Group 3

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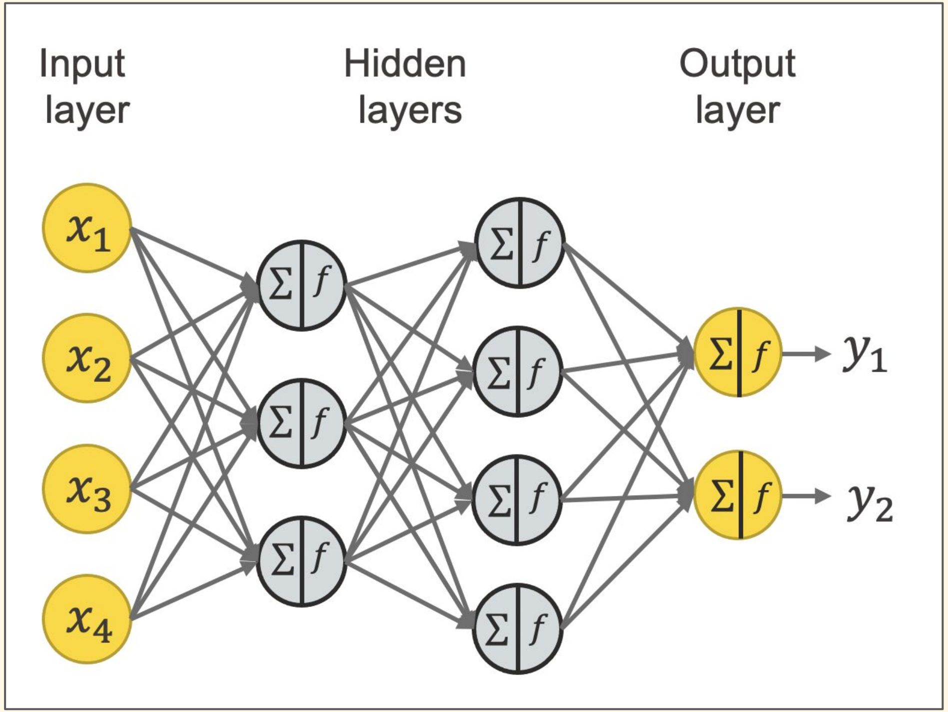
Watching Neural Networks Learn

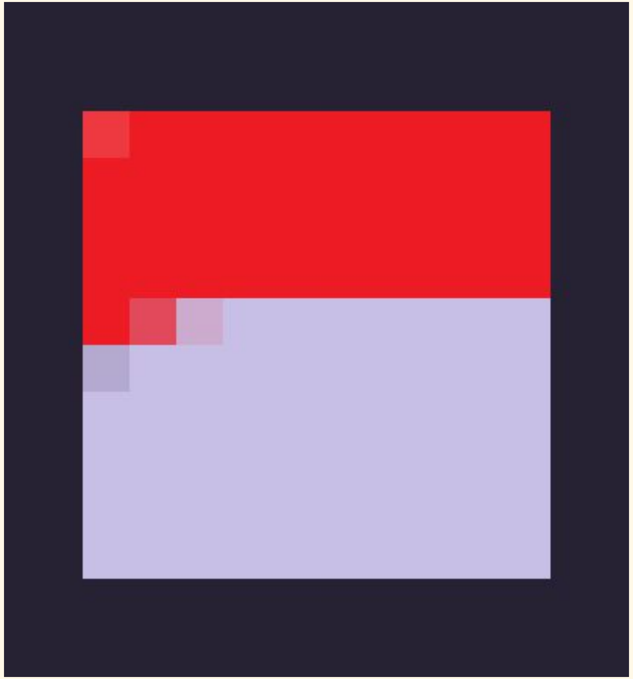
Left to Right: Kyle, Dom, George, Joey

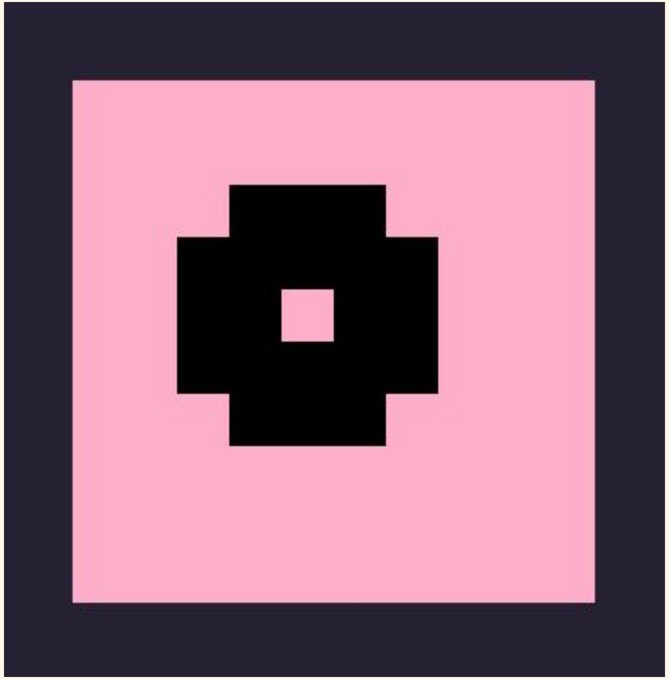
What Are Neural Networks?

A method in AI that teaches computers to learn in a way similar to a brain. It uses nodes called “neurons” interconnected in a layered structure that resembles a brain. It creates a system that computers use to continuously improve by learning from their mistakes.

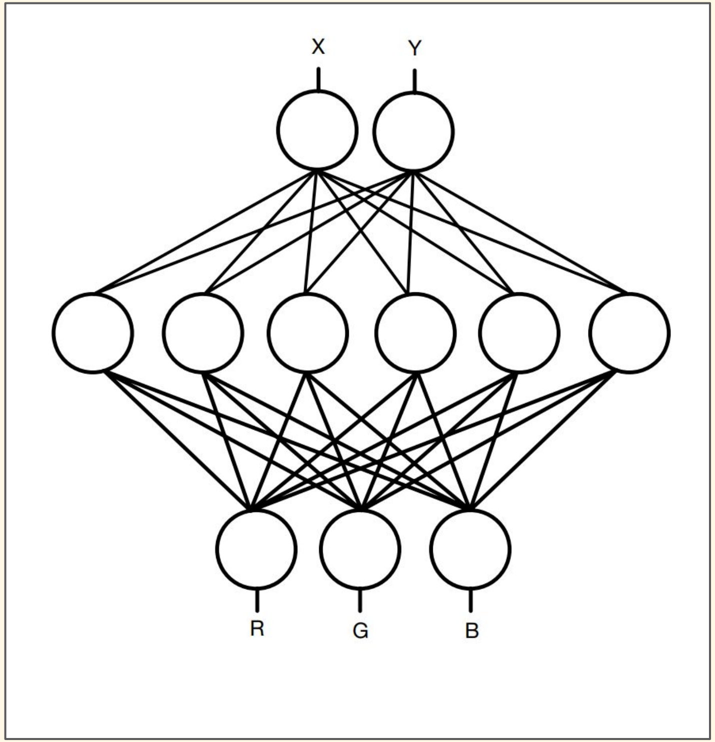


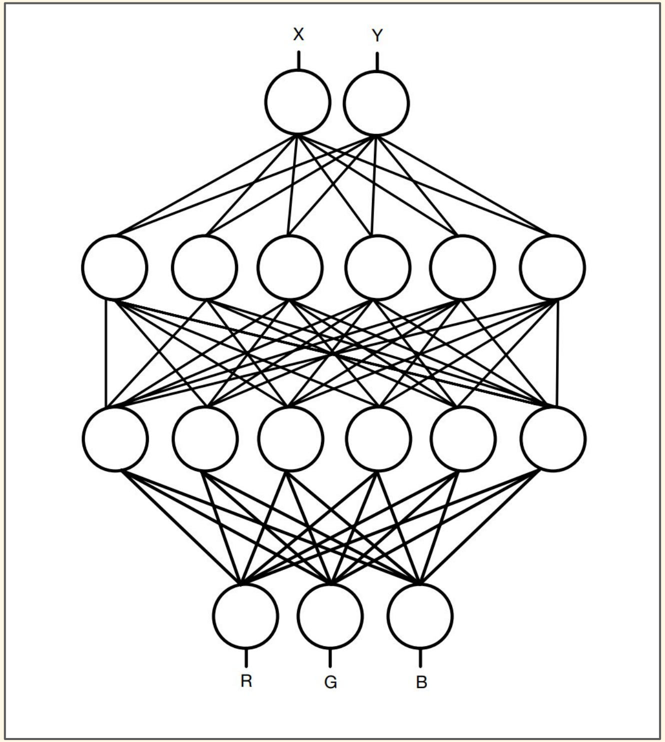
End Goal of Our Network



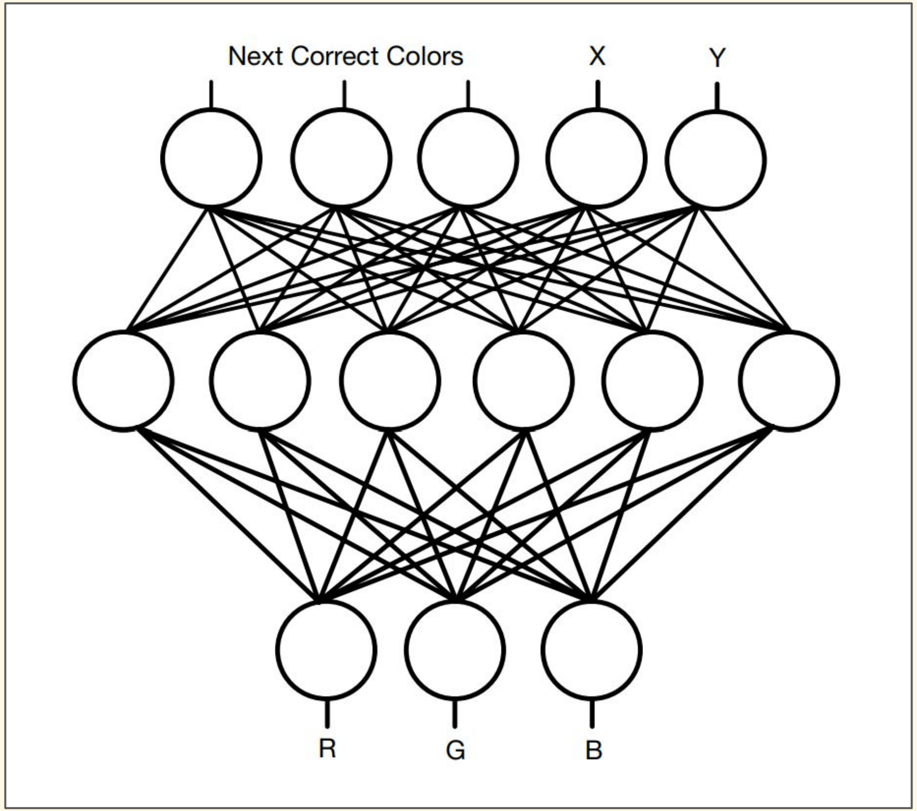


Testing Different Network Structures

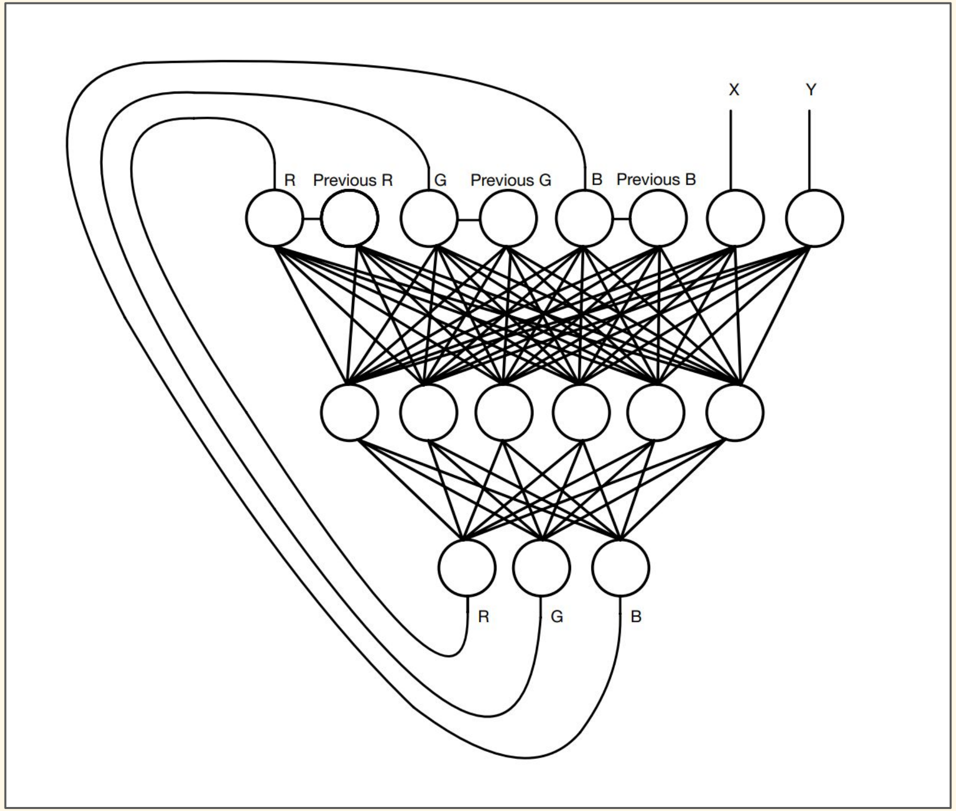




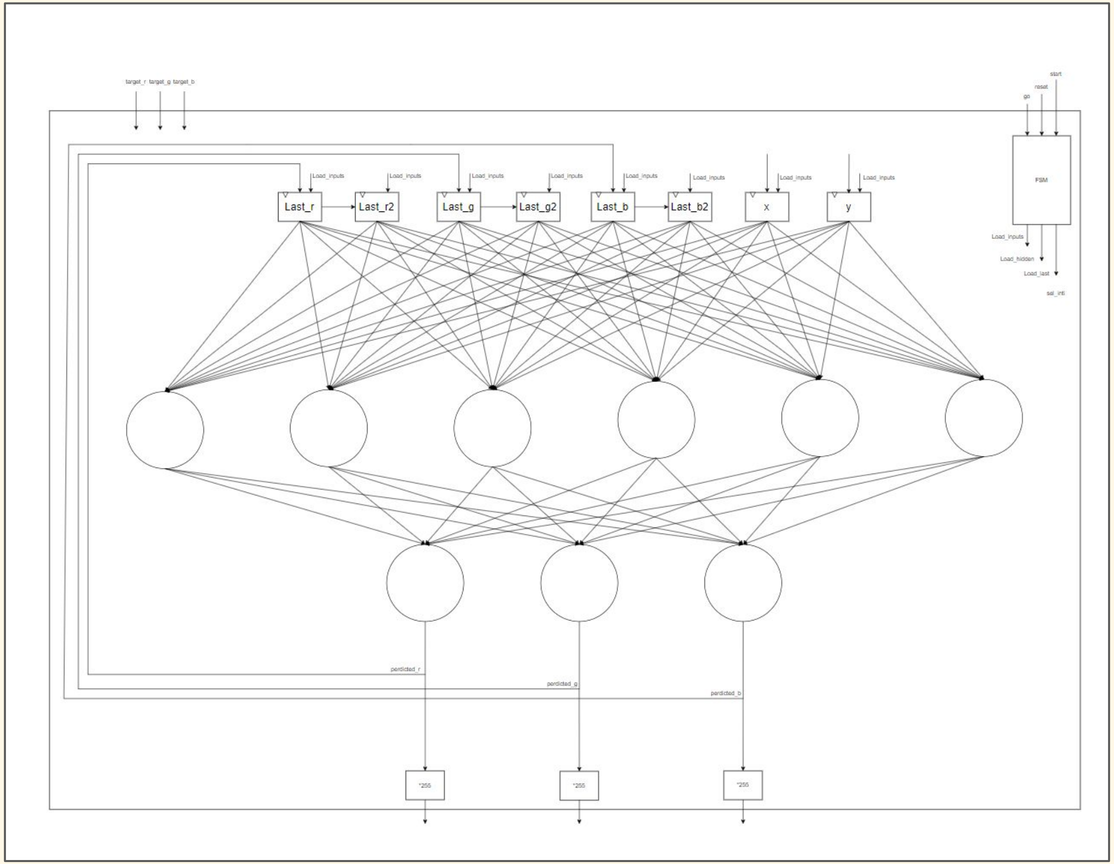
First Successful Network



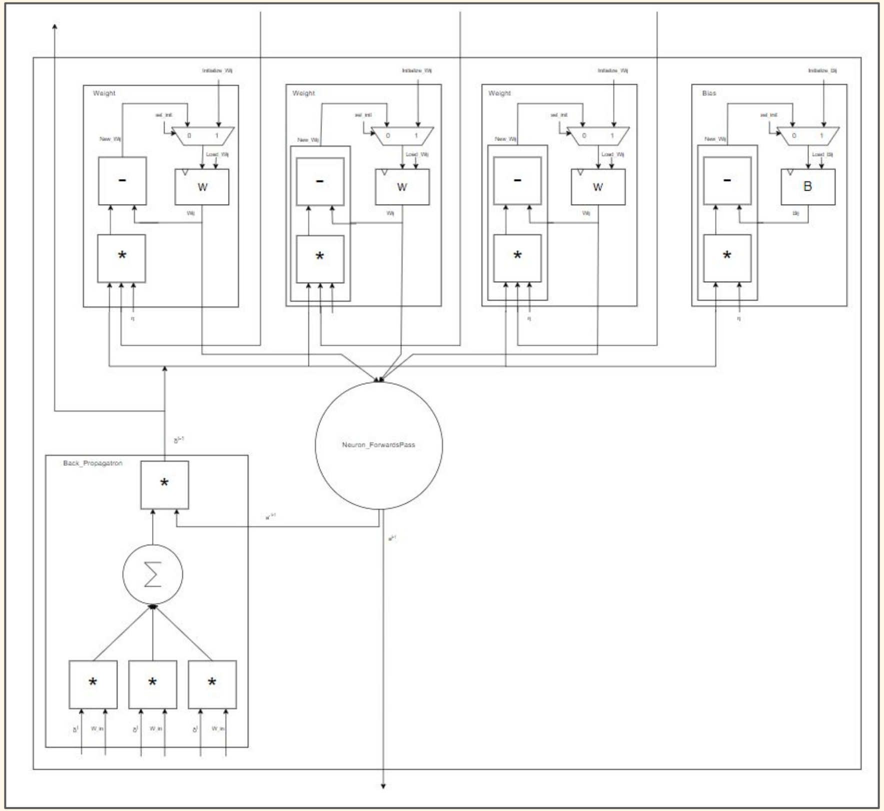
Our Network Structure



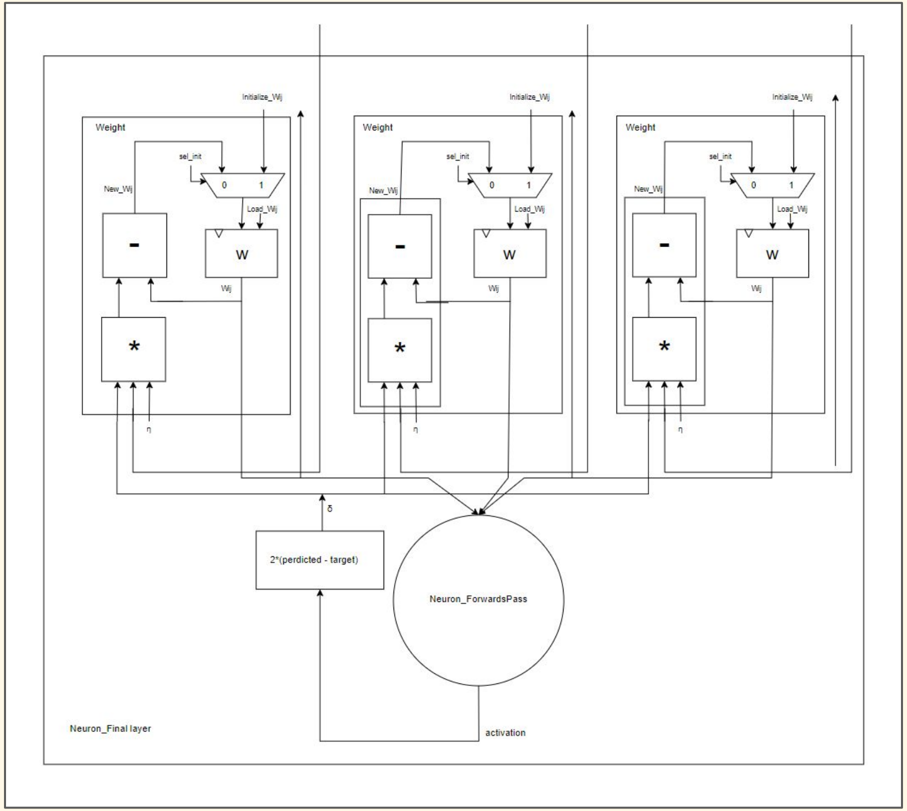
Moving to Hardware



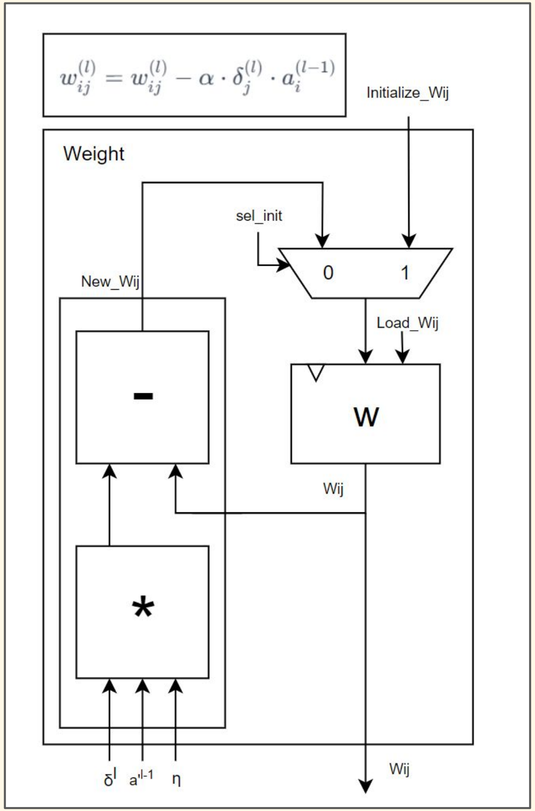
Complete Neuron



Output Layer Neuron

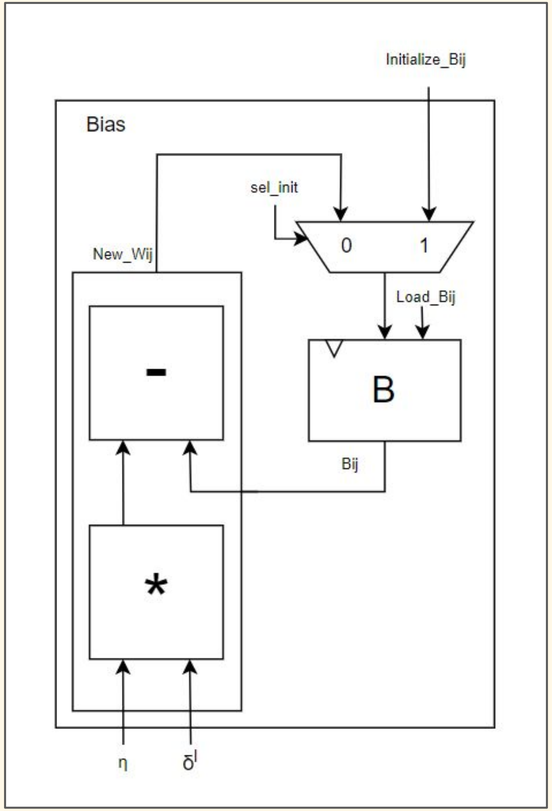


Neuron Weight

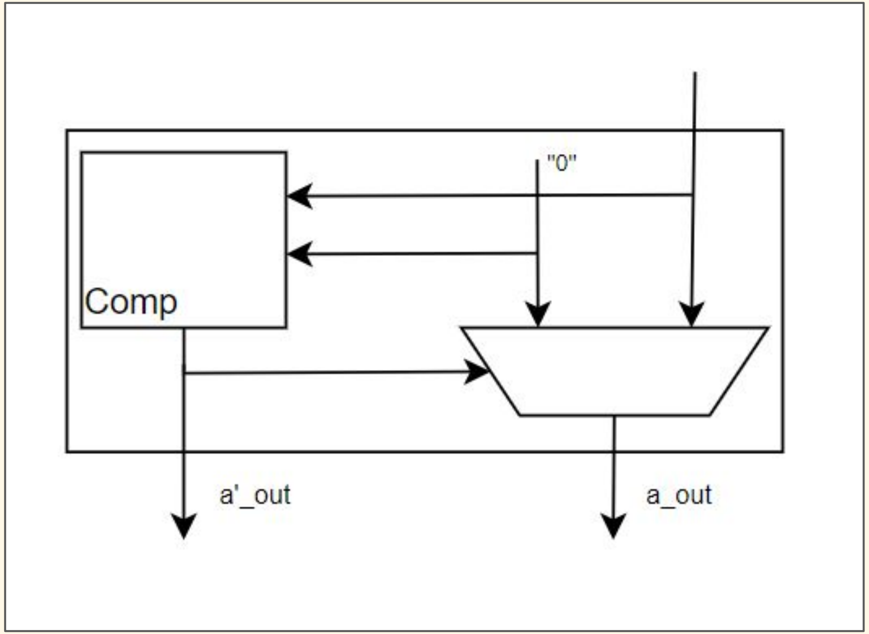


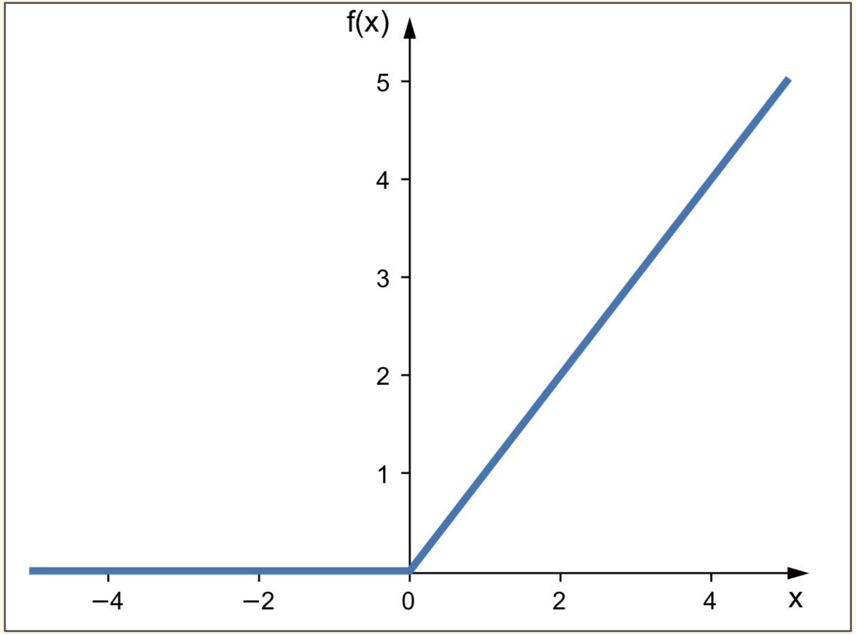
$$w_{ij}^{(l)} = w_{ij}^{(l)} - \alpha \cdot \delta_j^{(l)} \cdot a_i^{(l-1)}$$

Neuron Bias:

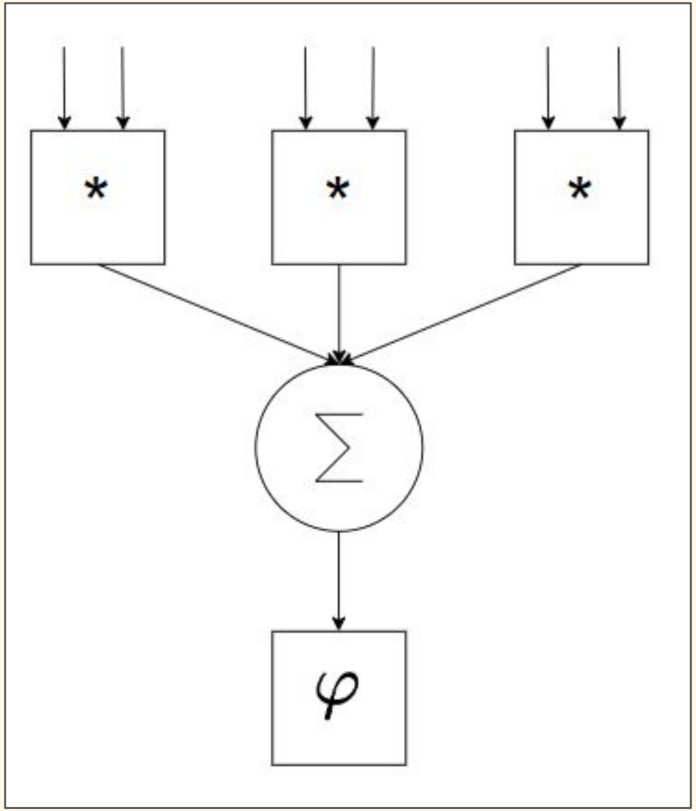

Initialize_Bij
Bias
sel_init
0
1
New_Wij
Load_Bij
-
B
Bij
*
η
δ^l

Neuron Activation Function





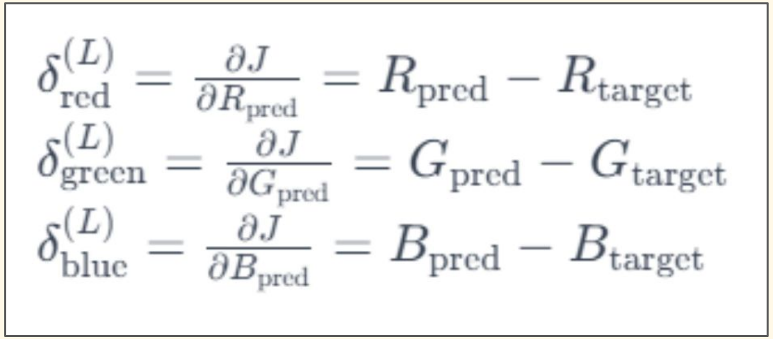
Neuron Weighted Summer



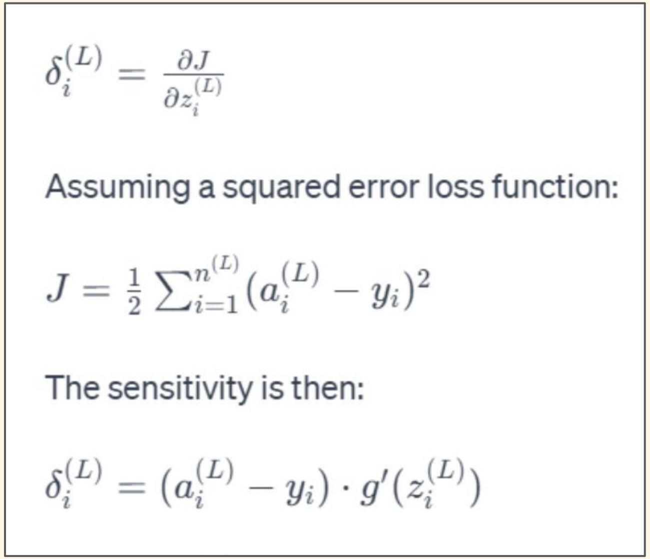
The forward propagation process is completed when the input data has passed through each layer and the final output is obtained.

Back Propagation

- Backwards Propagation is the process of adjusting the neural network weights to predict the output better



$$\delta_{\text{red}}^{(L)} = \frac{\partial J}{\partial R_{\text{pred}}} = R_{\text{pred}} - R_{\text{target}}$$
$$\delta_{\text{green}}^{(L)} = \frac{\partial J}{\partial G_{\text{pred}}} = G_{\text{pred}} - G_{\text{target}}$$
$$\delta_{\text{blue}}^{(L)} = \frac{\partial J}{\partial B_{\text{pred}}} = B_{\text{pred}} - B_{\text{target}}$$



$$\delta_i^{(L)} = \frac{\partial J}{\partial z_i^{(L)}}$$

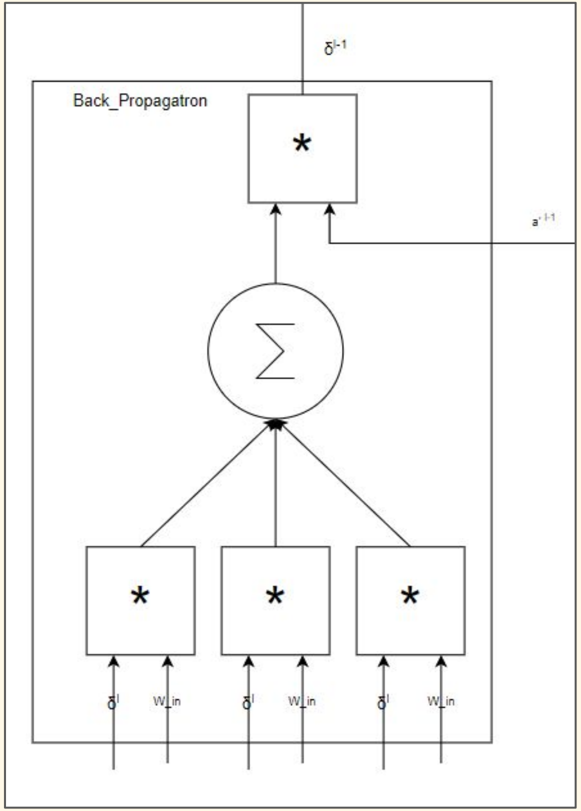
Assuming a squared error loss function:

$$J = \frac{1}{2} \sum_{i=1}^{n^{(L)}} (a_i^{(L)} - y_i)^2$$

The sensitivity is then:

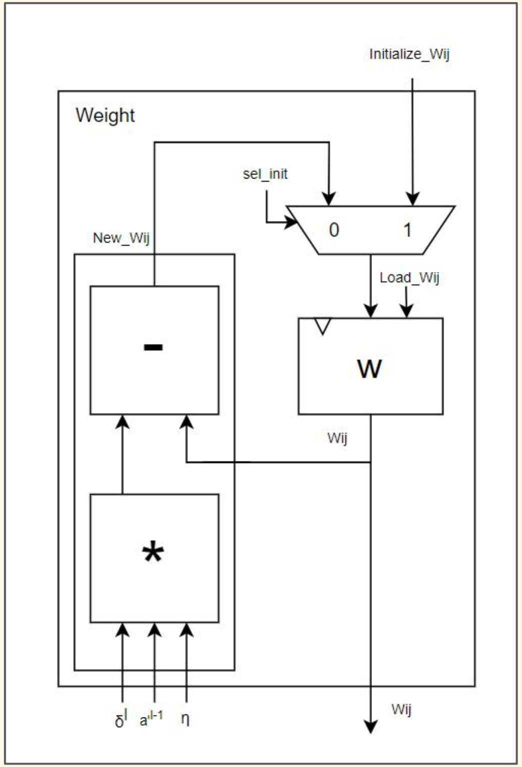
$$\delta_i^{(L)} = (a_i^{(L)} - y_i) \cdot g'(z_i^{(L)})$$

Backwards Propagating Sensitivity



$$\delta_j^{(l+1)} = g'^{(l+1)}(z_j^{(l+1)}) \sum_k w_{jk}^{(l+1)} \delta_k^{(l+2)}$$

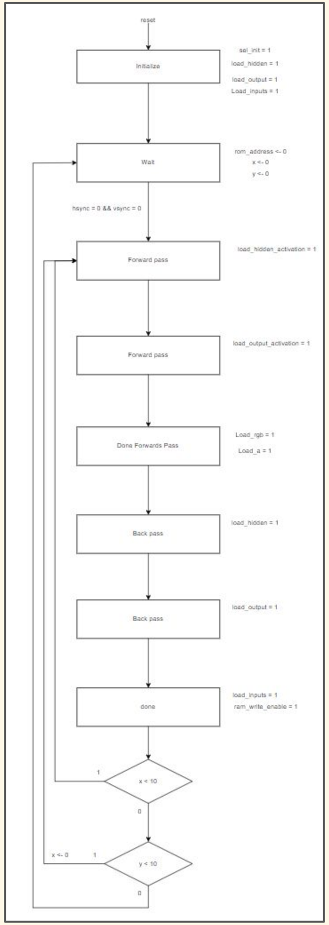
Adjusting the Weights and Bias



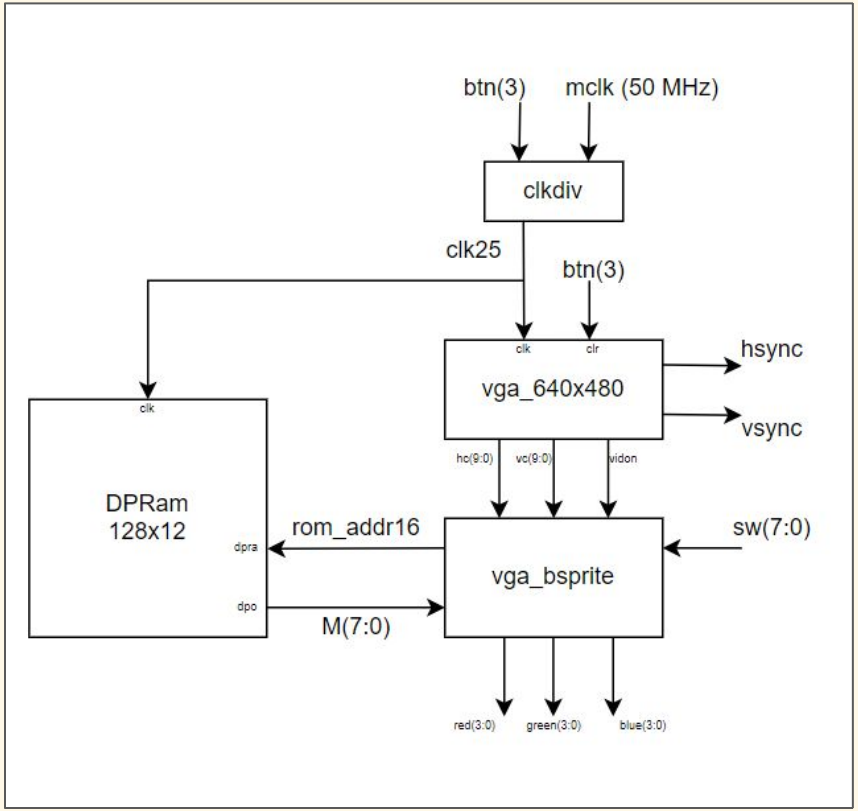
$$w_{ij}^{(l)} = w_{ij}^{(l)} - \alpha \cdot \delta_j^{(l)} \cdot a_i^{(l-1)}$$

$$b_j^{(l)} = b_j^{(l)} - \alpha \cdot \delta_j^{(l)}$$

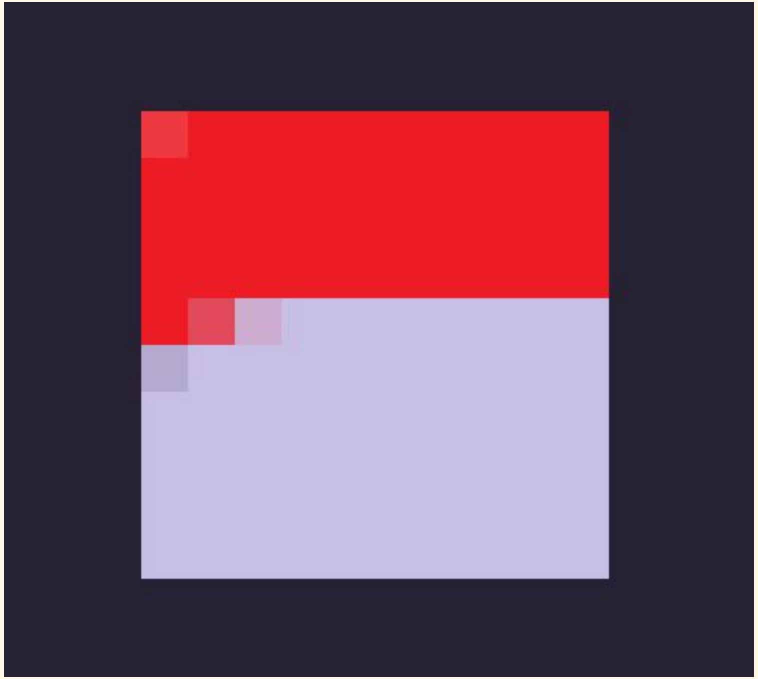
State Machine:



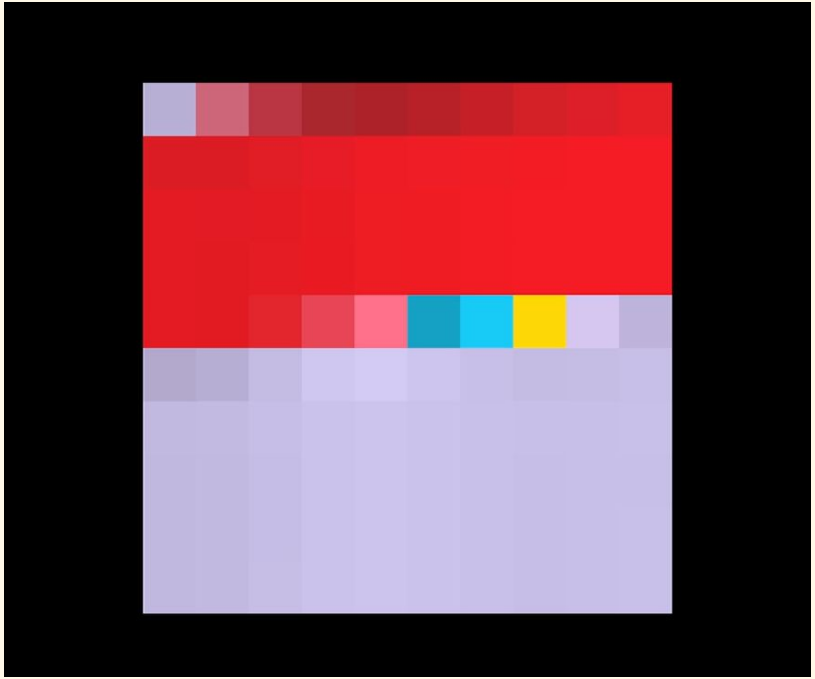
VGA Component:



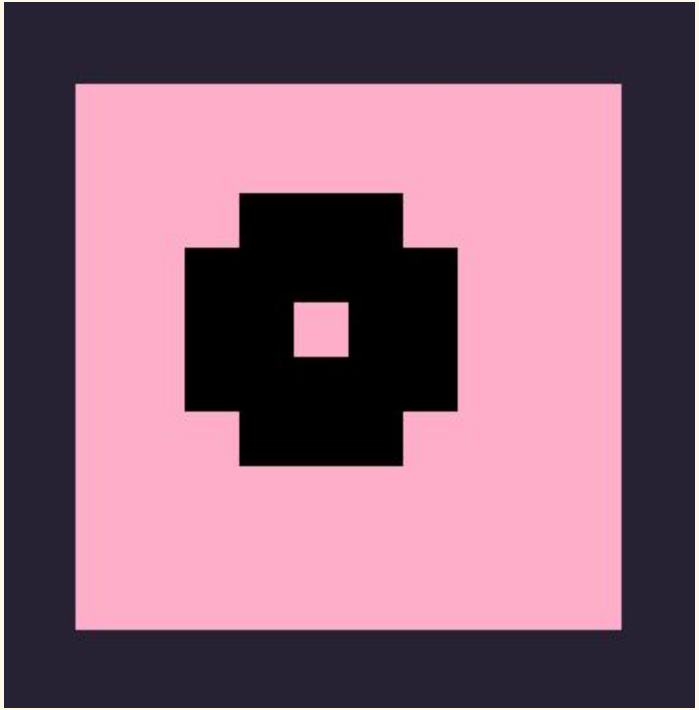
Results

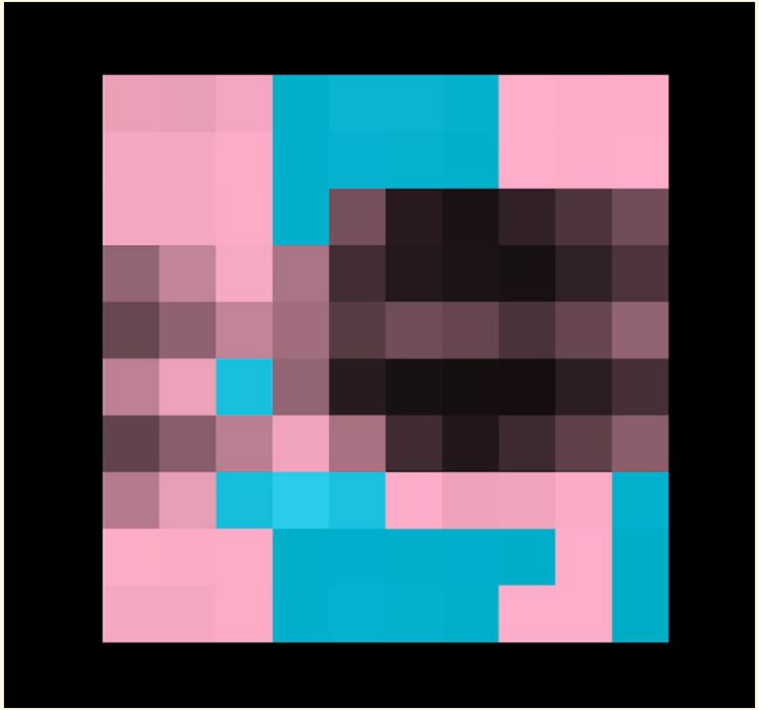


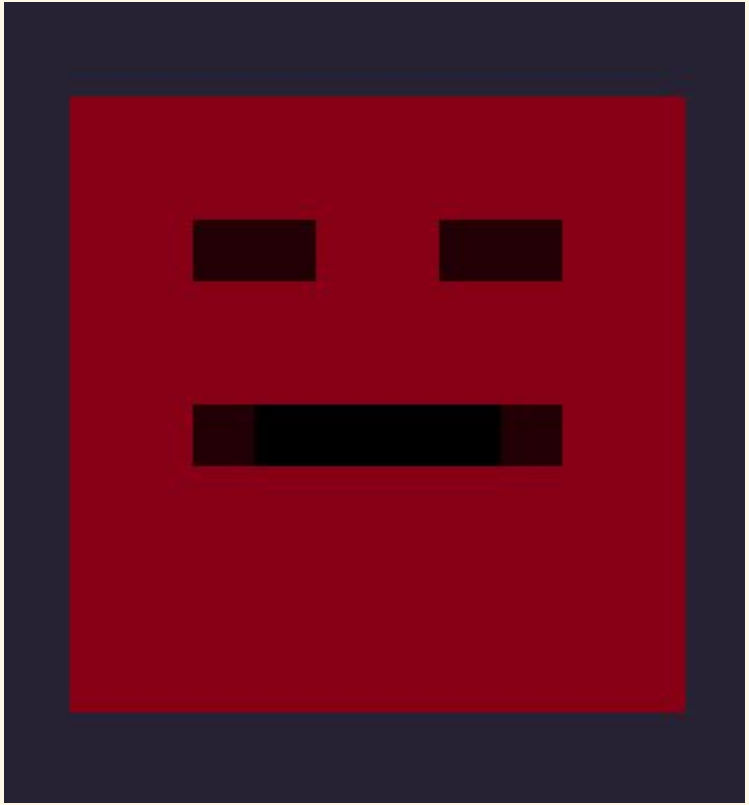
Target

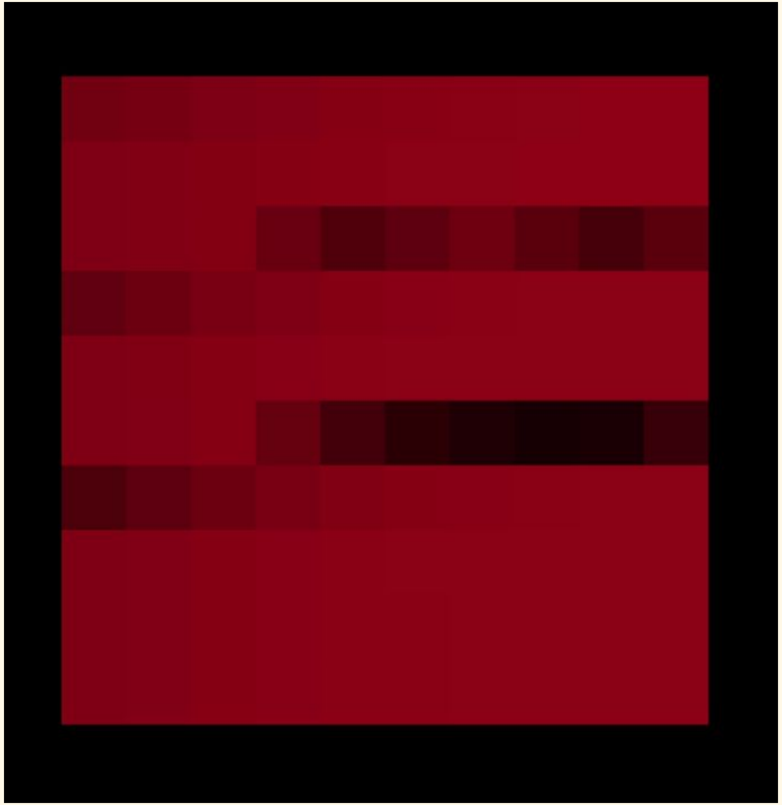


Predicted

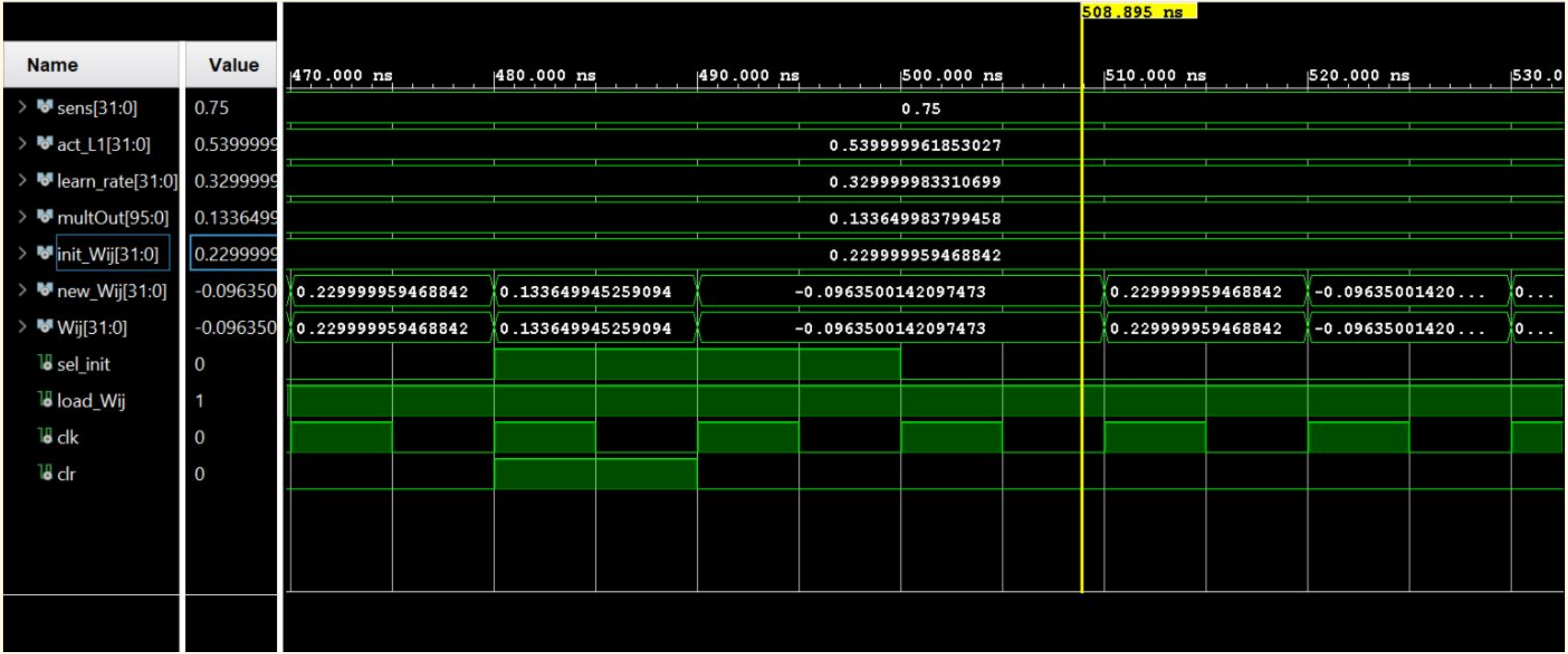






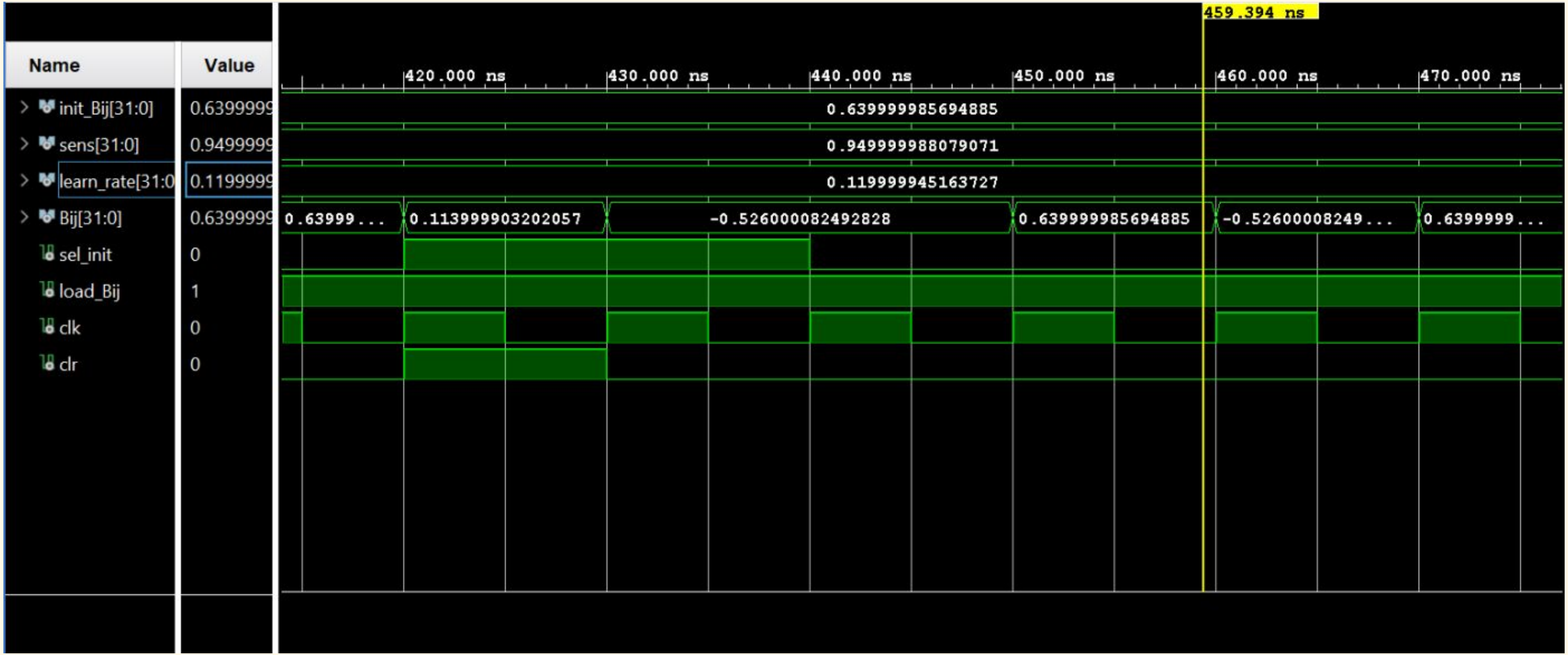


Simulation (Weight):



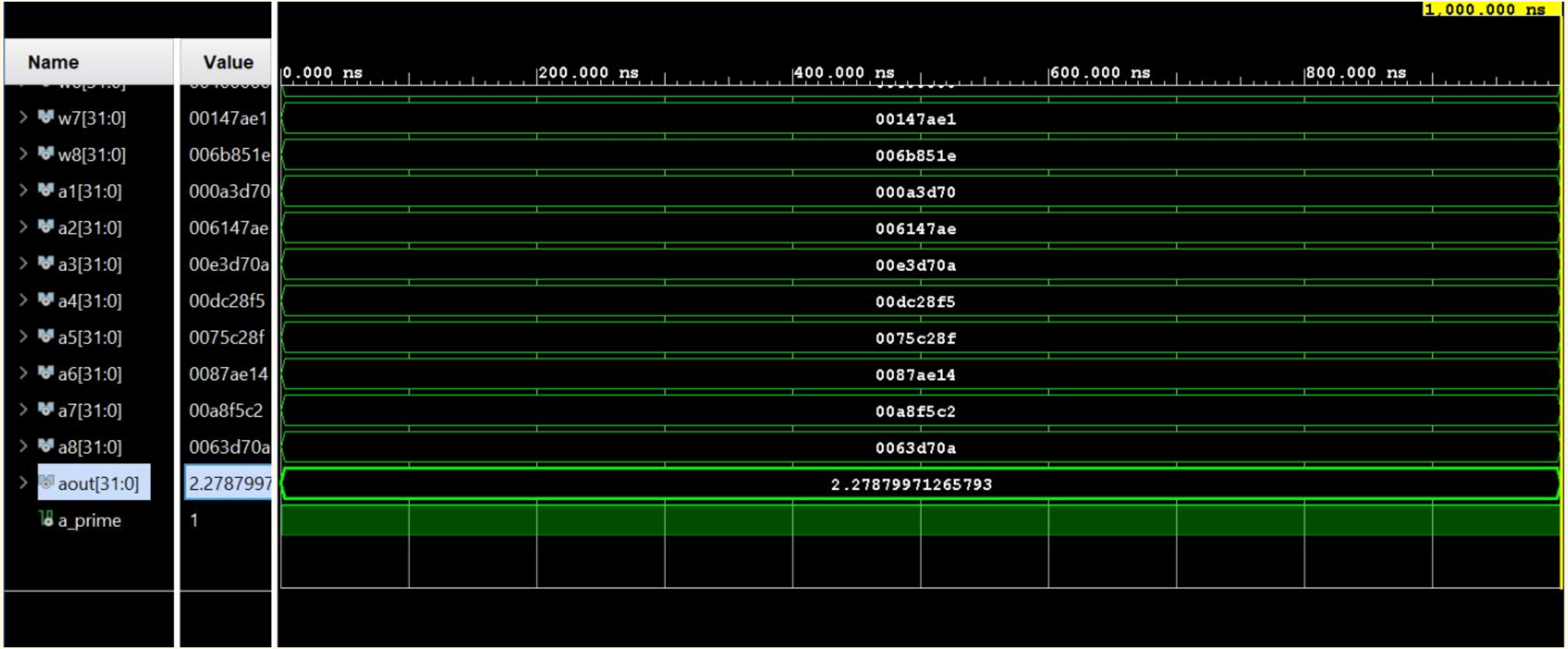
Name	Value
sens[31:0]	0.75
act_L1[31:0]	0.5399999
learn_rate[31:0]	0.3299999
multOut[95:0]	0.1336499
init_Wij[31:0]	0.2299999
new_Wij[31:0]	-0.096350
Wij[31:0]	-0.096350
sel_init	0
load_Wij	1
clk	0
clr	0

Simulation (Neuron Bias):



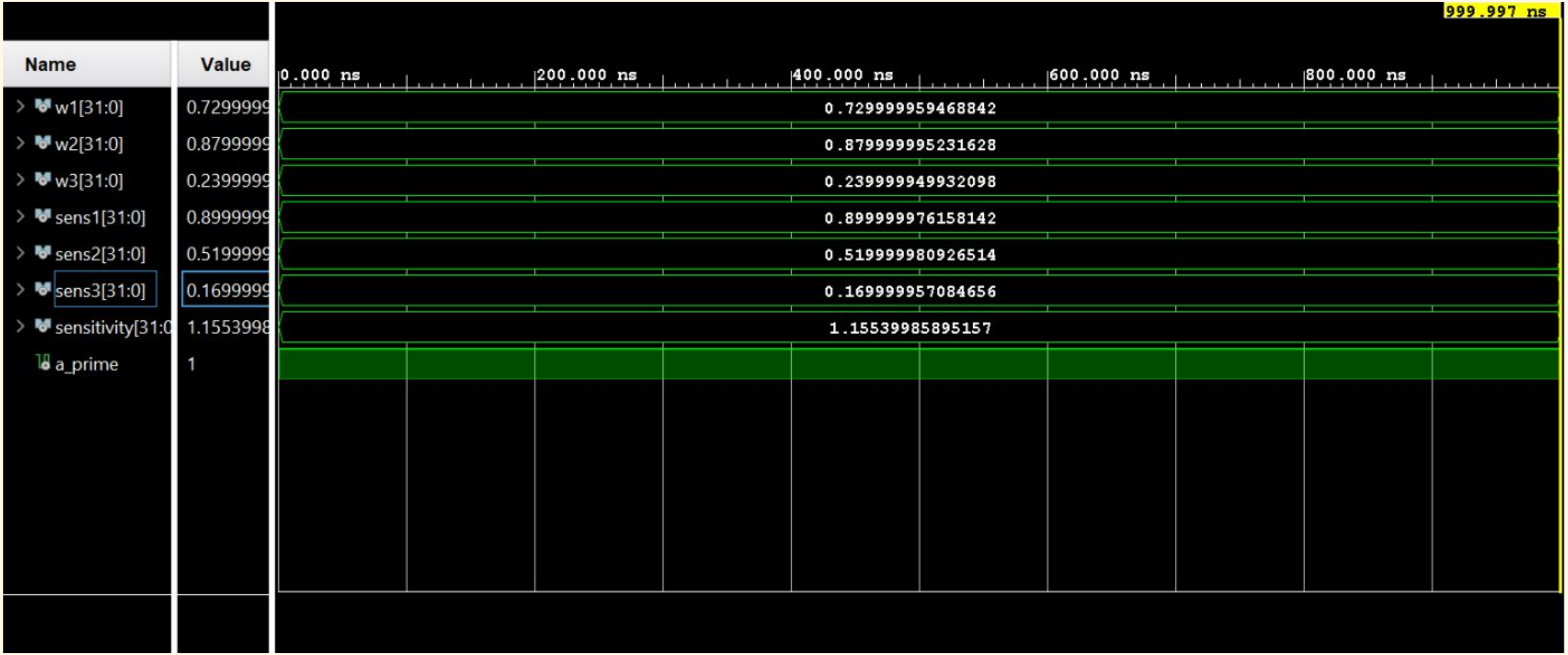
Name	Value
init_Bij[31:0]	0.6399999
sens[31:0]	0.9499999
learn_rate[31:0	0.1199999
Bij[31:0]	0.6399999
sel_init	0
load_Bij	1
clk	0
clr	0

Simulation (Forward Pass Neuron):



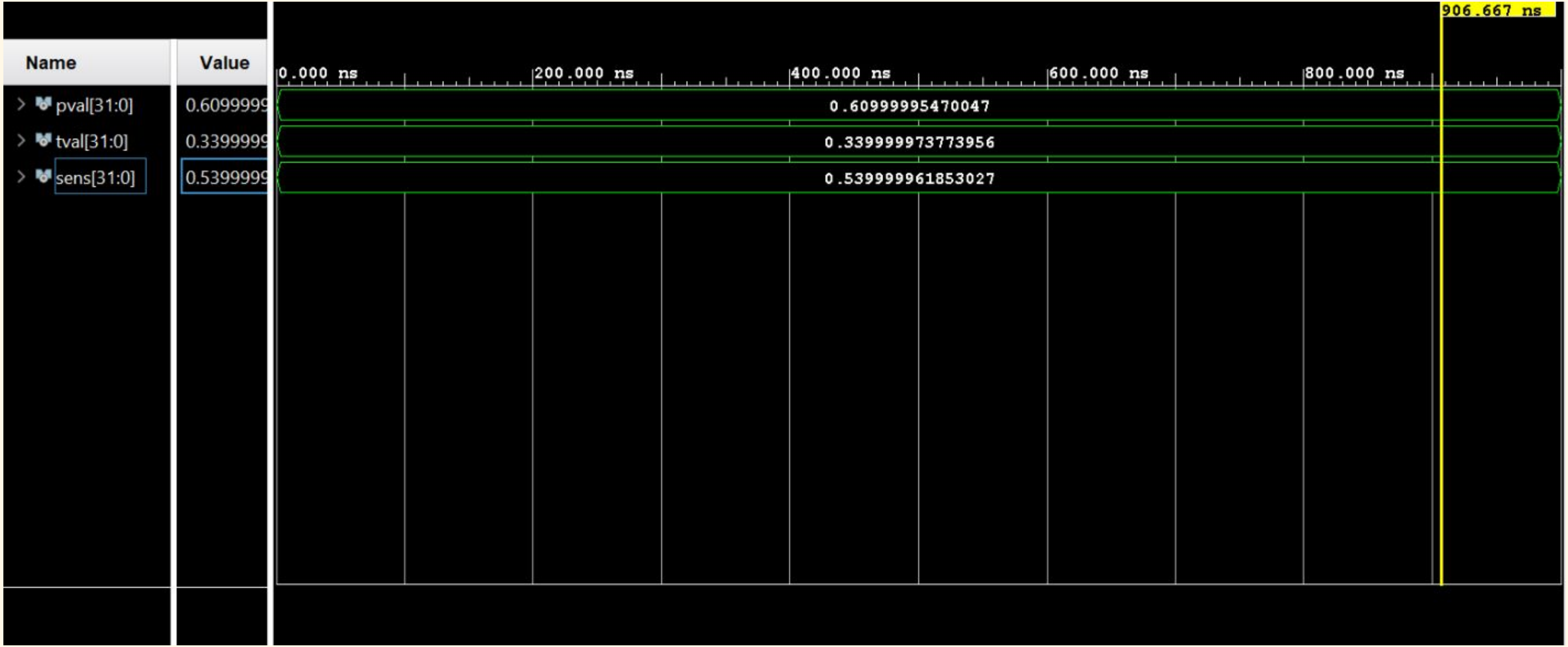
Name	Value
w7[31:0]	00147ae1
w8[31:0]	006b851e
a1[31:0]	000a3d70
a2[31:0]	006147ae
a3[31:0]	00e3d70a
a4[31:0]	00dc28f5
a5[31:0]	0075c28f
a6[31:0]	0087ae14
a7[31:0]	00a8f5c2
a8[31:0]	0063d70a
aout[31:0]	2.2787997
a_prime	1

Simulation (Back Propagation Neuron):



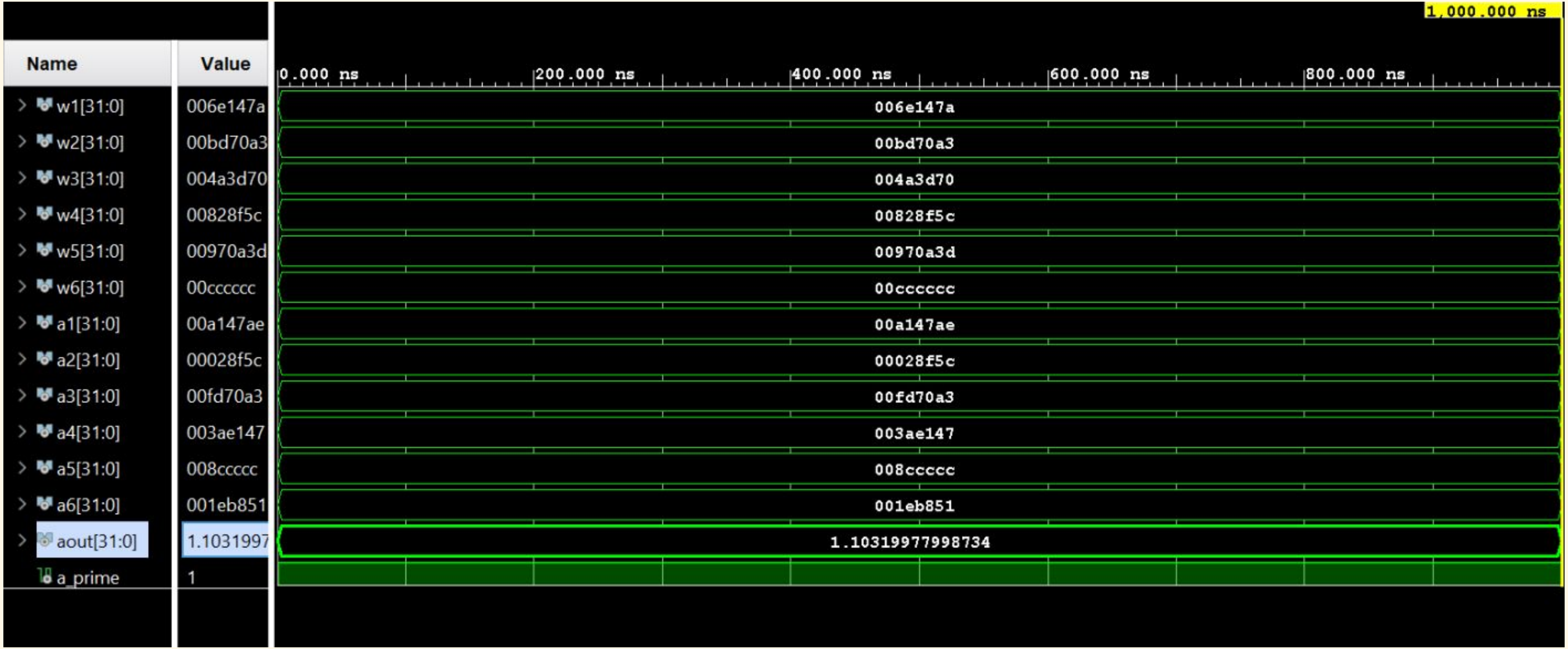
Name	Value	
w1[31:0]	0.7299999	0.729999959468842
w2[31:0]	0.8799999	0.879999995231628
w3[31:0]	0.2399999	0.239999949932098
sens1[31:0]	0.8999999	0.899999976158142
sens2[31:0]	0.5199999	0.519999980926514
sens3[31:0]	0.1699999	0.169999957084656
sensitivity[31:0	1.1553998	1.15539985895157
a_prime	1	

Simulation (Final Layer Sensitivity):



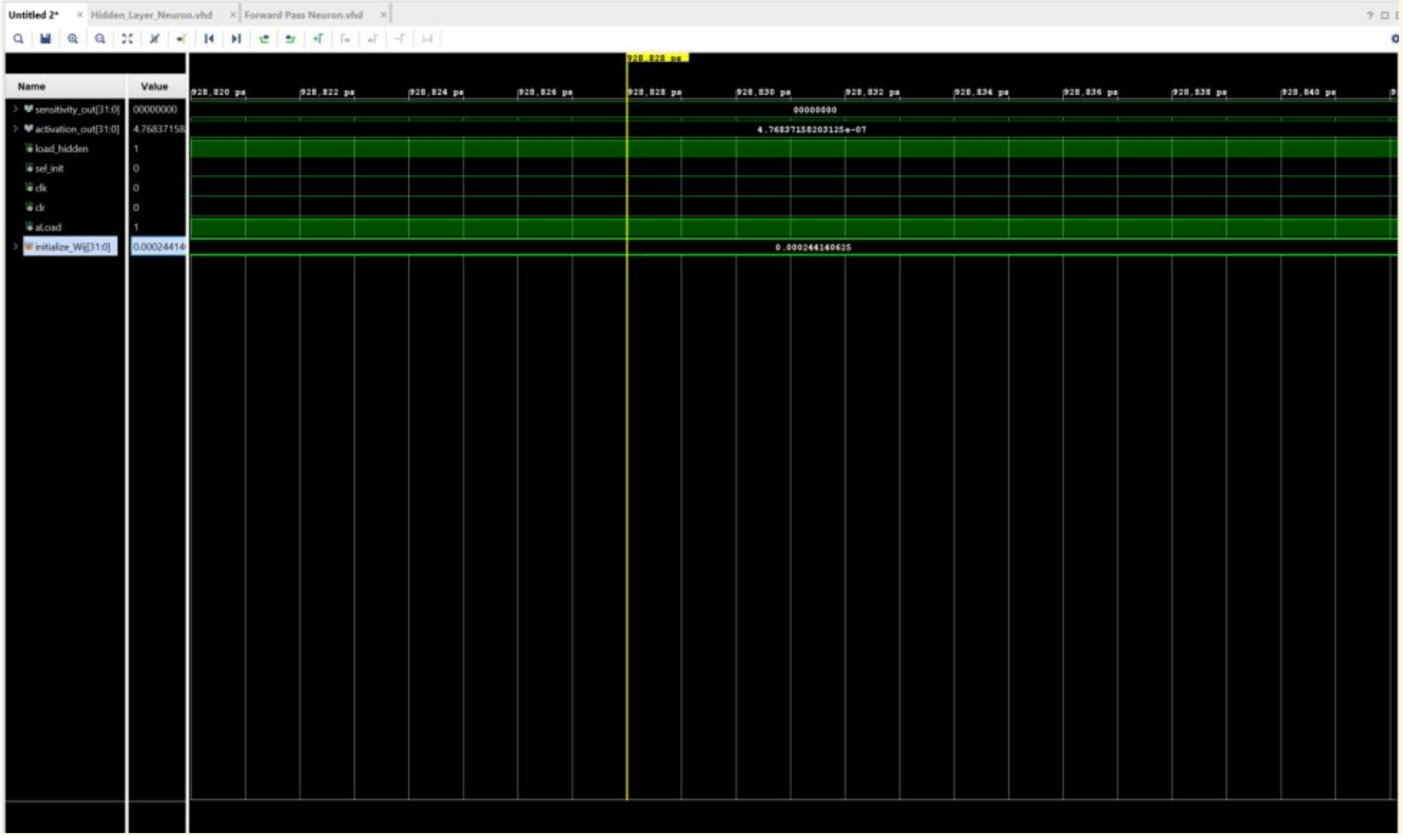
Name	Value	
pval[31:0]	0.6099999	0.60999995470047
tval[31:0]	0.3399999	0.339999973773956
sens[31:0]	0.5399999	0.539999961853027

Simulation (Output Layer Forward Pass Neuron):



Name	Value	
w1[31:0]	006e147a	006e147a
w2[31:0]	00bd70a3	00bd70a3
w3[31:0]	004a3d70	004a3d70
w4[31:0]	00828f5c	00828f5c
w5[31:0]	00970a3d	00970a3d
w6[31:0]	00cccccc	00cccccc
a1[31:0]	00a147ae	00a147ae
a2[31:0]	00028f5c	00028f5c
a3[31:0]	00fd70a3	00fd70a3
a4[31:0]	003ae147	003ae147
a5[31:0]	008ccccc	008ccccc
a6[31:0]	001eb851	001eb851
aout[31:0]	1.1031997	1.10319977998734
a_prime	1	

Simulation (Hidden Layer Neuron):



Name	Value
sensitivity_out[31:0]	00000000
activation_out[31:0]	4.76837158
load_hidden	1
sel_init	0
clk	0
clr	0
aLoad	1
initialize_Wij[31:0]	0.00024414

Some Problems Encountered:

- Utilizing Fixed Point Math
- Understanding Back and Forward Propagation Equations
- Exploding Gradients during back Propagation
- Predicted Picture Shifted to the Right

Questions