ผนวก 1

บัญชีสัญลักษณ์

A	a constant, gain หรือ พื้นที่
A_i	current amplification
A_v	voltage amplification
a_b	T-element internal current gain
B	base terminal
B'	the internal-base terminal
b	thermal constant
C	collector terminal
C	capacitance
C_E	emitter capacitance
C'_{cb}	collector-to-internal-base capacitance
C_{ce}	collector-to-emitter capacitance
C_C	collector capacitance
C_D	diffusion capacitance
C_n	capacitance on n side of transition region
C_T	transition capacitance
D	diffusion constant
D_n	electron diffusion constant
D_p	hole diffusion constant
E	พลังงาน หรือ ศักย์
E_a	acceptor energy level
E_d	donor energy level
E_f	Fermi energy
E_g	energy gap

$\mathcal{E}$ ความเข้มของสนามไฟฟ้า

e ประจุของอิเลคตรอน

exp exponential

f ความถี่

f alpha cutoff frequency (CB)

f alpha cutoff frequency (CE)

G gain or conductance

G_p power gain

g conductance

g_c collector conductance

g_{ce} collector-to-emitter conductance

g_m transconductance

g_n conductance due to electron

h Planck's constant

h_i input impedance

h_f forward-current gain

h_r reverse-voltage gain

h_o output admittance

determinant of hybrid parameter

I กระแส

I_B กระแส base

I_E กระแส emitter

I_J กระแส junction

I_n กระแส electron

I_o saturation current

I_{CO} collector saturation current

I_p กระแส hole

i small-signal current

J ความหนาแน่นของกระแส

j imaginary unit $= \sqrt{-1}$

K ตัวคงที่

k Boltzmann's constant, tapering ratio

L ความยาว

L_n diffusion lenth of electrons

L_p diffusion length of holes

l ความยาว

m มวล หรือ เลขจำนวนเต็ม

N เลขจำนวนเต็ม

N_a acceptor density

N_d donor density

NIC Negative Impedance Converter

n electron density, or inversion factor of NIC

n_i intrinsic electron density

n_{po} equilibrium electron density in p type

p hole density

p_i intrinsic hole density

p_o equilibrium hole density

p_{no} equilibrium hole density in n type

Q ประจุ หรือ figure of merit

R ความต้านทาน

R_e ความต้านทานของ emitter ที่รวมทั้งความต้านทานภายในและภายนอกของ emitter

R_E ความต้านทานของขั้ว emitter

R_f feedback resistance

R_i input resistance

R_o output resistance

r ความต้านทาน

r_b ความต้านทานของ base

r_{bb} ความต้านทาน spreading ของ base

r_c collector resistance

r_d ค่าแตกต่างระหว่าง collector resistance กับ mutual resistance; $r_c - r_m$

r_e emitter resistance

r_m mutual resistance

S ค่าความไวในการเปลี่ยนค่า capacitance ต่อการเปลี่ยนแปลงของศักย์ต่อค่า capacitance

s ความชันของเส้นตรงในการเปลี่ยนแปลง $N_d - N_a$ ต่อระยะทาง x

T อุณหภูมิ

T_J junction temperature

t เวลา

V ศักย์

V_A applied voltage to the junction

V_B barrier voltage หรือ base voltage

V_{BE} base-to-emitter voltage

V_C collector voltage

V_{CC} collector supply voltage

V_D diffusion voltage หรือ built-in voltage of junction ขณะไม่มีกระแสไหล

V_n transition potential on n side

V_p transition potential on p side

W ความกว้างของ transition region

W_B ความกว้างของ base

W_n ความกว้างของ depletion region on n side

W_p ความกว้างของ depletion region on p side

x ตัวแปร (ปรกติเป็นระยะทาง)

Y,y admittance

Z,z impedance

α_b small-signal CB short-circuit current gain

α_e small-signal CE short-circuit current gain

α_B Large-signal CB short-circuit current gain

α_E Large-signal CE short-circuit current gain

α_0 low-frequency value of alpha

β transport factor or feedback factor

ϵ_0 permittivity of free space

μ reverse-voltage transfer ratio = h_{rb}

μ_n mobility of electrons

μ_p mobility of holes

λ wavelength

ρ space charge density หรือ ความต้านทานจำเพาะ

σ ความนำจำเพาะ

σ_i intrinsic conductivity

σ_n electron conductivity

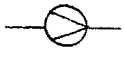
σ_p hole conductivity

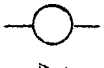
ω angular frequency

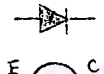
ω_α alpha cutoff frequency (CB)

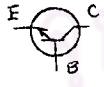
$\omega_{\alpha e}$ alpha cutoff frequency (CE)

Δ determinant หรือ small increment

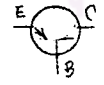

current generator


voltage generator

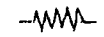

semiconductor diode

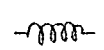


npn junction transistor



pnp junction transistor


ความต้านทาน


inductance coil

capacitor

ผนวก 2

Matrices

โดยพิจารณาสมการ

$$y_1 = a_{11}x_1 + a_{12}x_2$$
$$y_2 = a_{21}x_1 + a_{22}x_2$$

$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix}$$

เมื่อ $\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix}$ เป็น coefficient หรือ transmission matrix

ถ้า $[a] = [b]$

ดังนั้น $a_{11} = b_{11}$ $a_{12} = b_{12}$ $a_{21} = b_{21}$ $a_{22} = b_{22}$

ถ้า $k[a] = [b]$

ดังนั้น $ka_{11} = b_{11}$ $ka_{12} = b_{12}$ $ka_{21} = b_{21}$ $ka_{22} = b_{22}$

ถ้า $[a] \pm [b] = [c]$

ดังนั้น $a_{11} \pm b_{11} = c_{11}$ $a_{12} \pm b_{12} = c_{12}$ $a_{21} + b_{21} = c_{21}$ $a_{22} + b_{22} = c_{22}$

determinant ของ Δ^a คือ

$$a_{11}a_{22} - a_{12}a_{21} = \Delta^a$$

ถ้า $[a] \times [b] = [c]$

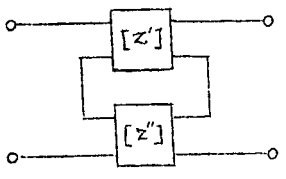
ดังนั้น ผลคูณจะเป็น ดังตัวอย่าง

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} a_{11}b_{11} + a_{12}b_{21} & a_{11}b_{12} + a_{12}b_{22} \\ a_{21}b_{11} + a_{22}b_{21} & a_{21}b_{12} + a_{22}b_{22} \end{bmatrix}$$

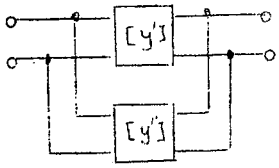
หรือถ้านำเอา two-by-two และ two-by-one matrices มาคูณกัน จะได้

$$\begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} \begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} a_{11}b_1 + a_{12}b_2 \\ a_{21}b_1 + a_{22}b_2 \end{bmatrix}$$

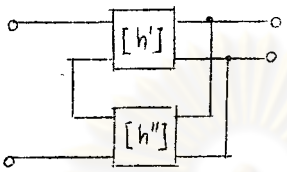
Networks อาจต่อกันเป็นอันดับหรือขนานที่ input และ output terminal จะได้ผลดังข้างล่างนี้



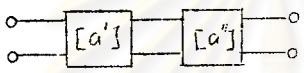
$$[z] = [z'] + [z'']$$



$$[y] = [y'] + [y'']$$



$$[h] = [h'] + [h'']$$



$$[a] = [a'] + [a'']$$

ความสัมพันธ์ระหว่าง determinant แบบต่างๆ

	ในเทอมของ					
	z	y	h	g	a	b
Δ^z	-	$\frac{1}{\Delta^y}$	$\frac{h_{11}}{h_{22}}$	$\frac{g_{22}}{g_{11}}$	$\frac{a_{12}}{a_{21}}$	$\frac{b_{12}}{b_{22}}$
Δ^y	$\frac{1}{\Delta^z}$	-	$\frac{h_{22}}{h_{11}}$	$\frac{g_{11}}{g_{22}}$	$\frac{a_{21}}{a_{12}}$	$\frac{b_{21}}{b_{22}}$
Δ^h	$\frac{z_{11}}{z_{22}}$	$\frac{y_{22}}{y_{11}}$	-	$\frac{1}{\Delta^g}$	$\frac{a_{11}}{a_{22}}$	$\frac{b_{22}}{b_{11}}$
Δ^g	$\frac{z_{22}}{z_{11}}$	$\frac{y_{11}}{y_{22}}$	$\frac{1}{\Delta^h}$	-	$\frac{a_{22}}{a_{11}}$	$\frac{b_{11}}{b_{22}}$
Δ^a	$\frac{z_{12}}{z_{21}}$	$\frac{y_{12}}{y_{21}}$	$-\frac{h_{12}}{h_{21}}$	$-\frac{g_{12}}{g_{21}}$	-	$\frac{1}{\Delta^b}$
Δ^b	$\frac{z_{21}}{z_{12}}$	$\frac{y_{21}}{y_{12}}$	$-\frac{h_{21}}{h_{12}}$	$-\frac{g_{21}}{g_{12}}$	$\frac{1}{\Delta^a}$	-

ความสัมพันธ์ระหว่าง matrix แบบต่างๆ

	ในเทอมของ					
	z	y	h	g	a	b
[z]	—	$\frac{y_{22}}{\Delta^y}\ \frac{-y_{12}}{\Delta^y}$ $\frac{-y_{21}}{\Delta^y}\ \frac{y_{11}}{\Delta^y}$	$\frac{\Delta^h}{h_{22}}\ \frac{h_{12}}{h_{22}}$ $\frac{-h_{21}}{h_{22}}\ \frac{1}{h_{22}}$	$\frac{1}{g_{11}}\ \frac{-g_{12}}{g_{11}}$ $\frac{g_{21}}{g_{11}}\ \frac{\Delta^g}{g_{11}}$	$\frac{a_{11}}{a_{21}}\ \frac{\Delta^a}{a_{21}}$ $\frac{1}{a_{21}}\ \frac{a_{22}}{a_{21}}$	$\frac{b_{22}}{b_{21}}\ \frac{1}{b_{21}}$ $\frac{\Delta^b}{b_{21}}\ \frac{b_{11}}{b_{21}}$
[y]	$\frac{z_{22}}{\Delta^z}\ \frac{-z_{12}}{\Delta^z}$ $\frac{-z_{21}}{\Delta^z}\ \frac{z_{11}}{\Delta^z}$	—	$\frac{1}{h_{11}}\ \frac{-h_{12}}{h_{11}}$ $\frac{h_{21}}{h_{11}}\ \frac{\Delta^h}{h_{11}}$	$\frac{\Delta^g}{g_{22}}\ \frac{g_{12}}{g_{22}}$ $\frac{-g_{21}}{g_{22}}\ \frac{1}{g_{22}}$	$\frac{a_{22}}{a_{12}}\ \frac{-\Delta^a}{a_{12}}$ $\frac{-1}{a_{12}}\ \frac{a_{11}}{a_{12}}$	$\frac{b_{11}}{b_{12}}\ \frac{-1}{b_{12}}$ $\frac{-\Delta^b}{b_{12}}\ \frac{b_{22}}{b_{12}}$
[h]	$\frac{\Delta^z}{z_{22}}\ \frac{z_{12}}{z_{22}}$ $\frac{-z_{21}}{z_{22}}\ \frac{1}{z_{22}}$	$\frac{1}{y_{11}}\ \frac{-y_{12}}{y_{11}}$ $\frac{y_{21}}{y_{11}}\ \frac{\Delta^y}{y_{11}}$	—	$\frac{g_{22}}{\Delta^g}\ \frac{-g_{12}}{\Delta^g}$ $\frac{-g_{21}}{\Delta^g}\ \frac{g_{11}}{\Delta^g}$	$\frac{a_{12}}{a_{22}}\ \frac{\Delta^a}{a_{22}}$ $\frac{-1}{a_{22}}\ \frac{a_{21}}{a_{22}}$	$\frac{b_{12}}{b_{11}}\ \frac{1}{b_{11}}$ $\frac{-\Delta^b}{b_{11}}\ \frac{b_{21}}{b_{11}}$
[g]	$\frac{1}{z_{11}}\ \frac{-z_{12}}{z_{11}}$ $\frac{z_{21}}{z_{11}}\ \frac{\Delta^z}{z_{11}}$	$\frac{\Delta^y}{y_{22}}\ \frac{y_{12}}{y_{22}}$ $\frac{-y_{21}}{y_{22}}\ \frac{1}{y_{22}}$	$\frac{h_{22}}{\Delta^h}\ \frac{-h_{12}}{\Delta^h}$ $\frac{-h_{21}}{\Delta^h}\ \frac{h_{11}}{\Delta^h}$	—	$\frac{a_{21}}{a_{11}}\ \frac{-\Delta^a}{a_{11}}$ $\frac{1}{a_{11}}\ \frac{a_{12}}{a_{11}}$	$\frac{b_{21}}{b_{22}}\ \frac{-1}{b_{22}}$ $\frac{\Delta^b}{b_{22}}\ \frac{b_{12}}{b_{22}}$
[a]	$\frac{z_{11}}{z_{21}}\ \frac{\Delta^z}{z_{21}}$ $\frac{1}{z_{21}}\ \frac{z_{22}}{z_{21}}$	$\frac{-y_{22}}{y_{21}}\ \frac{-1}{y_{21}}$ $\frac{-\Delta^y}{y_{21}}\ \frac{-y_{11}}{y_{21}}$	$\frac{-\Delta^h}{h_{21}}\ \frac{-h_{11}}{h_{21}}$ $\frac{-h_{22}}{h_{21}}\ \frac{-1}{h_{21}}$	$\frac{1}{g_{21}}\ \frac{g_{22}}{g_{21}}$ $\frac{g_{11}}{g_{21}}\ \frac{\Delta^g}{g_{21}}$	—	$\frac{b_{22}}{\Delta^b}\ \frac{b_{12}}{\Delta^b}$ $\frac{b_{21}}{\Delta^b}\ \frac{b_{11}}{\Delta^b}$
[b]	$\frac{z_{22}}{z_{12}}\ \frac{\Delta^z}{z_{12}}$ $\frac{1}{z_{12}}\ \frac{z_{11}}{z_{12}}$	$\frac{-y_{11}}{y_{12}}\ \frac{-1}{y_{12}}$ $\frac{-\Delta^y}{y_{12}}\ \frac{-y_{22}}{y_{12}}$	$\frac{1}{h_{21}}\ \frac{h_{11}}{h_{12}}$ $\frac{h_{22}}{h_{12}}\ \frac{\Delta^h}{h_{12}}$	$\frac{-\Delta^g}{g_{12}}\ \frac{-g_{22}}{g_{12}}$ $\frac{-g_{11}}{g_{12}}\ \frac{-1}{g_{12}}$	$\frac{a_{22}}{\Delta^a}\ \frac{a_{12}}{\Delta^a}$ $\frac{a_{21}}{\Delta^a}\ \frac{a_{11}}{\Delta^a}$	—

ผนวก 3

ความสัมพันธ์ระหว่าง parameter ต่างๆ

ความสัมพันธ์ระหว่าง parameter แบบ hybrid ต่างๆ อย่างประมาณ

	common-base parameters	common-emitter parameters	common-collector parameters
$[h_b]$	———	$\frac{1}{1+h_{fe}}\begin{bmatrix} h_{ie} & \Delta^h - h_{re} \\ -h_{fe} & h_{oe} \end{bmatrix}$ $\Delta^{h_b} \cong \frac{\Delta^h}{1+h_{fe}}$	$-\frac{1}{h_{fe}}\begin{bmatrix} h_i & \Delta^h + h_{fe} \\ h_{rc}h_{fc} & h_{oc} \end{bmatrix}$ $\Delta^{h_b} \cong \frac{-(h_{fc}+\Delta^{h_c})}{h_{fc}}$
$[h_e]$	$\frac{1}{1+h_{fb}}\begin{bmatrix} h_{ib} & \Delta^{h_b} - h_{rb} \\ -h_{fb} & h_{ob} \end{bmatrix}$ $\Delta^h \cong \frac{\Delta^{h_b}}{1+h_{fb}}$	———	$\begin{bmatrix} h_{ic} & 1-h_{rc} \\ -h_{fc} & h_{oc} \end{bmatrix}$ $\Delta^h \cong h_{fc} + \Delta^{h_c}$
$[h_c]$	$\frac{1}{1+h_{fb}}\begin{bmatrix} h_{ib} & 1+h_{fb} \\ -1 & h_{ob} \end{bmatrix}$ $\Delta^{h_c} \cong \frac{1}{1+h_{fb}}$	$\begin{bmatrix} h_{ie} & 1 \\ -(1+h_{fe}) & h_{oe} \end{bmatrix}$ $\Delta^{h_c} \cong 1+h_{fe}$	———

ความสัมพันธ์ระหว่าง parameter แบบ hybrid ต่างๆ อย่างแท้จริง

	common-base parameters	common-emitter parameters	common-collector parameters
$[h_b]$	———	$\frac{1}{1+h_{fe}+\Delta^h-h_{re}}\begin{bmatrix} h_{ie} & \Delta^h - h_{re} \\ -(\Delta^h+h_{fe}) & h_{oe} \end{bmatrix}$ $\Delta^{h_b} = \frac{\Delta^h}{1+h_{fe}+\Delta^h-h_{re}}$	$\frac{1}{\Delta^{h_c}}\begin{bmatrix} h_{ic} & \Delta^h + h_{fc} \\ -(\Delta^h - h_{rc}) & h_{oc} \end{bmatrix}$ $\Delta^{h_b} = \frac{1+h_{fc}+\Delta^{h_c}-h_{rc}}{\Delta^{h_c}}$
$[h_e]$	$\frac{1}{1+h_{fb}+\Delta^{h_b}-h_{rb}}\begin{bmatrix} h_{ib} & \Delta^{h_b}+h_{rb} \\ -(h_{fb}+\Delta^{h_b}) & h_{ob} \end{bmatrix}$ $\Delta^h = \frac{\Delta^{h_b}}{1+h_{fb}+\Delta^{h_b}-h_{rb}}$	———	$\begin{bmatrix} h_{ic} & 1-h_{rc} \\ -(1+h_{fc}) & h_{oc} \end{bmatrix}$ $\Delta^h = 1+h_{fc}+\Delta^{h_c}-h_{rc}$
$[h_c]$	$\frac{1}{1+h_{fb}+\Delta^{h_b}-h_{rb}}\begin{bmatrix} h_{ib} & 1+h_{rb} \\ -(1-h_{rb}) & h_{ob} \end{bmatrix}$ $\Delta^{h_c} = \frac{1}{1+h_{fb}+\Delta^{h_b}-h_{rb}}$	$\begin{bmatrix} h_{ie} & 1-h_{re} \\ -(1+h_{fe}) & h_{oe} \end{bmatrix}$ $\Delta^{h_c} = 1+h_{fe}+\Delta^h-h_{re}$	———

สูตรต่างๆโดยประมาณของ hybrid parameter ในเทอมของ T element

Common base

$$h_{ib} = r_e + r_b(1 - a_b)$$

$$h_{rb} = \frac{r_b}{r_c}$$

$$h_{fb} = -a_b$$

$$h_{ob} = \frac{1}{r_c}$$

$$a_b = -h_{fb}$$

$$r_b = \frac{h_{rb}}{h_{ob}}$$

$$r_e = h_{ib} - \frac{h_{rb}(1 + h_{fb})}{h_{ob}}$$

$$r_c = \frac{1}{h_{ob}}$$

Common Emitter

$$h_{ie} = r_b + (1 + a_e) r_e = r_b + \frac{r_e}{1 - a_b}$$

$$h_{re} = \frac{r_e}{r_d} = \frac{r_e}{(1 - a_b) r_c}$$

$$h_{fe} = a_e = \frac{a_b}{1 - a_b}$$

$$h_{oe} = \frac{1}{r_d} = \frac{1}{(1 - a_b) r_c}$$

$$a_e = h_{fe}$$

$$r_b = h_{ie} - \frac{h_{re}(1 + h_{fe})}{h_{oe}}$$

$$r_e = \frac{h_{re}}{h_{oe}}$$

$$r_c = \frac{h_{fe}}{h_{oe}}$$

$$r_d = \frac{1}{h_{oe}}$$

$$a_b = \frac{h_{fe}}{1 + h_{fe}}$$

Common Collector

$$h_{ic} = r_b + r_e a_e$$

$$h_{rc} = \frac{r_d}{r_d - r_e}$$

$$h_{fc} = - a_e$$

$$h_{oc} = \frac{1}{r_d}$$

$$a_e = - h_{fc}$$

$$r_b = h_{ic} + \frac{h_{fc}(1 - h_{rc})}{h_{oc}}$$

$$r_e = \frac{1}{h_{oc}}$$

$$r_c = - \frac{h_{fc}}{h_{oc}}$$

เบ็ดเตล็ด

$$b = \frac{r_m + r_b}{r_c + r_b}$$

$$a_b = \frac{r_m}{r_c}$$

$$\alpha_b = \frac{\alpha_e}{1 + \alpha_e}$$

$$\alpha_e = \frac{\alpha_b}{1 - \alpha_b}$$

$$\alpha_e = \frac{r_m - r_e}{r_c - r_m + r_e}$$

$$a_e = \frac{r_m}{r_c - r_m} = \frac{r_m}{r_d}$$

$$r_d = r_c - r_m$$

สูตรของ Gain และ Impedance

สูตรของ gain และ impedance ในเทอมของ hybrid parameter h_i, h_r, h_f, และ h_o

$$A_v = \frac{V_2}{V_1} = \frac{-h_f Z_L}{h_i + \Delta^h Z_L}$$

$$A_i = \frac{i_2}{i_1} = \frac{h_f}{1 + h_o Z_L}$$

$$Z_i = \frac{h_i + \Delta^h Z_L}{1 + h_o Z_L}$$

$$Z_o = \frac{h_i + Z_g}{\Delta^h + h_o Z_g}$$

สูตรของ Small-signal Amplifier ที่ใช้ T Element

Common Base

$$A_v = \frac{(r_m + r_b) R_L}{r_e (r_c + r_b + R_L) + r_b (r_c - r_m + R_L)}$$

$$A_i = \frac{-(r_m + r_b)}{r_c + r_b + R_L}$$

$$R_i = r_e + r_b \frac{r_c - r_m + R_L}{r_c + r_b + R_L}$$

$$R_o = r_c + r_b \left(1 - \frac{r_m + r_b}{r_e + r_b + R_g}\right)$$

Common Emitter

$$A_v = \frac{-(r_m - r_e) R_L}{r_e (r_c + R_L) + r_b (r_c - r_m + r_e + R_L)}$$

$$A_i = \frac{r_m - r_e}{r_c - r_m + r_e + R_L}$$

$$R_i = r_b + \frac{r_e (r_c + R_L)}{r_c - r_m + r_e + R_L}$$

$$R_o = r_c - r_m + r_e \left(1 + \frac{r_m - r_e}{r_e + r_b + R_g}\right)$$

Common Collector

$$A_V = \frac{r_c R_L}{r_c (r_e + R_L) + r_b (r_c - r_m + r_e + R_L)}$$

$$A_i = \frac{r_c}{r_c - r_m + r_e + R_L}$$

$$R_i = r_b + \frac{r_c (r_e + R_L)}{r_c - r_m + r_e + R_L}$$

$$R_o = r_e + (r_b + R_g) \frac{r_c - r_m}{r_c + r_b + R_g}$$

คุณสมบัติของ Gain และ Impedance ของวงจรสี่ขั้ว

	z	y	h	g	a	b
Z_i	$\frac{\Delta^z + z_{11} Z_L}{z_{22} + Z_L}$	$\frac{1 + y_{22} Z_L}{y_{11} + \Delta^y Z_L}$	$\frac{h_{11} + \Delta^h Z_L}{1 + h_{22} Z_L}$	$\frac{g_{22} + Z_L}{\Delta^g + g_{11} Z_L}$	$\frac{a_{12} + a_{11} Z_L}{a_{22} + a_{21} Z_L}$	$\frac{b_{12} + b_{22} Z_L}{b_{11} + b_{21} Z_L}$
Z_o	$\frac{\Delta^z + z_{22} Z_g}{z_{11} + Z_g}$	$\frac{1 + y_{11} Z_g}{y_{22} + \Delta^y Z_g}$	$\frac{h_{11} + Z_g}{\Delta^h + h_{22} Z_g}$	$\frac{g_{22} + \Delta^g Z_g}{1 + g_{11} Z_g}$	$\frac{a_{12} + a_{22} Z_g}{a_{11} + a_{21} Z_g}$	$\frac{b_{12} + b_{11} Z_g}{b_{22} + b_{21} Z_g}$
$\frac{V_2}{V_1}$	$\frac{z_{21} Z_L}{\Delta^z + z_{11} Z_L}$	$\frac{-y_{21} Z_L}{1 + y_{22} Z_L}$	$\frac{-h_{21} Z_L}{h_{11} + \Delta^h Z_L}$	$\frac{g_{21} Z_L}{g_{22} + Z_L}$	$\frac{Z_L}{a_{12} + a_{11} Z_L}$	$\frac{\Delta^b Z_L}{b_{12} + b_{22} Z_L}$
$\frac{i_2}{i_1}$	$\frac{-z_{21}}{z_{22} + Z_L}$	$\frac{y_{21}}{y_{11} + \Delta^y Z_L}$	$\frac{h_{21}}{1 + h_{22} Z_L}$	$\frac{-g_{21}}{\Delta^g + g_{11} Z_L}$	$\frac{-1}{a_{22} + a_{21} Z_L}$	$\frac{-\Delta^b}{b_{11} + b_{12} Z_L}$

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