ $\cong \frac{R_F}{1 + g_m R_D}$ $(r_d \approx 10 R_D)$	Medium (2 k Ω) $= R_F \ r_d \ R_D$ $\cong R_D$ $(R_F, r_d = 10R_D)$	Medium (-10) $= \left[-g_m(R_F \ r_d \ R_D) \right]$ $= \left[-g_m R_D \right]_{(R_f, r_d \approx 10R_D)}$
Voltage-divider bias E-MOSFET $V_{i} \circ V_{i} $	Medium (1 M Ω) $= \boxed{R_1 R_2}$	Medium (2 k Ω) $= R_D \ r_d \ _{(r_d = 10 R_0)}$ $\cong R_D$	Medium (-10) $= \begin{bmatrix} -g_m(r_d R_D) \\ -g_m R_D \end{bmatrix}$ $\equiv \begin{bmatrix} -g_m R_D \\ (r_d = 10 R_D) \end{bmatrix}$

Configuration	$A_{v_L} = V_o \ V_i$	Z_i	Z_o	
R _{sig} V,	$-g_m(R_D R_L)$	R_G	R_D	
V_i Z_i R_G R_S R_L	Including r_d : $-g_m(R_D R_L r_d)$	R_G	$R_D \ r_d$	
R _{sig} 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 Z_o Z_o	Including r_d : $\frac{-g_m(R_D R_L)}{1 + g_m R_S + \frac{R_D + R_S}{r_d}}$	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 Z_i R_2 R_S R_L	Including r_d : $-g_m(R_D R_L r_d)$	$R_1 \ R_2$	$R_D \ r_d;$	
V_{DD} R_{D}	$\frac{g_m(R_S R_L)}{1 + g_m(R_S R_L)}$	R_G	$R_S 1/g_m$	
V_i Z_i R_G R_S Z_o R_L	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	$\frac{R_S}{1 + \frac{g_m r_d R_S}{r_d + R_D}}$	
Rsig Vi	$g_m(R_D R_L)$	$\frac{R_S}{1 + g_m R_S}$	R_D	
$V_{i} \longrightarrow \overline{Z_{i}} \longrightarrow R_{S} \longrightarrow R_{D} \longrightarrow \overline{Z_{o}} \longrightarrow R_{L}$	Including r_d : $\cong g_m(R_D R_L)$	$Z_i = \frac{R_S}{1 + \frac{g_m r_d R_S}{r_d + R_D \ R_L}}$	$R_D \ r_d$	