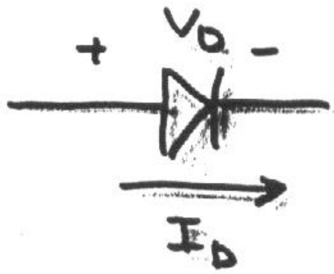
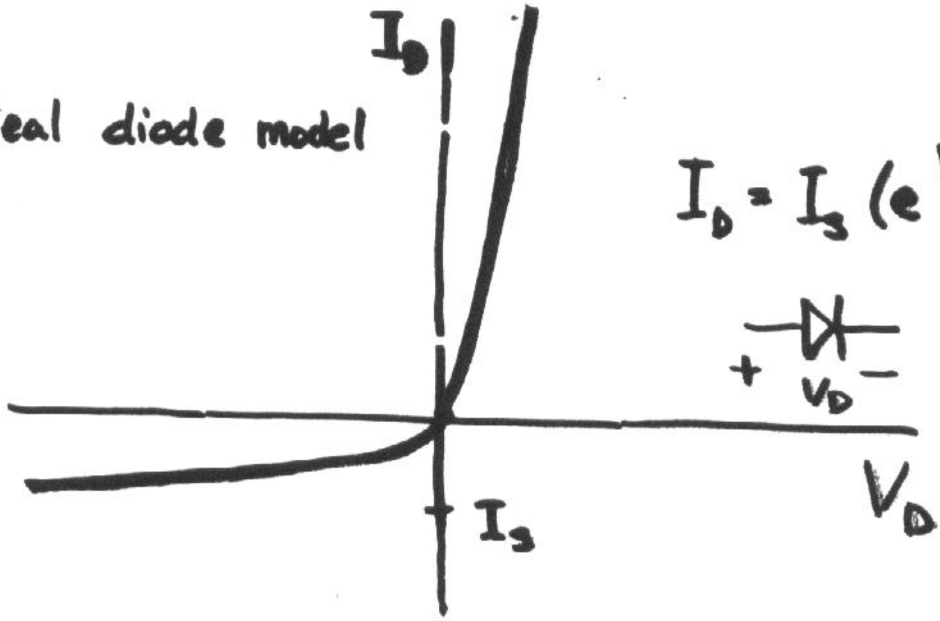
Diode Characteristics and Models



ideal diode model



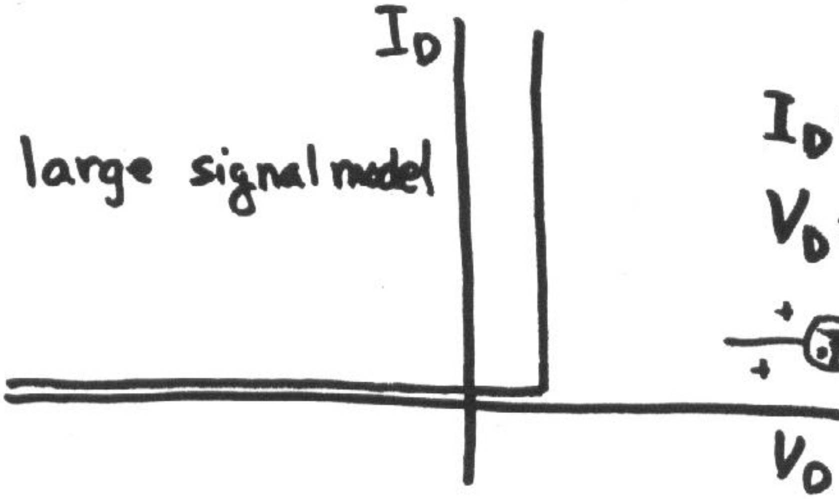
$$I_D = I_s\left(e^{V_D/V_T} - 1\right)$$

ideal rectifier model

$I_D = 0$ if $V_D < 0$

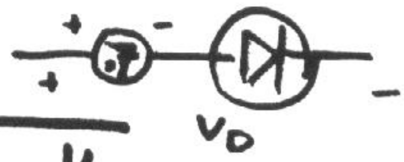
$V_D = 0$ if $I_D > 0$

large signal model

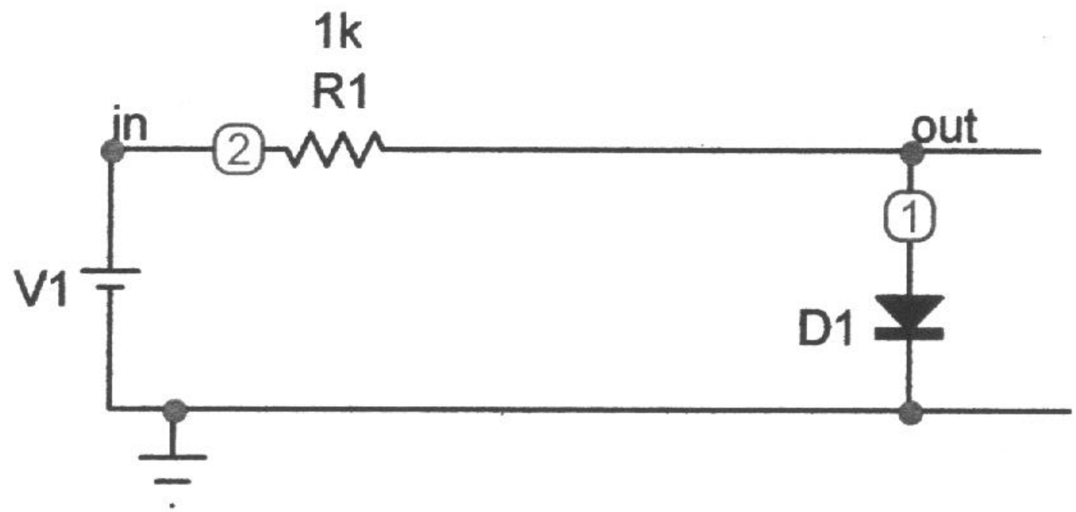


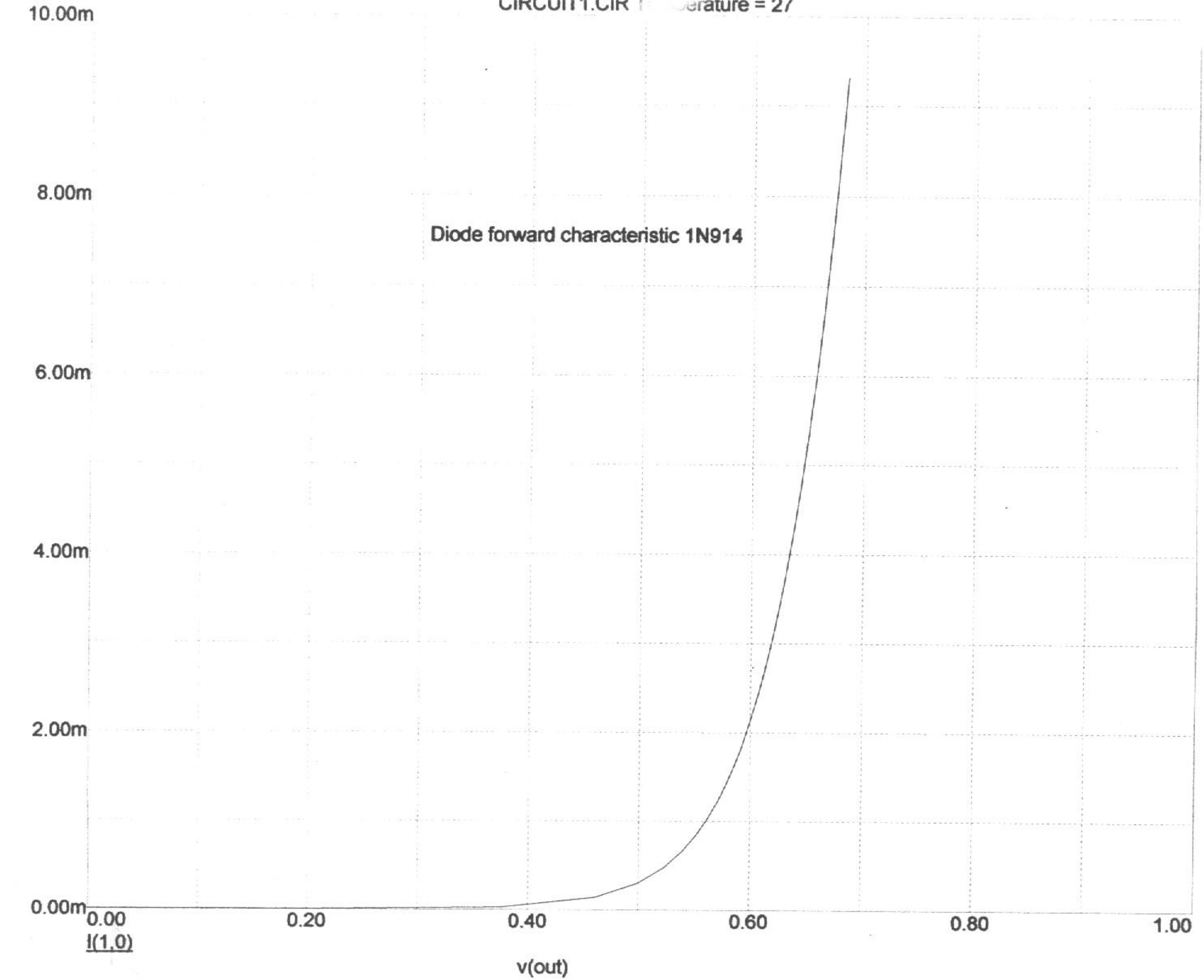
$I_D = 0$ if $V_D < 0.7v$

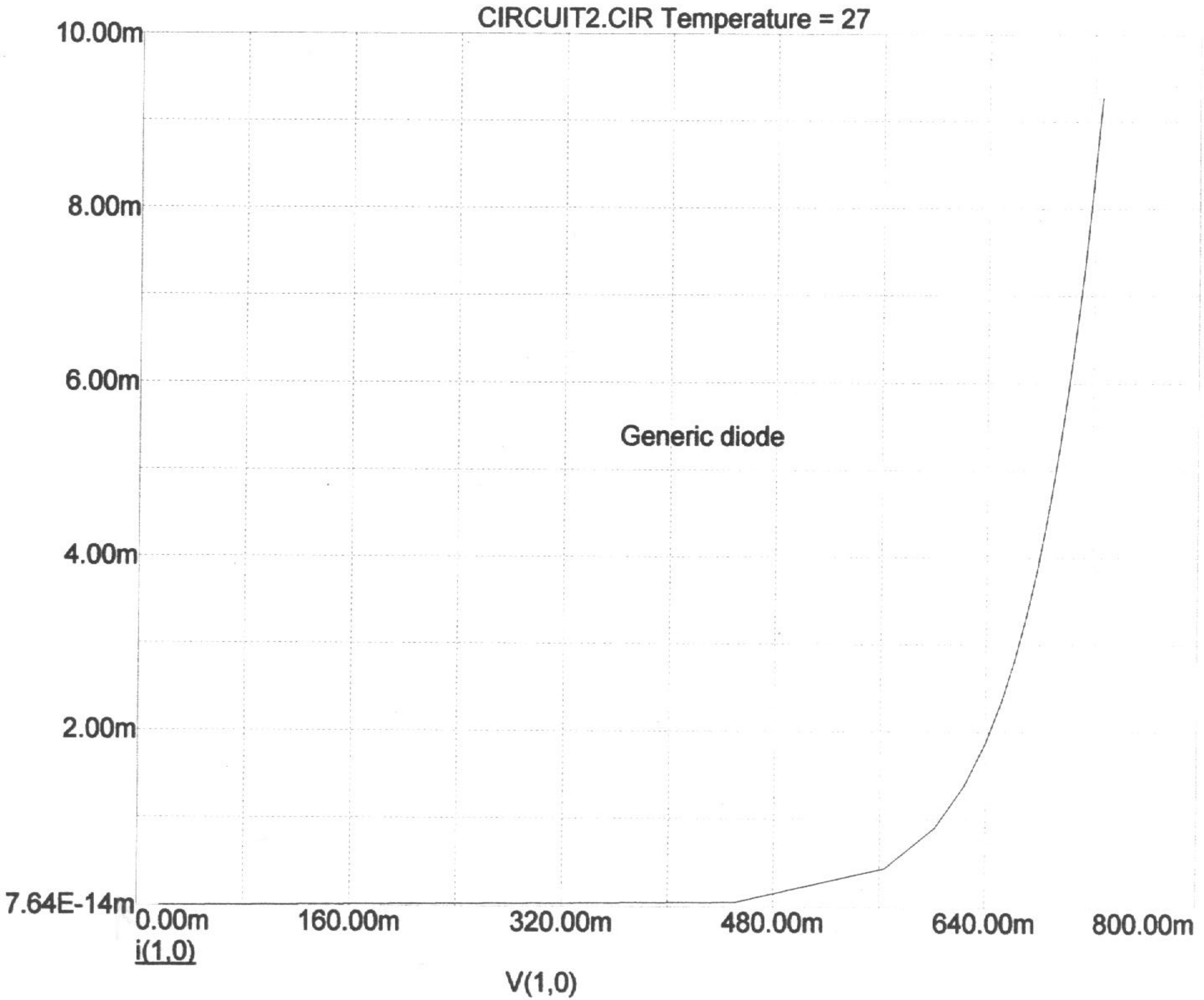
$V_D = 0.7v$ if $I_D > 0$



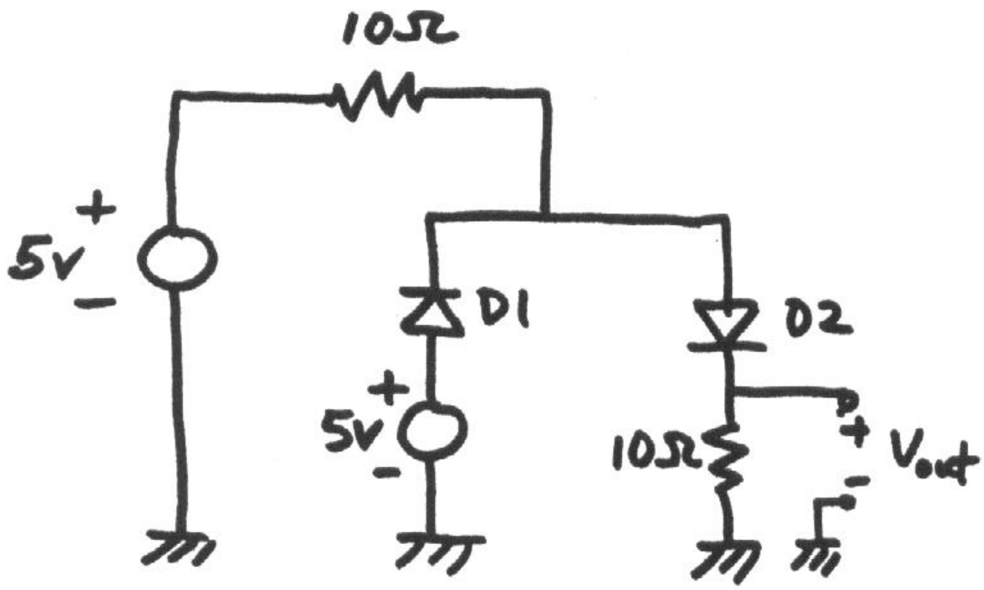
Diode forward characteristic 1N914




CIRCUIT1.CIR Temperature = 27
Diode forward characteristic 1N914
10.00m
8.00m
6.00m
4.00m
2.00m
0.00m
0.00
0.20
0.40
0.60
0.80
1.00
I(1,0)
v(out)


CIRCUIT2.CIR Temperature = 27
Generic diode
10.00m
8.00m
6.00m
4.00m
2.00m
7.64E-14m
0.00m
160.00m
320.00m
480.00m
640.00m
800.00m
i(1,0)
V(1,0)

Example:



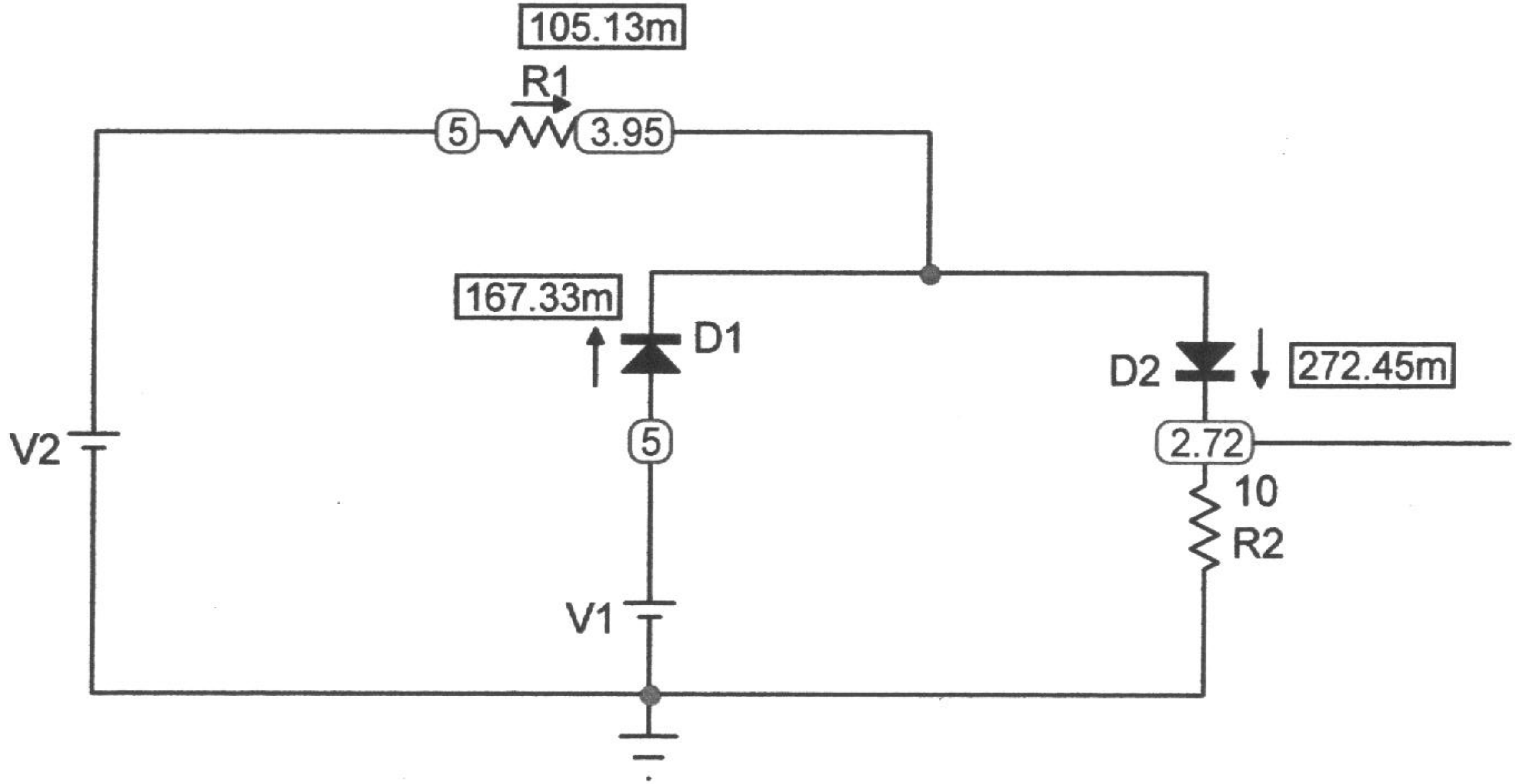
Use ideal rectifier model for diode

Find V_{out}.

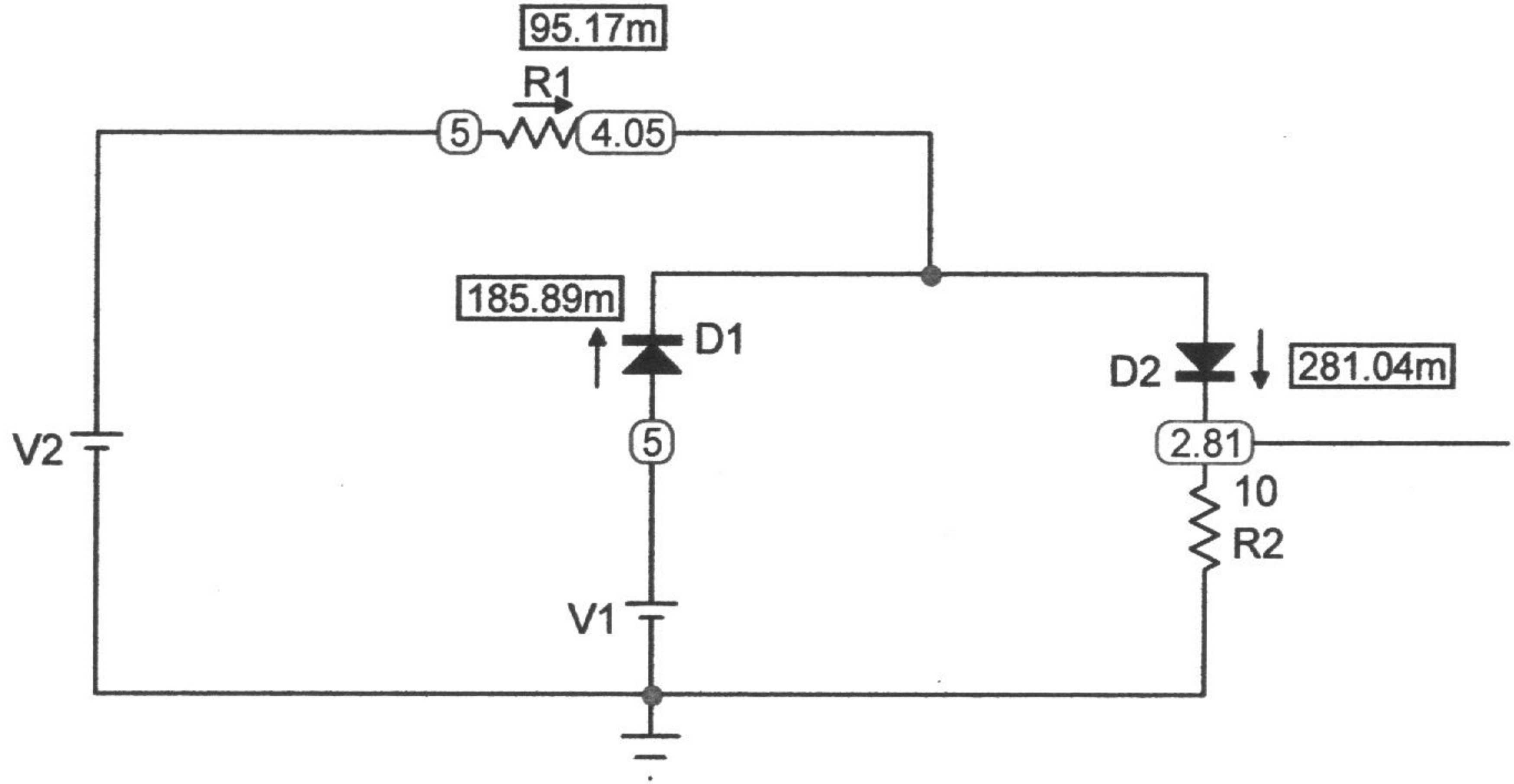
The key to solving diode circuits is to guessimate the diode bias condition solve circuit and check to be self-consistent.

D2: is conducting on = short circuit

D1: is "guessimated" off = open circuit



Diode ckt V1=V2= 5 diode = 1n914

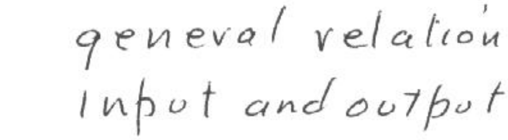


Diode ckt V1=V2= 5 diode = generic

Two port networks and dependent sources

So far have only dealt with independent sources, those external to a network which supply the excitations. There are other sources which arise when we want to look at circuit characteristics at a higher level, i.e, not interested in the inner details but instead want more general relations for voltage and current gains, input and output impedance etc. These other sources are "dependent" or "controlled" sources characterized by fact that their output is a function of some other voltage or current in the circuit.

Dependent sources arise when we look at circuits (or even a single active device like a transistor) as a general "two port" network whose model is characterized as a network with input V_1 and I_1, and an output with V_2 and I_2.



By taking two of the quantities as independent variables and the other two as dependendendent variables, it is possible to write six sets of equations characterizing the two port by means of a set of parameters (some sets have descriptive names.)

The two-port equation sets are:

$$V_1 = Z_{11} I_1 + Z_{12} I_2$$
$$V_2 = Z_{21} I_1 + Z_{22} I_2$$
(open ckt Z parameter description)

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$
$$I_2 = Y_{21} V_1 + Y_{22} V_2$$
(short ckt Y parameter description)

$$V_1 = h_{11} I_1 + h_{12} V_2$$
$$I_2 = h_{21} I_1 + h_{22} V_2$$
(hybrid h parameter description)

$$I_1 = g_{11} V_1 + g_{12} I_2$$
$$V_2 = g_{21} V_1 + g_{22} I_2$$
(inverse hybrid)

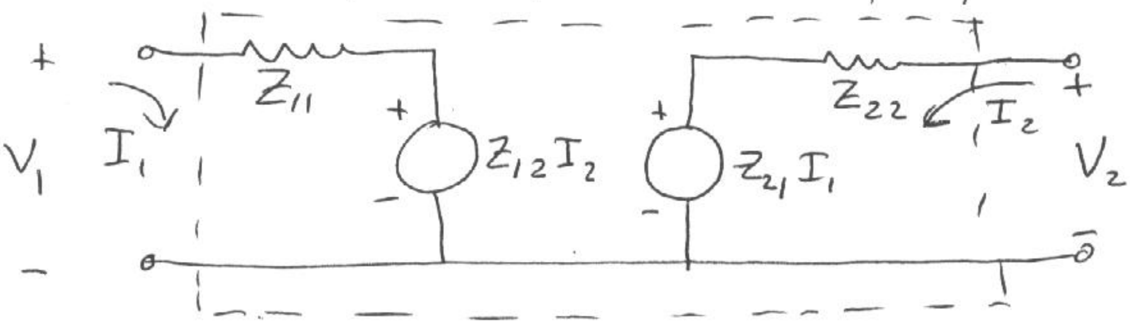
$$V_1 = a_{11} V_2 - a_{12} I_2$$
$$I_1 = a_{21} V_2 - a_{22} I_2$$
(Transmission)
(sometimes in t_{ij})

$$V_2 = b_{11} V_1 - b_{12} I_1$$
$$I_2 = b_{21} V_1 - b_{22} I_1$$
(inverse transmission)
(sometimes in S_{ij})

These sets are the recipes for a "circuit model" or "equivalent circuit model".

Note that if the circuit diagram is given - the parameters can be calculated. If the actual physical circuit is given - the parameters can be measured.

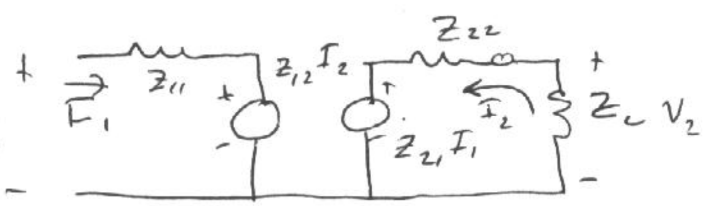
Consider the model associated with the Z parameter description: from the recipe get



Thing to note is that a new type of source has been introduced - in this case they are current controlled voltage sources.

Depending on which set of two-port equations are used, other types of dependent sources are introduced.

Simple example of application. "Calculate the voltage gain of a terminated two-port using Z parameters"



$$V_g = Z_{11} I_1 + Z_{12} I_2$$
$$0 = Z_{21} I_1 + (Z_{22} + Z_L) I_2$$

get for I_2

$$I_2 = \frac{-V_g Z_{21}}{(Z_{11})(Z_L + Z_{22}) - Z_{12} Z_{21}}$$

but $V_2 = -I_2 Z_L$ get

$$A_v = \frac{V_2}{V_g} = -\frac{I_2 Z_L}{V_g} = \frac{Z_{21} Z_L}{Z_{11} Z_{22} - Z_{12} Z_{21} + Z_{11} Z_L} = \frac{Z_{21} Z_L}{\Delta^Z + Z_{11} Z_L}$$

etc for the other xfr fncs of interest i.e. Voltge gain A_v, curent gain A_I, input, output imp Z_i, Z_o

C. Matrix Conversions

To Find	Given					
	z	y	h	g	a	b
$[z]$	—	$\begin{matrix} \frac{y_{22}}{\Delta^y} & \frac{-y_{12}}{\Delta^y} \\ \frac{-y_{21}}{\Delta^y} & \frac{y_{11}}{\Delta^y} \end{matrix}$	$\begin{matrix} \frac{\Delta^h}{h_{22}} & \frac{h_{12}}{h_{22}} \\ \frac{-h_{21}}{h_{22}} & \frac{1}{h_{22}} \end{matrix}$	$\begin{matrix} \frac{1}{g_{11}} & \frac{-g_{12}}{g_{11}} \\ \frac{g_{21}}{g_{11}} & \frac{\Delta^g}{g_{11}} \end{matrix}$	$\begin{matrix} \frac{a_{11}}{a_{21}} & \frac{\Delta^a}{a_{21}} \\ \frac{1}{a_{21}} & \frac{a_{22}}{a_{21}} \end{matrix}$	$\begin{matrix} \frac{b_{22}}{b_{21}} & \frac{1}{b_{21}} \\ \frac{\Delta^b}{b_{21}} & \frac{b_{11}}{b_{21}} \end{matrix}$
$[y]$	$\begin{matrix} \frac{z_{22}}{\Delta^z} & \frac{-z_{12}}{\Delta^z} \\ \frac{-z_{21}}{\Delta^z} & \frac{z_{11}}{\Delta^z} \end{matrix}$	—	$\begin{matrix} \frac{1}{h_{11}} & \frac{-h_{12}}{h_{11}} \\ \frac{h_{21}}{h_{11}} & \frac{\Delta^h}{h_{11}} \end{matrix}$	$\begin{matrix} \frac{\Delta^g}{g_{22}} & \frac{g_{12}}{g_{22}} \\ \frac{-g_{21}}{g_{22}} & \frac{1}{g_{22}} \end{matrix}$	$\begin{matrix} \frac{a_{22}}{a_{12}} & \frac{-\Delta^a}{a_{12}} \\ \frac{-1}{a_{12}} & \frac{a_{11}}{a_{12}} \end{matrix}$	$\begin{matrix} \frac{b_{11}}{b_{12}} & \frac{-1}{b_{12}} \\ \frac{-\Delta^b}{b_{12}} & \frac{b_{22}}{b_{12}} \end{matrix}$
$[h]$	$\begin{matrix} \frac{\Delta^z}{z_{22}} & \frac{z_{12}}{z_{22}} \\ \frac{-z_{21}}{z_{22}} & \frac{1}{z_{22}} \end{matrix}$	$\begin{matrix} \frac{1}{y_{11}} & \frac{-y_{12}}{y_{11}} \\ \frac{y_{21}}{y_{11}} & \frac{\Delta^y}{y_{11}} \end{matrix}$	—	$\begin{matrix} \frac{g_{22}}{\Delta^g} & \frac{-g_{12}}{\Delta^g} \\ \frac{-g_{21}}{\Delta^g} & \frac{g_{11}}{\Delta^g} \end{matrix}$	$\begin{matrix} \frac{a_{12}}{a_{22}} & \frac{\Delta^a}{a_{22}} \\ \frac{-1}{a_{22}} & \frac{a_{21}}{a_{22}} \end{matrix}$	$\begin{matrix} \frac{b_{12}}{b_{11}} & \frac{1}{b_{11}} \\ \frac{-\Delta^b}{b_{11}} & \frac{b_{21}}{b_{11}} \end{matrix}$
$[g]$	$\begin{matrix} \frac{1}{z_{11}} & \frac{-z_{12}}{z_{11}} \\ \frac{z_{21}}{z_{11}} & \frac{\Delta^z}{z_{11}} \end{matrix}$	$\begin{matrix} \frac{\Delta^y}{y_{22}} & \frac{y_{12}}{y_{22}} \\ \frac{-y_{21}}{y_{22}} & \frac{1}{y_{22}} \end{matrix}$	$\begin{matrix} \frac{h_{22}}{\Delta^h} & \frac{-h_{12}}{\Delta^h} \\ \frac{-h_{21}}{\Delta^h} & \frac{h_{11}}{\Delta^h} \end{matrix}$	—	$\begin{matrix} \frac{a_{21}}{a_{11}} & \frac{-\Delta^a}{a_{11}} \\ \frac{1}{a_{11}} & \frac{a_{12}}{a_{11}} \end{matrix}$	$\begin{matrix} \frac{b_{21}}{b_{22}} & \frac{-1}{b_{22}} \\ \frac{\Delta^b}{b_{22}} & \frac{b_{12}}{b_{22}} \end{matrix}$
$[a]$	$\begin{matrix} \frac{z_{11}}{z_{21}} & \frac{\Delta^z}{z_{21}} \\ \frac{1}{z_{21}} & \frac{z_{22}}{z_{21}} \end{matrix}$	$\begin{matrix} \frac{-y_{22}}{y_{21}} & \frac{-1}{y_{21}} \\ \frac{-\Delta^y}{y_{21}} & \frac{-y_{11}}{y_{21}} \end{matrix}$	$\begin{matrix} \frac{-\Delta^h}{h_{21}} & \frac{-h_{11}}{h_{21}} \\ \frac{-h_{22}}{h_{21}} & \frac{-1}{h_{21}} \end{matrix}$	$\begin{matrix} \frac{1}{g_{21}} & \frac{g_{22}}{g_{21}} \\ \frac{g_{11}}{g_{21}} & \frac{\Delta^g}{g_{21}} \end{matrix}$	—	$\begin{matrix} \frac{b_{22}}{\Delta^b} & \frac{b_{12}}{\Delta^b} \\ \frac{b_{21}}{\Delta^b} & \frac{b_{11}}{\Delta^b} \end{matrix}$
$[b]$	$\begin{matrix} \frac{z_{22}}{z_{12}} & \frac{\Delta^z}{z_{12}} \\ \frac{1}{z_{12}} & \frac{z_{11}}{z_{12}} \end{matrix}$	$\begin{matrix} \frac{-y_{11}}{y_{12}} & \frac{-1}{y_{12}} \\ \frac{-\Delta^y}{y_{12}} & \frac{-y_{22}}{y_{12}} \end{matrix}$	$\begin{matrix} \frac{1}{h_{12}} & \frac{h_{11}}{h_{12}} \\ \frac{h_{22}}{h_{12}} & \frac{\Delta^h}{h_{12}} \end{matrix}$	$\begin{matrix} \frac{-\Delta^g}{g_{12}} & \frac{-g_{22}}{g_{12}} \\ \frac{-g_{11}}{g_{12}} & \frac{-1}{g_{12}} \end{matrix}$	$\begin{matrix} \frac{a_{22}}{\Delta^a} & \frac{a_{12}}{\Delta^a} \\ \frac{a_{21}}{\Delta^a} & \frac{a_{11}}{\Delta^a} \end{matrix}$	

B. Properties of the Terminated Four-Terminal Network

To Find	Given					
	z	y	h	g	a	b
Z_i	$\frac{\Delta^z + z_{11}Z_L}{z_{22} + Z_L}$	$\frac{1 + y_{22}Z_L}{y_{11} + \Delta^y Z_L}$	$\frac{h_{11} + \Delta^h Z_L}{1 + h_{22}Z_L}$	$\frac{g_{22} + Z_L}{\Delta^g + g_{11}Z_L}$	$\frac{a_{12} + a_{21}Z_L}{a_{22} + a_{21}Z_L}$	$\frac{b_{12} + b_{22}Z_L}{b_{11} + b_{21}Z_L}$
Z_o	$\frac{\Delta^z + z_{22}Z_G}{z_{11} + Z_G}$	$\frac{1 + y_{11}Z_G}{y_{22} + \Delta^y Z_G}$	$\frac{h_{11} + Z_G}{\Delta^h + h_{22}Z_G}$	$\frac{g_{22} + \Delta^g Z_G}{1 + g_{11}Z_G}$	$\frac{a_{12} + a_{22}Z_G}{a_{11} + a_{21}Z_G}$	$\frac{b_{12} + b_{11}Z_G}{b_{22} + b_{21}Z_G}$
A_v	$\frac{z_{21}Z_L}{\Delta^z + z_{11}Z_L}$	$\frac{-y_{21}Z_L}{1 + y_{22}Z_L}$	$\frac{-h_{21}Z_L}{h_{11} + \Delta^h Z_L}$	$\frac{g_{21}Z_L}{g_{22} + Z_L}$	$\frac{Z_L}{a_{12} + a_{11}Z_L}$	$\frac{\Delta^b Z_L}{b_{12} + b_{22}Z_L}$
A_i	$\frac{-z_{21}}{z_{22} + Z_L}$	$\frac{y_{21}}{y_{11} + \Delta^y Z_L}$	$\frac{h_{21}}{1 + h_{22}Z_L}$	$\frac{-g_{21}}{\Delta^g + g_{11}Z_L}$	$\frac{-1}{a_{22} + a_{21}Z_L}$	$\frac{-\Delta^b}{b_{11} + b_{12}Z_L}$

Δ is the parameter determinant. For example, if x parameters were to be defined, $\Delta^x = x_{11}x_{22} - x_{12}x_{21}$.