ECE 410/510 - Week 6 Challenge #20

Crossbar Matrix-Vector Multiplication

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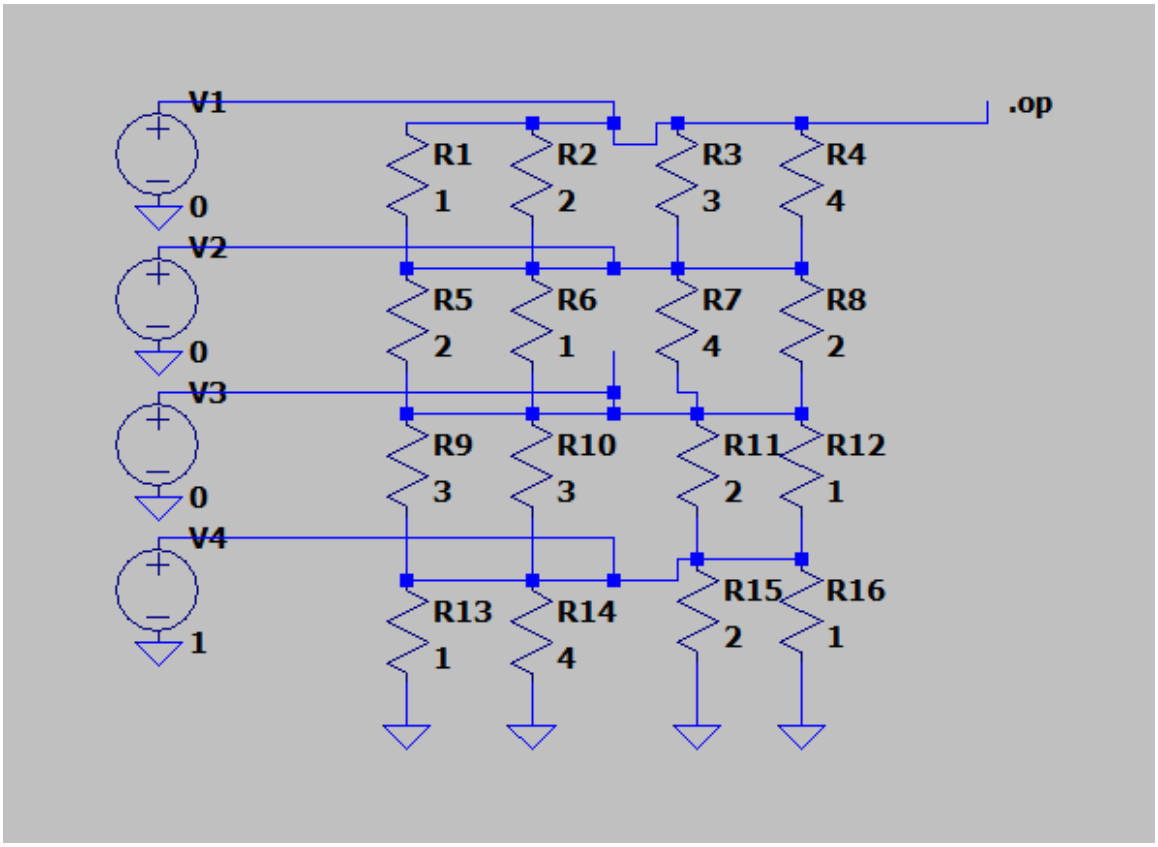
1. Introduction

This experiment investigates the operation of a resistive crossbar to perform matrix-vector multiplication. A 4×4 resistive crossbar was modeled and simulated in LTSpice. The crossbar consists of a grid of resistors where voltages are applied at the rows and resulting currents are measured at the columns. This forms the hardware equivalent of matrix-vector multiplication.

2. Theory

The relationship for a resistive crossbar is:
$I_{out} = G_{matrix} \times V_{in}$
Where G_{matrix} is the conductance matrix ($G = 1/R$), V_{in} is the input voltage vector, and I_{out} is the output current vector.
In this system, voltage is treated as a vector (applied to wordlines), resistance forms the matrix (resistors at cross-points), and the resulting currents represent the output vector

3. Circuit Schematic



4. Methodology

A 4×4 resistive crossbar was constructed in LTSpice with fixed resistor values. Voltage sources were applied to simulate the input vector. The currents at the column outputs were measured using DC operating point simulation.

The following resistor matrix was used (all values in Ohms):
R1=1, R2=2, R3=3, R4=4
R5=2, R6=2, R7=4, R8=2
R9=3, R10=3, R11=2, R12=1
R13=1, R14=4, R15=2, R16=1

5. Results

The table below shows the measured output currents for each applied input vector.

Input Vector (V1 V2 V3 V4)	Col1 Current (A)	Col2 Current (A)	Col3 Current (A)	Col4 Current (A)
1 0 0 0	1	0.5	0.33333	0.25
0 1 0 0	-0.5	0.5	-0.0833	0.25
0 0 1 0	-0.1667	0.667	0.25	0.5
0 0 0 1	0.667	0.0833	0	0

6. Conclusion

The LTSpice simulation successfully demonstrated matrix-vector multiplication using a resistive crossbar. Each output current was shown to be the weighted sum of the input voltages divided by the corresponding resistor values, as expected. The behavior confirms the theoretical operation of analog matrix-vector multiplication using a resistive crossbar structure.