

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING: A CONVERSATIONAL APPROACH

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The engineering workflow you will use throughout this book

CHAPTER - 8

PART 4 · ≈ 35 MIN

When the System Changes and Grows

Change one resistor and test the prediction you made in Part 1. Then add a third unknown node. The model changes, the matrix grows — and the engineering workflow, and the MATLAB command, stay the same.

4

Problem

›

Model

›

Compute

›

Analyze

›

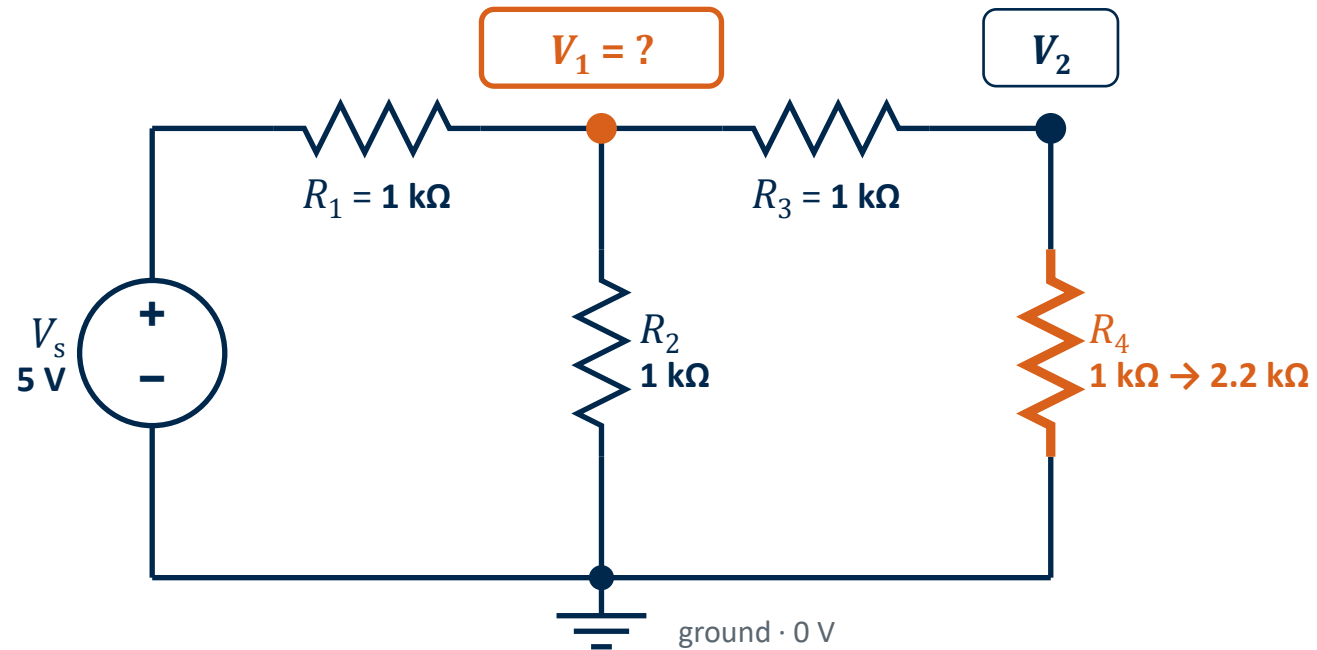
Validate

›

Improve



PREDICT



If R_4 increases from $1\text{ k}\Omega$ to $2.2\text{ k}\Omega$, what happens to V_1 ?

- A V_1 increases
- B V_1 decreases
- C V_1 stays the same

Find the answer you wrote in Part 1. Keep it, or change it now — with a reason. You now know Parts 2 and 3.

Part 1, slide 9 — the same question. R_4 still does not touch node V_1 .

Commit one more time. Then we let the model answer.

Problem



Model



Compute



Analyze



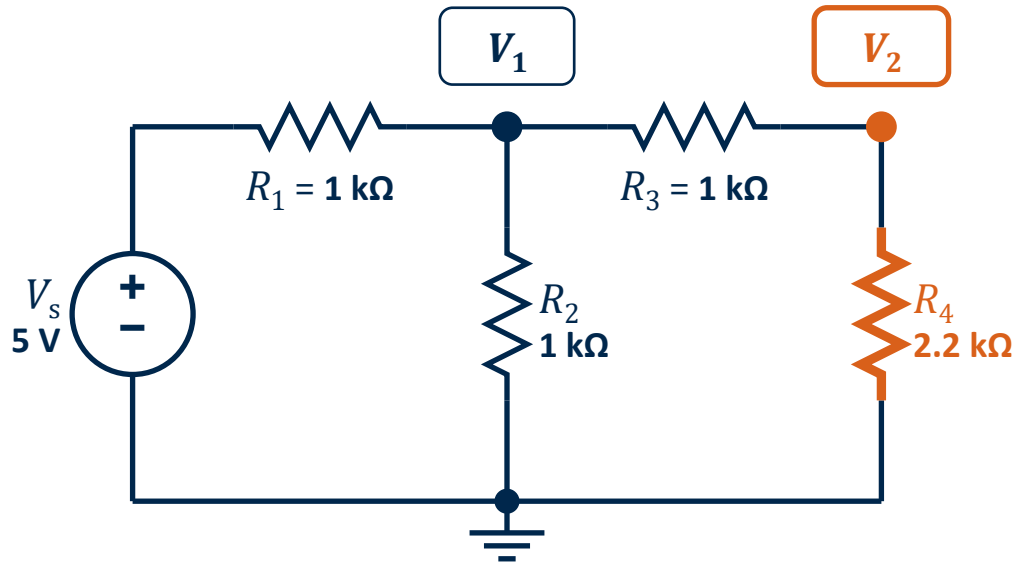
Validate



Improve



One physical change, one matrix change



SYMBOLIC (Part 2)

$$\begin{bmatrix} 1/R_1 + 1/R_2 + 1/R_3 & -1/R_3 \\ -1/R_3 & \boxed{1/R_3 + 1/R_4} \end{bmatrix}$$

NUMERICAL (mS)

$$\begin{bmatrix} 3 & -1 \\ -1 & 2 \end{bmatrix} \rightarrow \begin{bmatrix} 3 & -1 \\ -1 & \boxed{1.4545} \end{bmatrix}$$

ASK THE ROOM

Only one number in A changed. Can BOTH voltages still change? Why?

$$a_{22} = 1/R_3 + 1/R_4 = 1/1 + 1/2.2 = 1 + 0.4545 = \mathbf{1.4545 \text{ mS}}$$

R4 touches only V2 and ground: it sits in V2's diagonal entry and nowhere else. b is unchanged.

Change a resistor, change its conductance entries — and only those.

Problem



Model



Compute



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Improve



Predict, then compute

```
% R4 = 2.2 kOhm: only a22 changes  
A = [3 -1; -1 1 + 1/2.2];  
b = [5; 0];  
V = A\b
```

COMMAND WINDOW

```
V =  
    2.1622  
    1.4865
```

Same command as Part 3. Only one number in A was edited.

REVIEW NOTE Resistance vs conductance

$G = 1/R$: 1 k $\Omega \rightarrow$ 1 mS, 2.2 k $\Omega \rightarrow$ 0.4545 mS. More resistance, less conductance.

THE MODEL'S ANSWER

$$V_1 = 2.1622 \text{ V}$$

$$V_2 = 1.4865 \text{ V}$$

Part 1 prediction: **A** — **V1 increases**, even though R4 never touches V1.

CHECK YOUR REASON

Was your reason about R4 and V2, about coupling through R3 — or a guess? The next two slides test the reasoning.

The coupled model says V1 rises. Nothing touched V1 — the change arrived through R3.

Problem



Model



Compute



Analyze



Validate



Improve



How much did each node respond?

Node	Original (R4 = 1 kΩ)	Modified (R4 = 2.2 kΩ)	Change	% change	RESPONSE
V_1	2.000 V	2.162 V	+0.162 V	+8.1 %	V_1 
V_2	1.000 V	1.486 V	+0.486 V	+48.6 %	V_2 

REVIEW NOTE Percentage change

$(\text{new} - \text{old}) / \text{old} \times 100 \%$

$V_1: 0.162 / 2.000 \approx 8.1 \%$. $V_2: 0.486 / 1.000 \approx 48.6 \%$.

SENSITIVITY — IN WORDS

In this circuit, V_2 responds more strongly to the R_4 change than V_1 . The effect propagates through R_3 , but the response depends on the entire network.

ASK THE ROOM

If V_2 fed a sensor that must stay within $\pm 5 \%$, which node would worry you most when R_4 drifts — and how would you know without the model?

Same change, different responses. The node closest to the change is the most sensitive.

Problem



Model



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Analyze



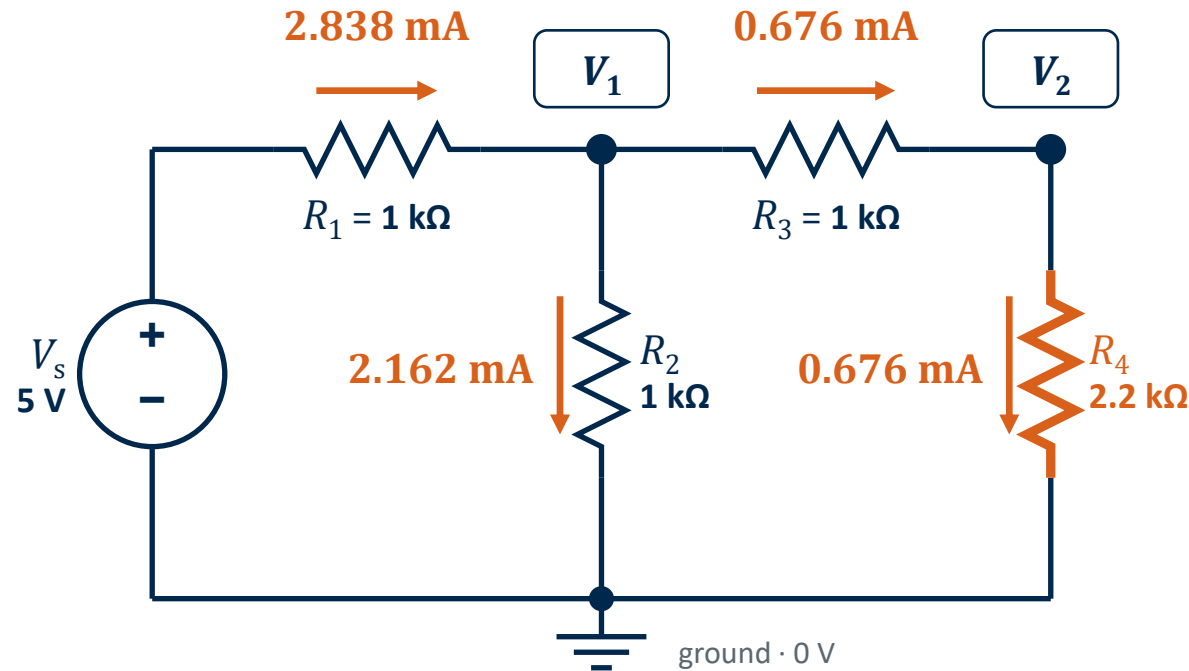
Validate



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Can we explain the change physically?



Actual directions, modified circuit. Values rounded to 3 decimals.

CURRENTS (WAS → NOW)

$$V_1 = 2.162 \text{ V} \quad V_2 = 1.486 \text{ V}$$

$$R_1: 3 \rightarrow 2.838 \text{ mA}$$

$$R_2: 2 \rightarrow 2.162 \text{ mA}$$

$$R_3: 1 \rightarrow 0.676 \text{ mA}$$

$$R_4: 1 \rightarrow 0.676 \text{ mA}$$

CONSERVATION STILL HOLDS

$$\text{At } V_1: 2.838 \text{ in} = 2.162 + 0.676 \text{ out} \quad \checkmark$$

$$\text{At } V_2: 0.676 \text{ in} = 0.676 \text{ out} \quad \checkmark$$

Less current drawn from V2 → V2 rises → less current leaves V1 through R3 → V1 rises.

Bigger R4 draws less current from V2. V2 rises, R3 carries less, and V1 rises too — coupling at work.

Problem



Model



Compute

**Analyze**

Validate



Improve



What if we had to try ten resistors?

OPTIONAL

```
R4 = [0.5 1 2.2 4.7 10]; % kOhm

fprintf('R4 (kOhm)  V1 (V)  V2 (V) \n');

for k = 1:numel(R4)
    A = [3 -1; -1 1 + 1/R4(k)];
    V = A\[5; 0];
    fprintf('%5.1f  %6.3f  %6.3f\n', R4(k), V)
end
```

OUTPUT R4 (kΩ) V1 (V) V2 (V)

0.5	1.875	0.625	4.7	2.298	1.895
1.0	2.000	1.000	10.0	2.391	2.174
2.2	2.162	1.486			

WHY THIS MATTERS

By hand: one elimination per value. With a verified computational implementation, we can predict five alternatives quickly. Physical validation remains a separate step.

The trust comes first: R4 = 1 kΩ must reproduce 2 V and 1 V.

AI CAN DRAFT THE LOOP

THINK → PSEUDOCODE → AI → CODE. Ask AI for the sweep only after you know what it should do — then check the 1 kΩ row, the units and the trend yourself.

A trusted model turns one answer into a design study. Verify it on a case you know before you sweep.

Problem



Model



Compute



Analyze



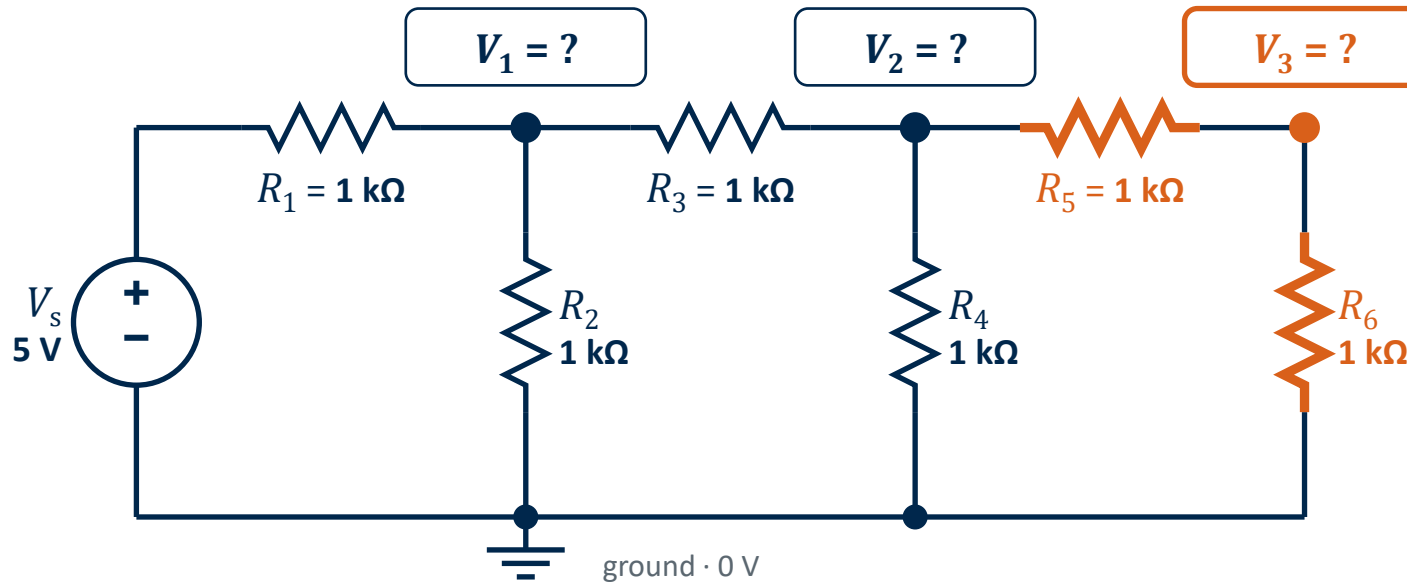
Validate



Improve



What if the circuit had another unknown?



COUNT FIRST

3 unknown node voltages

→ 3 node balances

→ 3 independent equations

ASK THE ROOM

Before writing anything: which unknown nodes does V1 connect to directly? How many nonzero entries will row 1 have?

Same source and R1–R4. New: R5 from V2 to V3, R6 from V3 to ground. A conceptual schematic — not a wiring diagram.

A bigger system needs more equations — one balance for every unknown node, built exactly as before.

Problem

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The same physics builds a larger matrix

$$\begin{bmatrix}
 G_1 + G_2 + G_3 & -G_3 & 0 \\
 -G_3 & G_3 + G_4 + G_5 & -G_5 \\
 0 & -G_5 & G_5 + G_6
 \end{bmatrix}
 \begin{bmatrix}
 V_1 \\
 V_2 \\
 V_3
 \end{bmatrix}
 =
 \begin{bmatrix}
 G_1 V_s \\
 0 \\
 0
 \end{bmatrix}
 \quad G_i = 1/R_i \text{ in mS}$$

SAME RULES

Diagonal: all conductances touching the node.

Off-diagonal: minus the conductance joining two unknown nodes.

b: the source enters only at V1.

REVIEW NOTE Zeros

$a_{13} = a_{31} = 0$: no resistor joins V1 and V3. They still influence each other — but only through V2.

REVIEW NOTE Dimensions

3 unknowns $\rightarrow$ A is 3×3 (rows $\times$ columns); x and b are 3×1 column vectors. One row per node, one column per unknown.

The matrix still mirrors the circuit: where there is no resistor, there is a zero.

Problem



Model



Compute



Analyze



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Improve



A larger system, the same MATLAB command

$$\begin{bmatrix} 3 & -1 & 0 \\ -1 & 3 & -1 \\ 0 & -1 & 2 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} 5 \\ 0 \\ 0 \end{bmatrix}$$

A in mS
V in V
b in mA

PREDICTED NODE VOLTAGES

$$V_1 = 25/13 \approx 1.9231 \text{ V}$$

$$V_2 = 10/13 \approx 0.7692 \text{ V}$$

$$V_3 = 5/13 \approx 0.3846 \text{ V}$$

```
A = [3 -1 0; -1 3 -1; 0 -1 2];
b = [5; 0; 0];
```

```
v = A\b
r = A*v - b
```

VERIFY BY SUBSTITUTION (× 1/13)

Row 1: $3(25) - 10 = 65 \rightarrow 65/13 = 5 \checkmark$

Row 2: $-25 + 3(10) - 5 = 0 \checkmark$ Row 3: $-10 + 2(5) = 0 \checkmark$

REVIEW NOTE 3 × 3 MATLAB syntax

Spaces separate entries; ; separates rows. A 3 × 3 A needs a 3 × 1 b.

The system grew; the command did not. $V = A \backslash b$, then $r = A * V - b$: residual ≈ 0 mA (verification only).

Problem



Model

**Compute**

Analyze



Validate



Improve



From prediction to experiment

BUILD THE 2-NODE
NETWORK



MEASURE NODE
VOLTAGES



EXTEND TO 3 NODES



MEASURE AGAIN



COMPARE WITH
MATLAB

YOU WILL USE

real resistors · a breadboard · a battery-
powered 5 V supply · a digital multimeter

WHAT IS NEW IN THE LAB

measured component values, the real
source voltage, and one circuit that grows
from 1 to 3 unknown nodes

REVIEW NOTE

Predict vs measure

A prediction comes from the model; a
measurement from the real circuit. Expect small
differences.

NEXT — PART 5 · A CORRECT SOLUTION TO THE WRONG MODEL

If MATLAB satisfies our equations but physical measurements disagree, what should we investigate?

The model makes predictions. The lab tests them. Part 5: what to do when they disagree.

Problem



Model



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