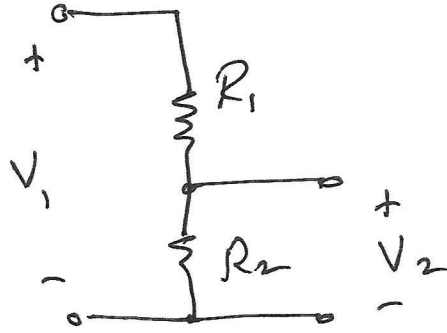
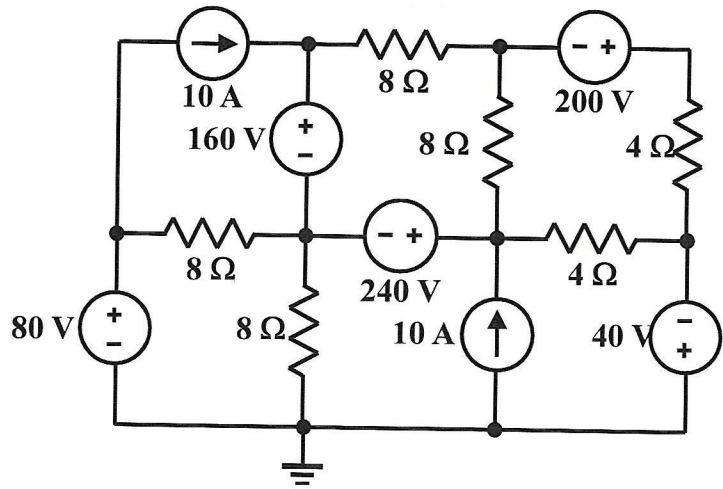


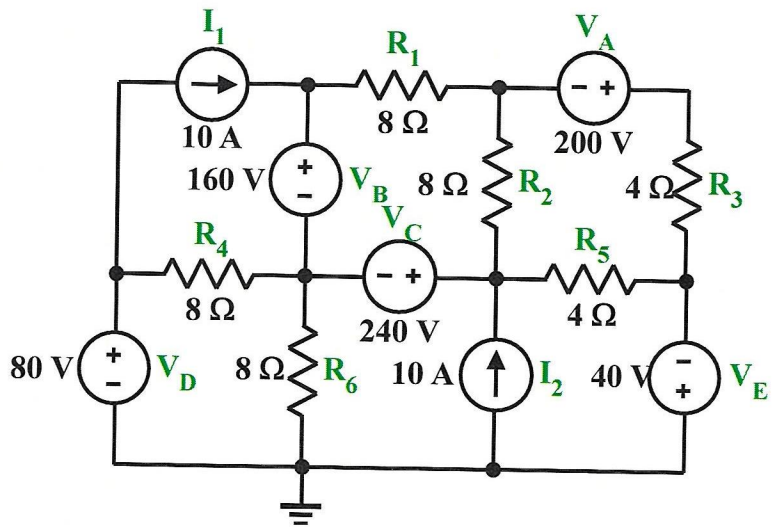
Symbolic Circuit Analysis with MATLAB (SCAM)



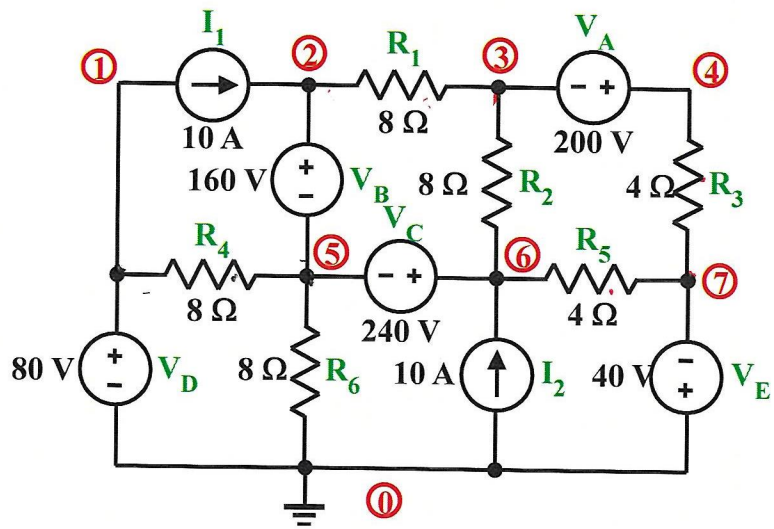
$$\frac{V_2}{V_1} = \frac{R_2}{R_1 + R_2}$$



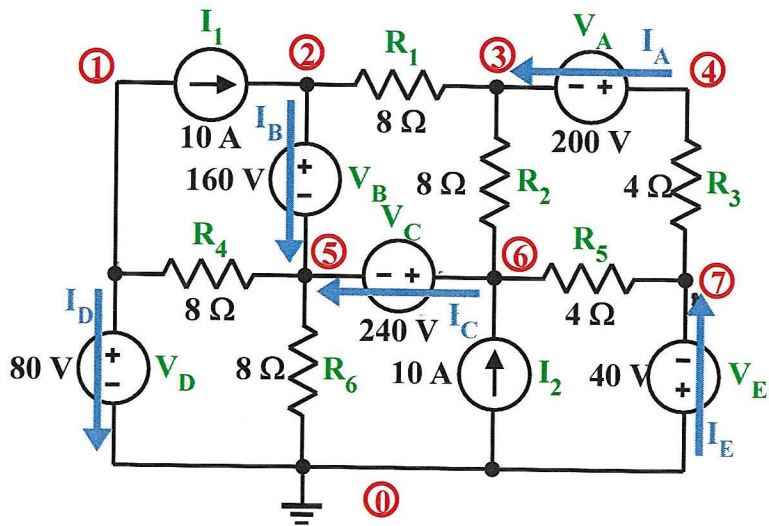
Label components



Label nodes



Define voltage-source currents (must satisfy the PSC)



Write KCL at each node (except the reference node), with independent current sources on the rhs

$$\text{Node 1: } \frac{V_1 - V_5}{R_4} + I_D = -I_1$$

$$\text{Node 2: } \frac{V_2 - V_3}{R_1} + I_B = I_1$$

$$\text{Node 3: } \frac{V_3 - V_2}{R_1} + \frac{V_3 - V_6}{R_2} - I_A = 0$$

$$\text{Node 4: } I_A + \frac{V_4 - V_7}{R_3} = 0$$

$$\text{Node 5: } -I_B + \frac{V_5 - V_1}{R_4} + \frac{V_5}{R_6} - I_C = 0$$

$$\text{Node 6: } I_C + \frac{V_6 - V_3}{R_2} + \frac{V_6 - V_7}{R_5} = I_2$$

$$\text{Node 7: } \frac{V_7 - V_4}{R_3} + \frac{V_7 - V_6}{R_5} - I_E = 0$$

$$\text{Node 0: } -I_D - \frac{V_5}{R_6} + I_E = -I_2 \quad \text{this is redundant}$$

Write constraint equation for each voltage source

$$V_A: \quad \overset{\curvearrowright}{V_3 - V_4} = V_A \quad \times$$

$$V_B: \quad V_2 - V_5 = V_B$$

$$V_C: \quad V_6 - V_5 = V_C$$

$$V_D: \quad V_1 = V_D$$

$$V_E: \quad -V_7 = V_E$$

	V_1	V_2	V_3	V_4	V_5	V_6	V_7	I_A	I_B	I_C	I_D	I_E
N_1	$\frac{1}{R_4}$				$-\frac{1}{R_4}$						1	
N_2		$\frac{1}{R_1}$	$-\frac{1}{R_1}$						1			
N_3		$-\frac{1}{R_1}$	$\frac{1}{R_1}$	$\frac{1}{R_2}$		$-\frac{1}{R_2}$		-1				
N_4				$\frac{1}{R_3}$			$-\frac{1}{R_3}$	1				
N_5	$-\frac{1}{R_4}$				$\frac{1}{R_2} + \frac{1}{R_2}$				-1	-1		
N_6			$-\frac{1}{R_2}$			$\frac{1}{R_2} + \frac{1}{R_5}$	$-\frac{1}{R_5}$			1		
N_7				$-\frac{1}{R_3}$		$-\frac{1}{R_5}$	$\frac{1}{R_3} + \frac{1}{R_5}$					-1
V_A			-1	1								
V_B		1			-1							
V_C					-1	1						
V_D	1											
V_E							-1					

×

V_1
V_2
V_3
V_4
V_5
V_6
V_7
I_A
I_B
I_C
I_D
I_E

=

$-I_1$
I_1
0
0
0
I_2
0
V_A
V_B
V_C
V_D
V_E

A

```
>> fname="My_Example.cir";
>> ISU_scam
```

Started -- please be patient.

Netlist:

```
I1 1 2 10
R1 2 3 8
VA 4 3 200
VB 2 5 160
R2 3 6 8
R3 4 7 4
R4 1 5 8
VC 6 5 240
R5 6 7 4
VD 1 0 80
R6 5 0 8
I2 0 6 10
VE 0 7 40
```

The A matrix:

```
[ 1/R4,      0,      0,      0,      -1/R4,      0,      0,      0,      0,      0,      1,      0]
[      0,  1/R1,      -1/R1,      0,      0,      0,      0,      0,      1,      0,      0,      0]
[      0, -1/R1, 1/R1 + 1/R2,      0,      0,      0,      -1/R2,      0,      -1,      0,      0,      0]
[      0,      0,      0,  1/R3,      0,      0,      0,      -1/R3,      1,      0,      0,      0]
[-1/R4,      0,      0,      0, 1/R4 + 1/R6,      0,      0,      0,      0,      -1,      -1,      0]
[      0,      0,      -1/R2,      0,      0, 1/R2 + 1/R5,      -1/R5,      0,      0,      1,      0,      0]
[      0,      0,      0, -1/R3,      0,      0,      -1/R5, 1/R3 + 1/R5,      0,      0,      0,      -1]
[      0,      0,      -1,      1,      0,      0,      0,      0,      0,      0,      0,      0]
[      0,      1,      0,      0,      -1,      0,      0,      0,      0,      0,      0,      0]
[      0,      0,      0,      0,      -1,      1,      0,      0,      0,      0,      0,      0]
[      1,      0,      0,      0,      0,      0,      0,      0,      0,      0,      0,      0]
[      0,      0,      0,      0,      0,      0,      0,      0,      -1,      0,      0,      0]
```

The x vector:

```
v_1
```

v_2
 v_3
 v_4
 v_5
 v_6
 v_7
 I_VA
 I_VB
 I_VC
 I_VD
 I_VE

The z vector:

-I1
 I1
 0
 0
 0
 I2
 0
 VA
 VB
 VC
 VD
 VE

The matrix equation:

$$\begin{aligned}
 I_{VD} + v_1/R4 - v_5/R4 &== -I1 \\
 I_{VB} + v_2/R1 - v_3/R1 &== I1 \\
 v_3*(1/R1 + 1/R2) - v_2/R1 - v_6/R2 - I_{VA} &== 0 \\
 I_{VA} + v_4/R3 - v_7/R3 &== 0 \\
 v_5*(1/R4 + 1/R6) - I_{VC} - v_1/R4 - I_{VB} &== 0 \\
 I_{VC} - v_3/R2 - v_7/R5 + v_6*(1/R2 + 1/R5) &== I2 \\
 v_7*(1/R3 + 1/R5) - v_4/R3 - v_6/R5 - I_{VE} &== 0 \\
 v_4 - v_3 &== VA
 \end{aligned}$$

$$\begin{aligned}
v_2 - v_5 &== VB \\
v_6 - v_5 &== VC \\
v_1 &== VD \\
-v_7 &== VE
\end{aligned}$$

The solution:

$$v_1 == VD$$

$$\begin{aligned}
v_2 == & (R1*R2*R4*R5*VB - R2*R4*R5*R6*VA - R1*R4*R5*R6*VA + R1*R2*R4*R6*VB + R1*R3*R4*R5*VB + R1*R2*R5*R6*VB \\
& + R1*R3*R4*R6*VB + R2*R3*R4*R5*VB + R1*R3*R5*R6*VB + R2*R3*R4*R6*VB + R1*R4*R5*R6*VB + R2*R3*R5*R6*VB - \\
& R1*R2*R4*R6*VC - R1*R3*R4*R6*VC - R2*R3*R4*R6*VC - R1*R4*R5*R6*VC + R1*R2*R5*R6*VD + R1*R3*R5*R6*VD + \\
& R2*R3*R5*R6*VD - R1*R2*R4*R6*VE - R1*R3*R4*R6*VE - R2*R3*R4*R6*VE - R1*R4*R5*R6*VE - R2*R4*R5*R6*VE + \\
& I1*R1*R2*R4*R5*R6 + I1*R1*R3*R4*R5*R6 + I2*R1*R2*R4*R5*R6 + I1*R2*R3*R4*R5*R6 + I2*R1*R3*R4*R5*R6 + \\
& I2*R2*R3*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + \\
& R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)
\end{aligned}$$

$$\begin{aligned}
v_3 == & -(R1*R2*R4*R5*VA + R1*R2*R4*R6*VA + R1*R2*R5*R6*VA + R1*R4*R5*R6*VA + R2*R4*R5*R6*VA - R2*R3*R4*R5*VB \\
& - R2*R3*R4*R6*VB - R2*R3*R5*R6*VB - R1*R3*R4*R5*VC - R1*R3*R5*R6*VC + R2*R3*R4*R6*VC - R1*R3*R5*R6*VD - \\
& R2*R3*R5*R6*VD + R1*R2*R4*R5*VE + R1*R2*R4*R6*VE + R1*R2*R5*R6*VE + R1*R3*R4*R6*VE + R2*R3*R4*R6*VE + \\
& R1*R4*R5*R6*VE + R2*R4*R5*R6*VE - I1*R1*R3*R4*R5*R6 - I1*R2*R3*R4*R5*R6 - I2*R1*R3*R4*R5*R6 - \\
& I2*R2*R3*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + \\
& R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)
\end{aligned}$$

$$\begin{aligned}
v_4 == & (R1*R3*R4*R5*VA + R1*R3*R4*R6*VA + R2*R3*R4*R5*VA + R1*R3*R5*R6*VA + R2*R3*R4*R6*VA + R2*R3*R5*R6*VA \\
& + R2*R3*R4*R5*VB + R2*R3*R4*R6*VB + R2*R3*R5*R6*VB + R1*R3*R4*R5*VC + R1*R3*R5*R6*VC - R2*R3*R4*R6*VC + \\
& R1*R3*R5*R6*VD + R2*R3*R5*R6*VD - R1*R2*R4*R5*VE - R1*R2*R4*R6*VE - R1*R2*R5*R6*VE - R1*R3*R4*R6*VE - \\
& R2*R3*R4*R6*VE - R1*R4*R5*R6*VE - R2*R4*R5*R6*VE + I1*R1*R3*R4*R5*R6 + I1*R2*R3*R4*R5*R6 + I2*R1*R3*R4*R5*R6 \\
& + I2*R2*R3*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + \\
& R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)
\end{aligned}$$

$$\begin{aligned}
v_5 == & -(R6*(R1*R4*R5*VA + R2*R4*R5*VA + R2*R4*R5*VB + R1*R2*R4*VC + R1*R3*R4*VC + R2*R3*R4*VC + R1*R4*R5*VC \\
& - R1*R2*R5*VD - R1*R3*R5*VD - R2*R3*R5*VD + R1*R2*R4*VE + R1*R3*R4*VE + R2*R3*R4*VE + R1*R4*R5*VE + \\
& R2*R4*R5*VE - I1*R1*R2*R4*R5 - I1*R1*R3*R4*R5 - I2*R1*R2*R4*R5 - I1*R2*R3*R4*R5 - I2*R1*R3*R4*R5 - \\
& I2*R2*R3*R4*R5))/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + \\
& R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)
\end{aligned}$$

$$v_6 == (R1*R2*R4*R5*VC - R2*R4*R5*R6*VA - R2*R4*R5*R6*VB - R1*R4*R5*R6*VA + R1*R3*R4*R5*VC + R1*R2*R5*R6*VC + R2*R3*R4*R5*VC + R1*R3*R5*R6*VC + R2*R3*R5*R6*VC + R2*R4*R5*R6*VC + R1*R2*R5*R6*VD + R1*R3*R5*R6*VD + R2*R3*R5*R6*VD - R1*R2*R4*R6*VE - R1*R3*R4*R6*VE - R2*R3*R4*R6*VE - R1*R4*R5*R6*VE - R2*R4*R5*R6*VE + I1*R1*R2*R4*R5*R6 + I1*R1*R3*R4*R5*R6 + I2*R1*R2*R4*R5*R6 + I1*R2*R3*R4*R5*R6 + I2*R1*R3*R4*R5*R6 + I2*R2*R3*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)$$

$$v_7 == -VE$$

$$I_VA == -(R1*R4*R5*VA + R1*R4*R6*VA + R2*R4*R5*VA + R1*R5*R6*VA + R2*R4*R6*VA + R2*R5*R6*VA + R2*R4*R5*VB + R2*R4*R6*VB + R2*R5*R6*VB + R1*R4*R5*VC + R1*R5*R6*VC - R2*R4*R6*VC + R1*R5*R6*VD + R2*R5*R6*VD + R1*R4*R5*VE + R2*R4*R5*VE + R1*R5*R6*VE + R2*R5*R6*VE + I1*R1*R4*R5*R6 + I1*R2*R4*R5*R6 + I2*R1*R4*R5*R6 + I2*R2*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)$$

$$I_VB == (R2*R4*R6*VC - R2*R4*R6*VA - R2*R5*R6*VA - R2*R4*R5*VB - R2*R4*R6*VB - R3*R4*R5*VB - R2*R5*R6*VB - R3*R4*R6*VB - R3*R5*R6*VB - R4*R5*R6*VB - R2*R4*R5*VA + R3*R4*R5*VC + R3*R4*R6*VC + R3*R5*R6*VC + R4*R5*R6*VC - R2*R5*R6*VD - R2*R4*R5*VE - R2*R5*R6*VE + I1*R1*R2*R4*R5 + I1*R1*R2*R4*R6 + I1*R1*R3*R4*R5 + I1*R1*R2*R5*R6 + I1*R1*R3*R4*R6 + I1*R2*R3*R4*R5 + I1*R1*R3*R5*R6 + I1*R2*R3*R4*R6 + I1*R1*R4*R5*R6 + I1*R2*R3*R5*R6 - I2*R2*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)$$

$$I_VC == -(R1*R4*R5*VA + R1*R5*R6*VA - R2*R4*R6*VA - R2*R4*R6*VB - R3*R4*R5*VB - R3*R4*R6*VB - R3*R5*R6*VB - R4*R5*R6*VB + R1*R2*R4*VC + R1*R3*R4*VC + R1*R2*R6*VC + R2*R3*R4*VC + R1*R3*R6*VC + R1*R4*R5*VC + R2*R3*R6*VC + R1*R5*R6*VC + R2*R4*R6*VC + R3*R4*R5*VC + R3*R4*R6*VC + R3*R5*R6*VC + R4*R5*R6*VC + R1*R2*R6*VD + R1*R3*R6*VD + R2*R3*R6*VD + R1*R5*R6*VD + R1*R2*R4*VE + R1*R3*R4*VE + R1*R2*R6*VE + R2*R3*R4*VE + R1*R3*R6*VE + R1*R4*R5*VE + R2*R3*R6*VE + R1*R5*R6*VE + I1*R1*R2*R4*R6 - I2*R1*R2*R4*R5 + I1*R1*R3*R4*R6 - I2*R1*R3*R4*R5 + I1*R2*R3*R4*R6 - I2*R2*R3*R4*R5 + I1*R1*R4*R5*R6 - I2*R1*R3*R5*R6 - I2*R2*R3*R5*R6 - I2*R2*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)$$

$$I_VD == -(R1*R5*R6*VA + R2*R5*R6*VA + R2*R5*R6*VB + R1*R2*R6*VC + R1*R3*R6*VC + R2*R3*R6*VC + R1*R5*R6*VC + R1*R2*R5*VD + R1*R2*R6*VD + R1*R3*R5*VD + R1*R3*R6*VD + R2*R3*R5*VD + R2*R3*R6*VD + R1*R5*R6*VD + R2*R5*R6*VD + R1*R2*R6*VE + R1*R3*R6*VE + R2*R3*R6*VE + R1*R5*R6*VE + R2*R5*R6*VE + I1*R1*R2*R4*R5 + I1*R1*R2*R4*R6 + I1*R1*R3*R4*R5 + I1*R1*R3*R4*R6 + I1*R2*R3*R4*R5 + I1*R2*R3*R4*R6 - I2*R1*R2*R5*R6 + I1*R1*R4*R5*R6 - I2*R1*R3*R5*R6 + I1*R2*R4*R5*R6 - I2*R2*R3*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5$$

+ R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)

I_VE == -(R1*R4*R5*VA + R2*R4*R5*VA + R1*R5*R6*VA + R2*R5*R6*VA + R2*R4*R5*VB + R2*R5*R6*VB + R1*R2*R4*VC + R1*R3*R4*VC + R1*R2*R6*VC + R2*R3*R4*VC + R1*R3*R6*VC + R1*R4*R5*VC + R2*R3*R6*VC + R1*R5*R6*VC + R1*R2*R6*VD + R1*R3*R6*VD + R2*R3*R6*VD + R1*R5*R6*VD + R2*R5*R6*VD + R1*R2*R4*VE + R1*R3*R4*VE + R1*R2*R6*VE + R2*R3*R4*VE + R1*R3*R6*VE + R1*R4*R5*VE + R2*R3*R6*VE + R2*R4*R5*VE + R1*R5*R6*VE + R2*R5*R6*VE + I1*R1*R2*R4*R6 + I1*R1*R3*R4*R6 + I2*R1*R2*R4*R6 + I1*R2*R3*R4*R6 + I2*R1*R3*R4*R6 + I1*R1*R4*R5*R6 + I2*R2*R3*R4*R6 + I1*R2*R4*R5*R6 + I2*R1*R4*R5*R6 + I2*R2*R4*R5*R6)/(R1*R2*R4*R5 + R1*R2*R4*R6 + R1*R3*R4*R5 + R1*R2*R5*R6 + R1*R3*R4*R6 + R2*R3*R4*R5 + R1*R3*R5*R6 + R2*R3*R4*R6 + R1*R4*R5*R6 + R2*R3*R5*R6 + R2*R4*R5*R6)

Elapsed time is 4.00561 seconds.

>> eval(z)

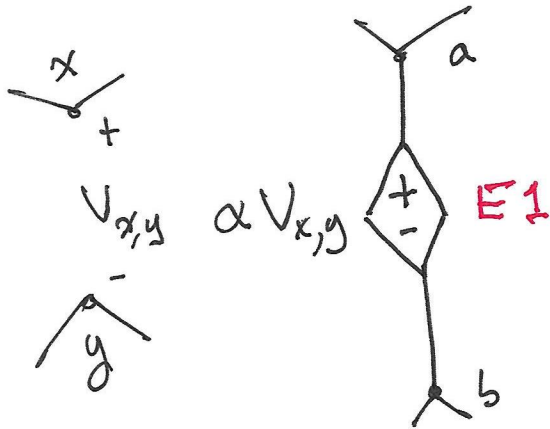
>> eval(v-1)

↑
lower case

simplify(v-1)

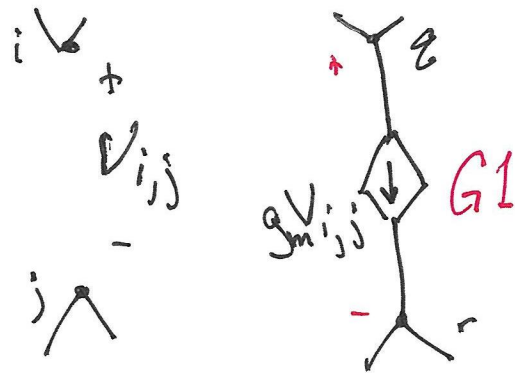
Controlled Sources

VCVS



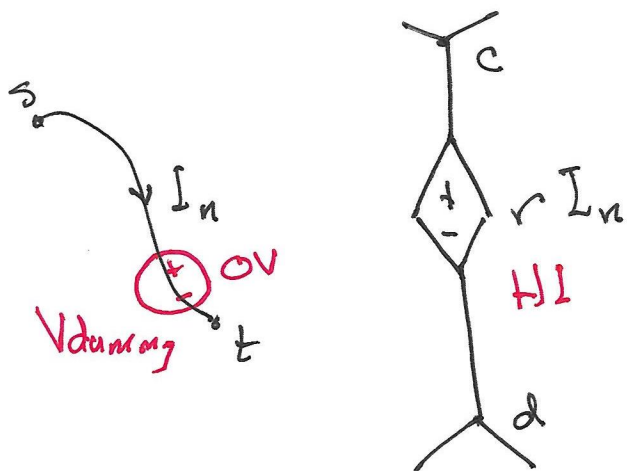
$E1 \quad a \quad b \quad x \quad y \quad \propto$

VCCS



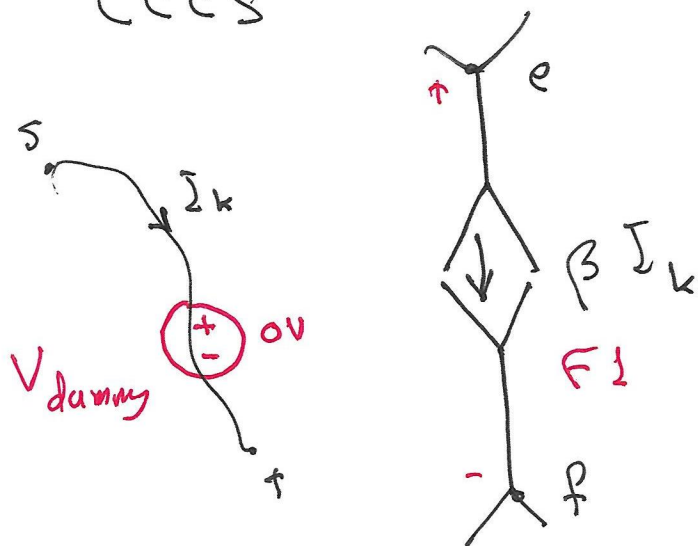
$G1 \quad z \quad r \quad i \quad j \quad g_m$

CCVS



H1	c	d	Vdummy	r
Vdummy	s	t	DC	0

CCCS



F1	e	f	Vdummy	beta
Vdummy	s	t	DC	0