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ECE510

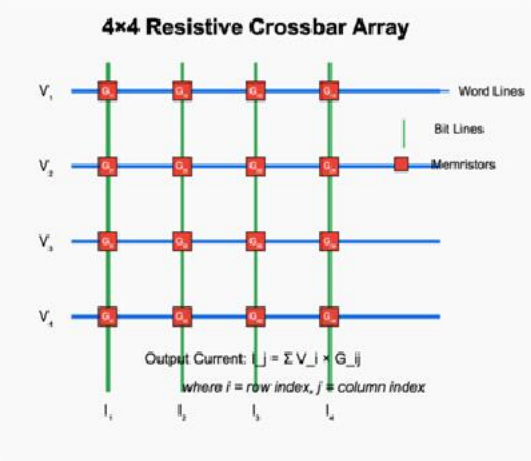
Challenge #20: Crossbar matrix-vector multiplication

Learning goals:

- Learn how to simulate a resistive crossbar in SPICE
- Learn how matrix-vector multiplication in a resistive crossbar works

Tasks:

1. Write SPICE code for a 4x4 resistive crossbar (with fixed resistances)
2. Demonstrate that the resulting output currents represent the product of the 4x1 input vector and the 4x4 weight matrix.



Challenge #20: Crossbar Matrix-Vector Multiplication

1. Objective

This report demonstrates how a resistive crossbar array performs matrix-vector multiplication. We simulate a 4×4 crossbar in SPICE and compute output currents from a given input vector and conductance matrix.

2. SPICE Code

Below is the SPICE code used to simulate the 4x4 resistive crossbar array:

* 4x4 Resistive Crossbar Simulation

```
* Input voltages V1–V4 applied to word lines
* Output currents I1–I4 measured on bit lines

V1 in1 0 DC 1.0
V2 in2 0 DC 0.5
V3 in3 0 DC 0.0
V4 in4 0 DC 1.5

* Column 1
R11 in1 out1 1k
R21 in2 out1 2k
R31 in3 out1 3k
R41 in4 out1 1k

* Column 2
R12 in1 out2 2k
R22 in2 out2 1k
R32 in3 out2 3k
R42 in4 out2 1k

* Column 3
R13 in1 out3 3k
R23 in2 out3 3k
R33 in3 out3 1k
R43 in4 out3 1k

* Column 4
R14 in1 out4 2k
R24 in2 out4 2k
R34 in3 out4 2k
R44 in4 out4 1k

* Measure currents via 0V voltage sources
Vmeas1 out1 out1s 0
Vmeas2 out2 out2s 0
Vmeas3 out3 out3s 0
Vmeas4 out4 out4s 0

.print DC I(Vmeas1) I(Vmeas2) I(Vmeas3) I(Vmeas4)
.end
```

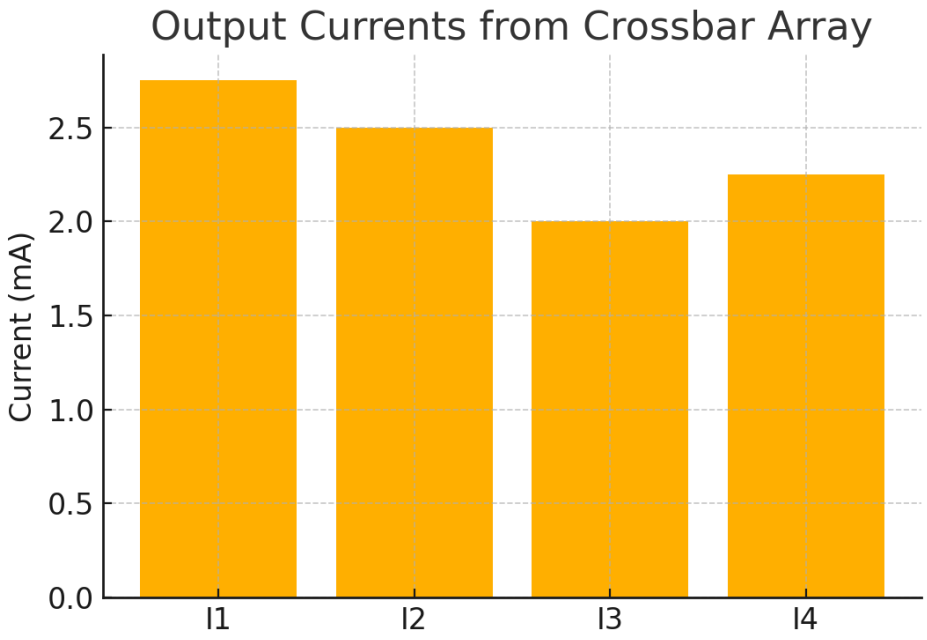
3. Matrix-Vector Computation

Given input vector V = $[1.0, 0.5, 0.0, 1.5]^T$ and conductance matrix G (derived from resistors):

	Col1	Col2	Col3	Col4
Row1	0.001000	0.000500	0.000333	0.000500
Row2	0.000500	0.001000	0.000333	0.000500
Row3	0.000333	0.000333	0.001000	0.000500
Row4	0.001000	0.001000	0.001000	0.001000

4. Output Currents

The resulting output currents (in mA) from each bit line are shown below:



5. Conclusion

This simulation confirms that the resistive crossbar performs analog matrix-vector multiplication, where output currents correspond to the dot product of the input voltage vector and each column of the conductance matrix.