Memristors HW4

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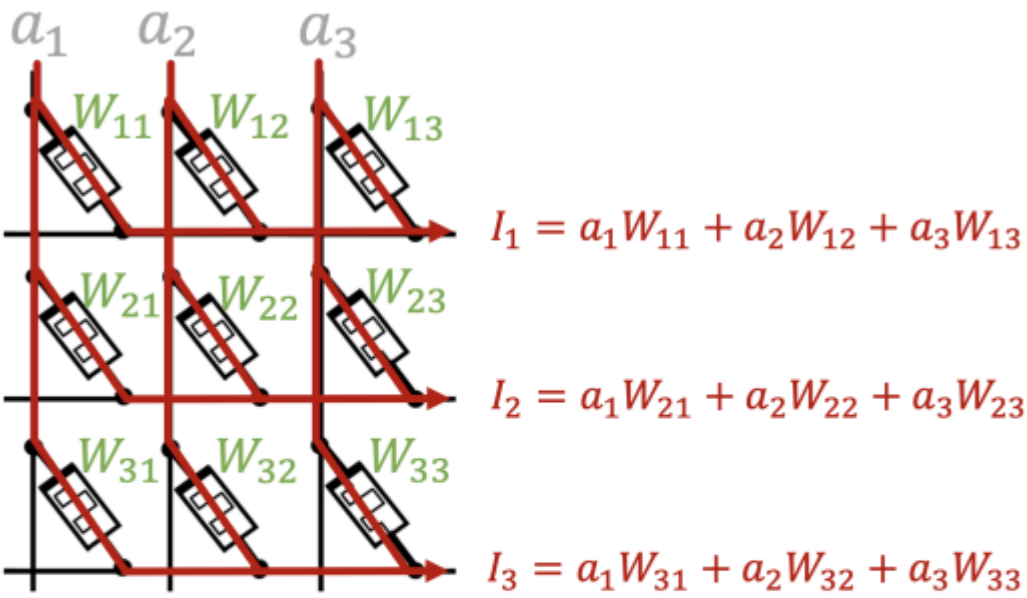
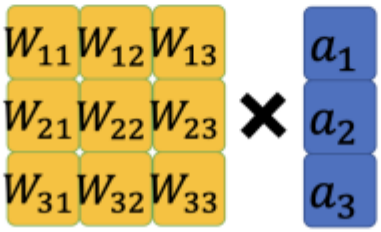
Question 1 – Matrix Multiplication





$$\begin{pmatrix} 1 & 1/2 & 1/3 \\ 1/4 & 1/5 & 1/6 \\ 1/7 & 1/8 & 1/9 \end{pmatrix} \begin{pmatrix} 1.2 \\ 3.3 \\ 5 \end{pmatrix} \approx \begin{pmatrix} 4.52 \\ 1.79 \\ 1.14 \end{pmatrix}$$

Part a

A values are in voltage

R values are in Ohm

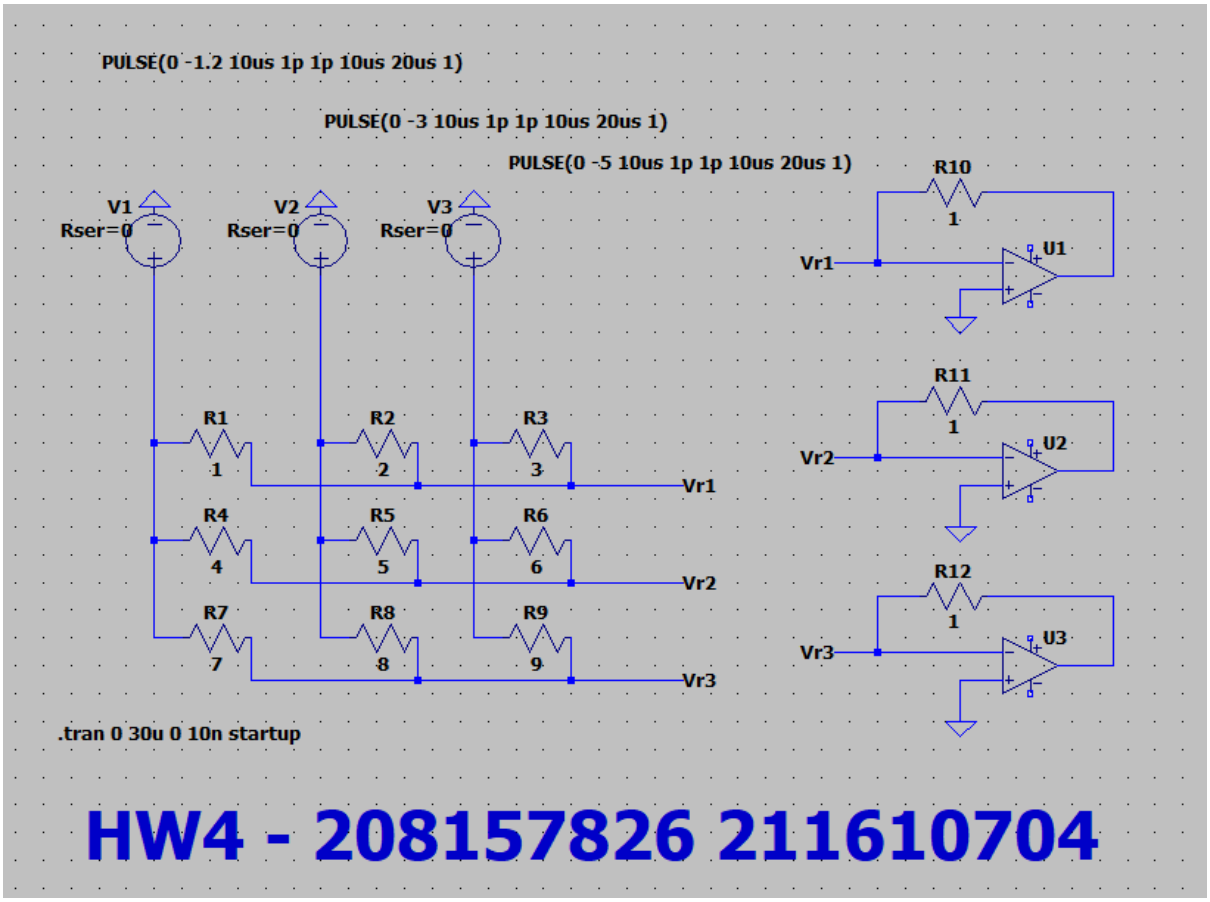
a1 = 1.2, a2 = 3.3, a3 = 5

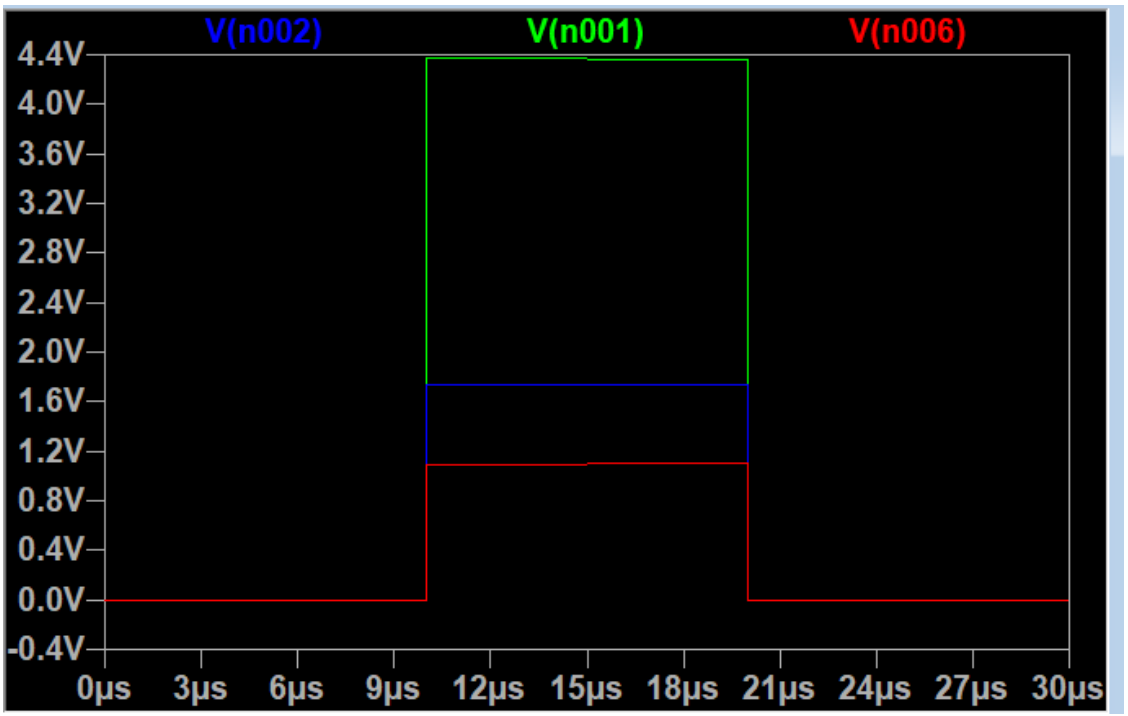
R11 = 1, R12 = 2, R13 = 3

R21 = 4, R22 = 5, R23 = 6

R31 = 7, R32 = 8, R33 = 9

Part b





Green is measured at 4.3666589V and belongs to the first matrix row.

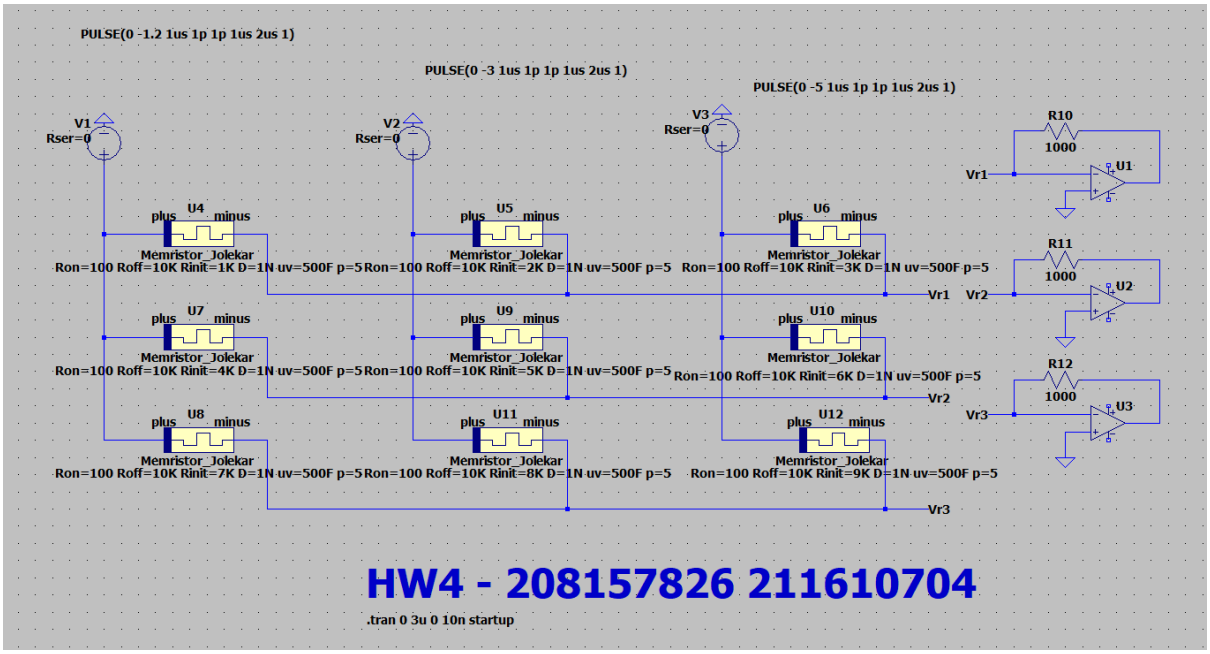
Blue is measured at 1.7333347V and belongs to the second matrix row.

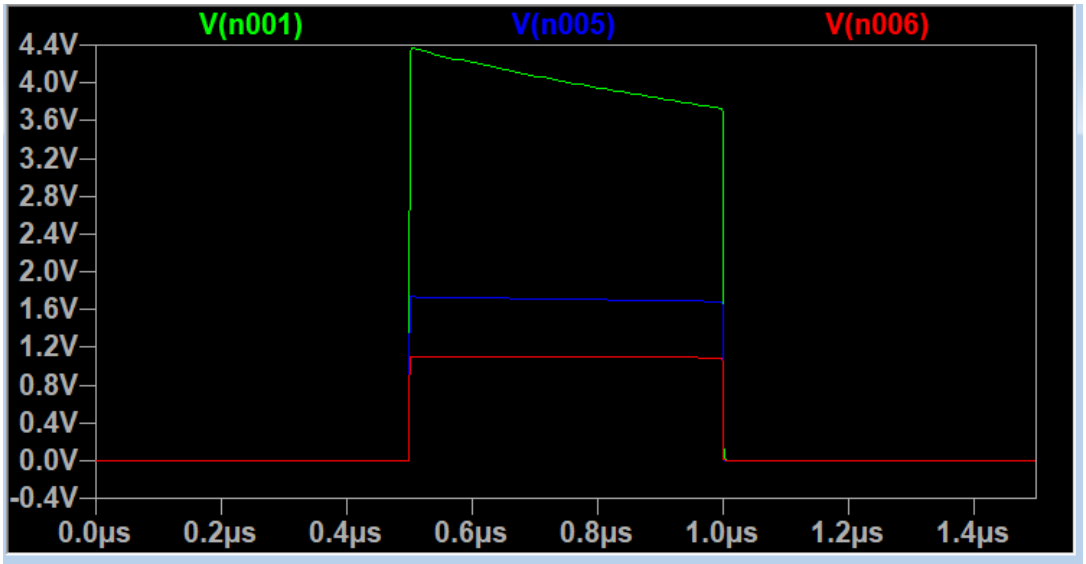
Red is measured at 1.1019849V and belongs to the third matrix row.

Part c

Ass given the voltage measure on the output of each OpAmp is $V_{out} = -Rf * I_{in}$ hence if we raise the resistance on the matrix resistors the current will drop accordingly, but we can compensate on this drop by increasing Rf by the same factor. So before changing the resistance $Rf = 1$ now with the increase in the resistance by a factor of 1000 the new Rf is equal to 1000.

Part d





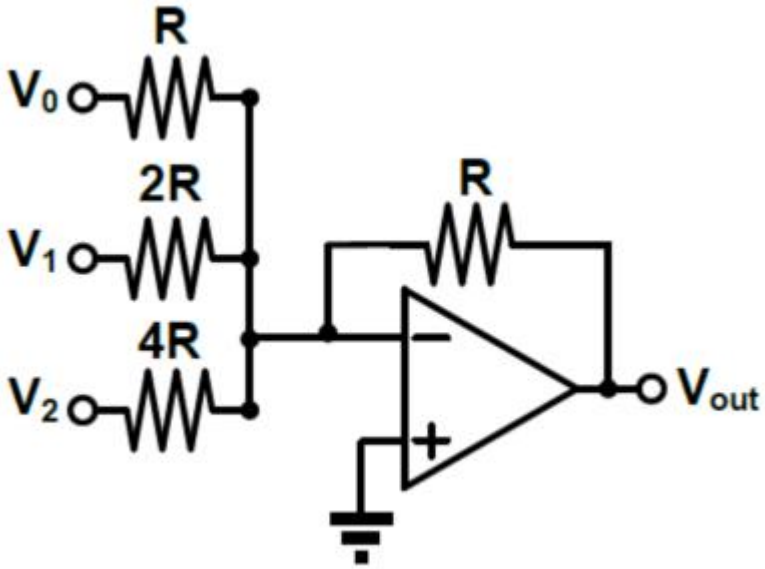
Green is measured at 4.3666589V and belongs to the first matrix row.

Blue is measured at 1.7333347V and belongs to the second matrix row.

Red is measured at 1.1019849V and belongs to the third matrix row.

In the beginning of the pulse denoted as t=0 we get the same results as the matrix with the resistors since the values of the memristors are at their initial value R_init, but over time current flows thru the memristors leading to a change in their memristance hence the circuit stops to behave as the normal resistors matrix, and we see a degradation in the voltage measurements.

Question 2 – Digital to Analog Converter



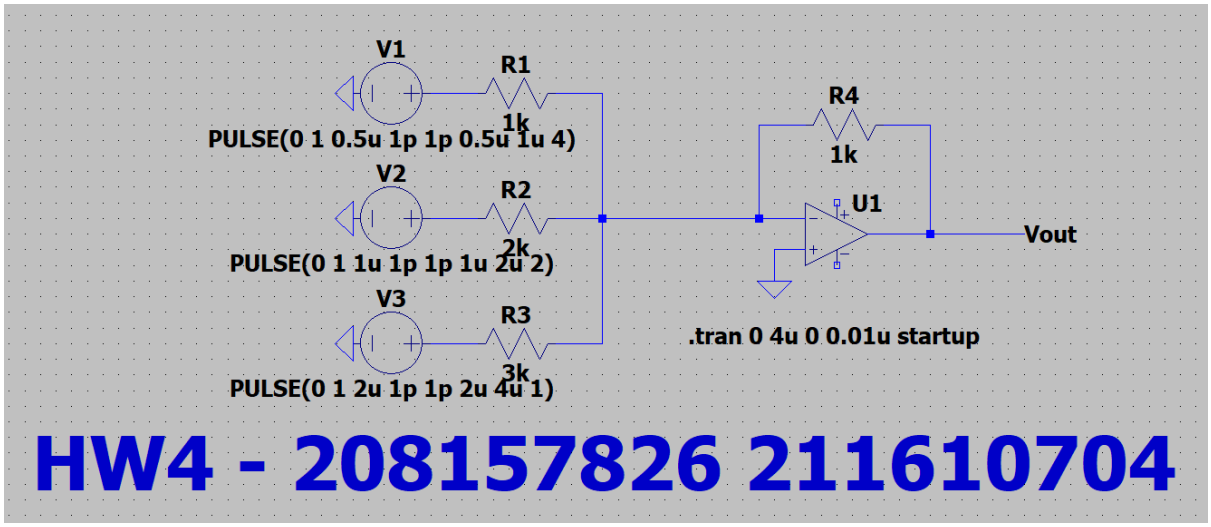
Part a

$$\frac{V_{out}}{R} = -\left(\frac{V_0}{R} + \frac{V_1}{2R} + \frac{V_2}{4R}\right)$$

$$V_{out} = -\left(V_0 + \frac{V_1}{2} + \frac{V_2}{4}\right)$$

the voltage in the negative terminal is Ground since the OpAmp works hard to keep the difference between the pos and neg terminals Zero. Hence the current flowing from V_out is equivalent to the current flowing from the three channels together hence the above derivation gives V_out as a function of V0, V1, and V2

Part b


V1
R1
1k
PULSE(0 1 0.5u 1p 1p 0.5u 1u 4)
V2
R2
2k
PULSE(0 1 1u 1p 1p 1u 2u 2)
V3
R3
3k
PULSE(0 1 2u 1p 1p 2u 4u 1)
R4
1k
U1
Vout
.tran 0 4u 0 0.01u startup
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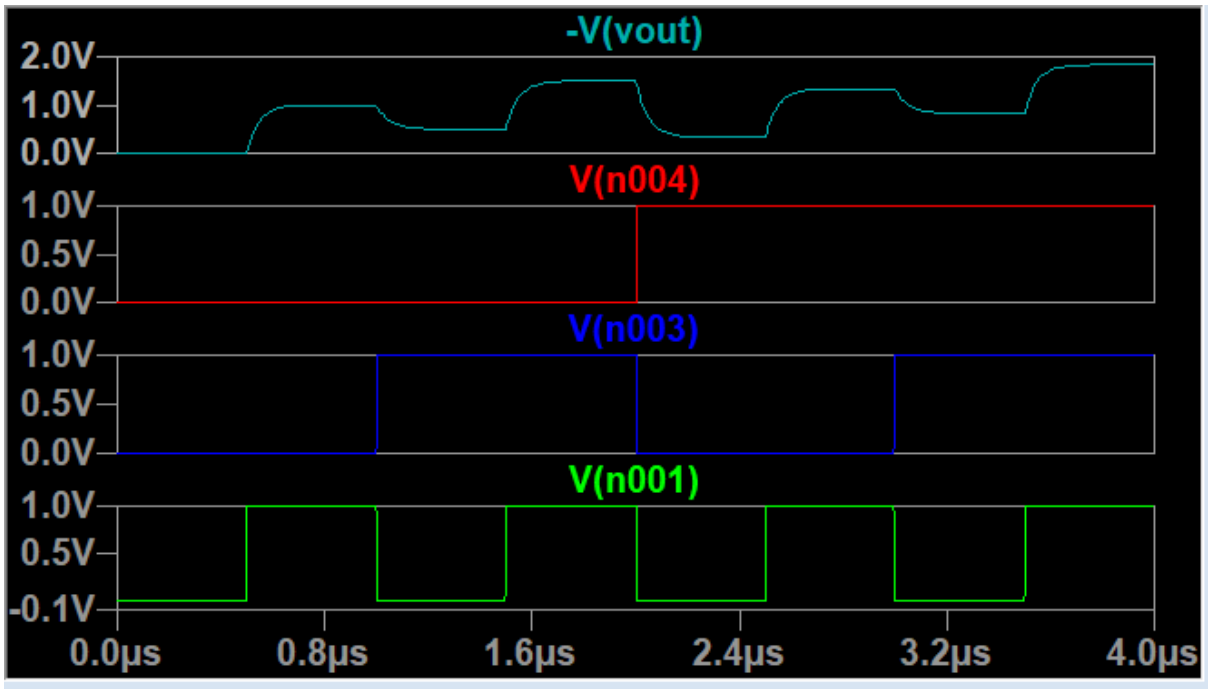
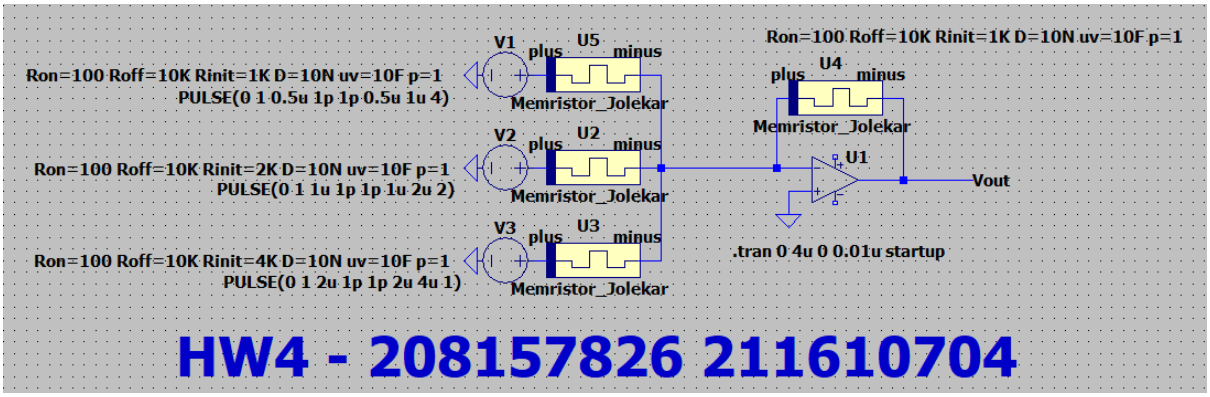

-V(vout)
2.0V
1.0V
0.0V
V(n004)
1.0V
0.5V
0.0V
V(n003)
1.0V
0.5V
0.0V
V(n001)
1.0V
0.5V
-0.1V
0.0µs
0.8µs
1.6µs
2.4µs
3.2µs
4.0µs

Part c


Ron=100 Roff=10K Rinit=1K D=10N uv=10F p=1
PULSE(0 1 0.5u 1p 1p 0.5u 1u 4)
V1
plus
U5
minus
Memristor_Jolekar
Ron=100 Roff=10K Rinit=2K D=10N uv=10F p=1
PULSE(0 1 1u 1p 1p 1u 2u 2)
V2
plus
U2
minus
Memristor_Jolekar
Ron=100 Roff=10K Rinit=4K D=10N uv=10F p=1
PULSE(0 1 2u 1p 1p 2u 4u 1)
V3
plus
U3
minus
Memristor_Jolekar
Ron=100 Roff=10K Rinit=1K D=10N uv=10F p=1
plus
U4
minus
Memristor_Jolekar
U1
Vout
.tran 0 4u 0 0.01u startup
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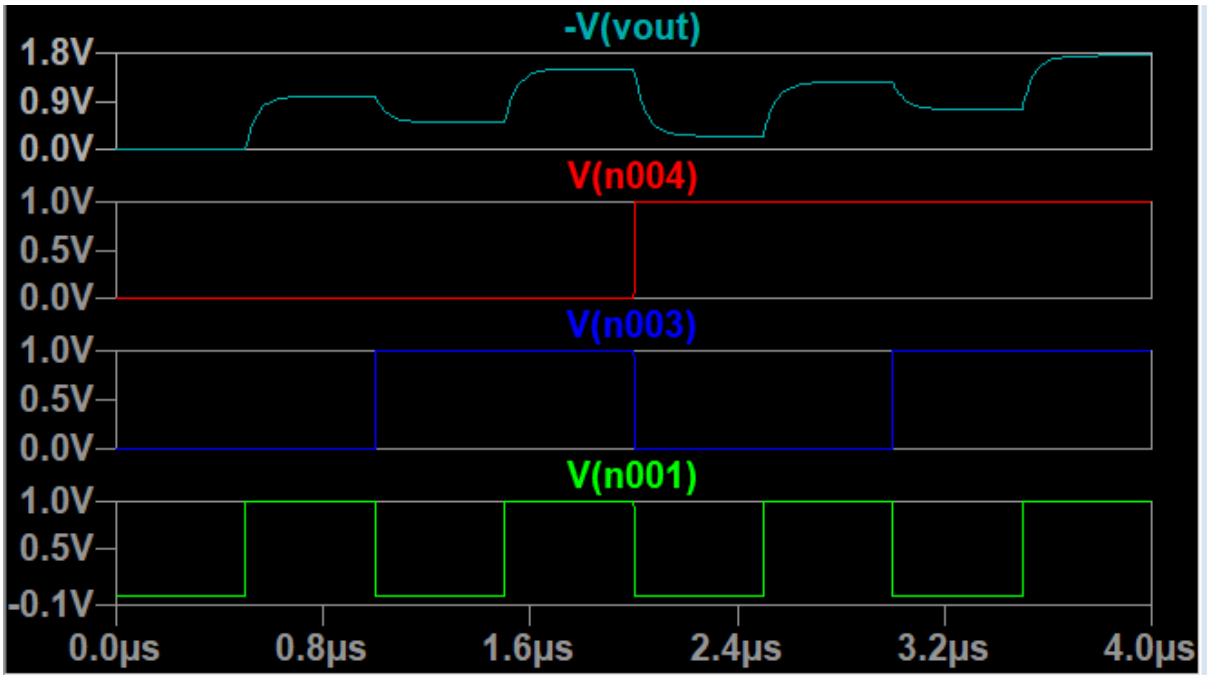
-V(vout)
1.8V
0.9V
0.0V
V(n004)
1.0V
0.5V
0.0V
V(n003)
1.0V
0.5V
0.0V
V(n001)
1.0V
0.5V
-0.1V
0.0µs
0.8µs
1.6µs
2.4µs
3.2µs
4.0µs