4-Bit Carry Look Ahead Adder

Group Number: 1

Group Members:

- Annika Sinha (2022082)
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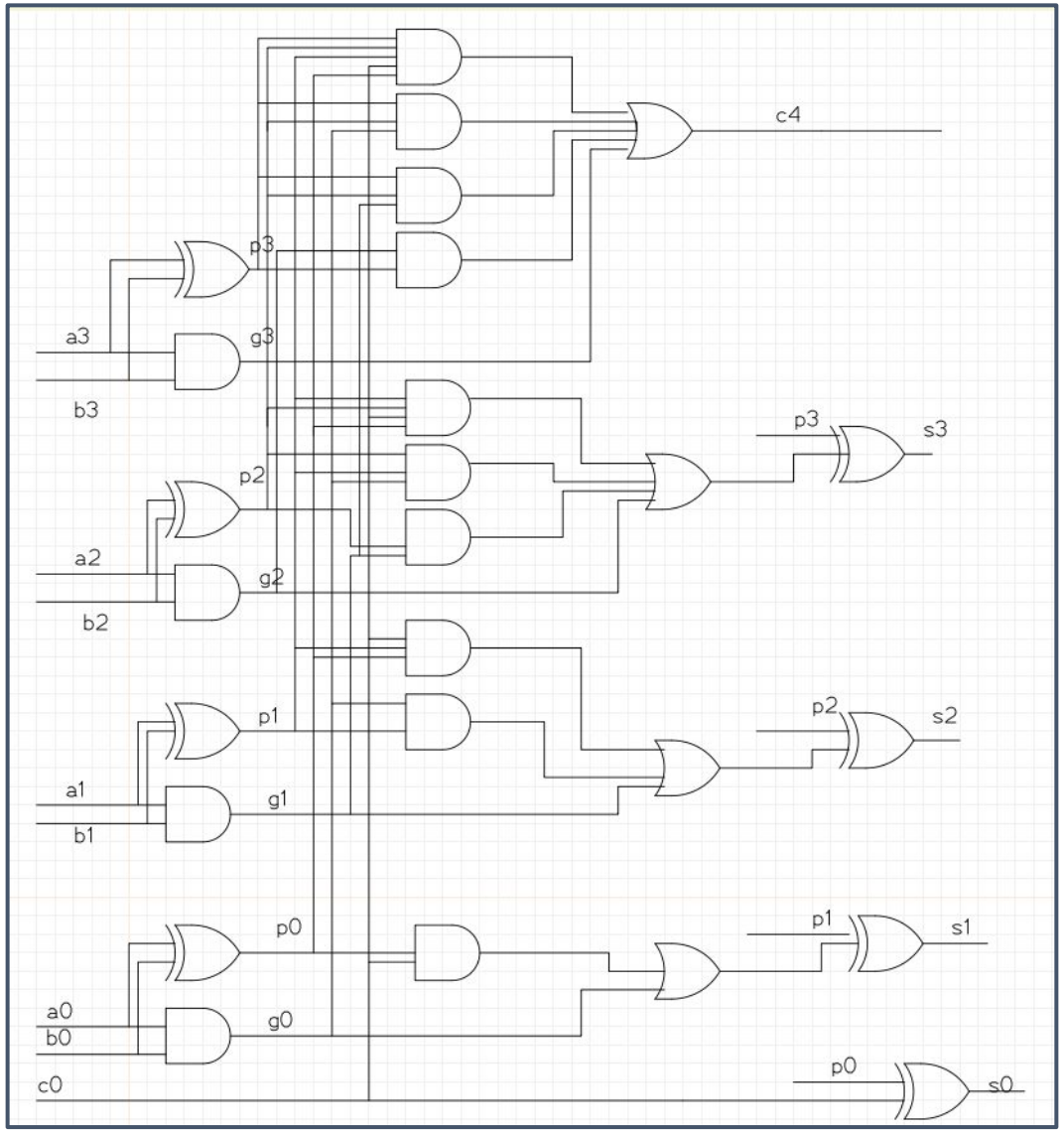
Schematic – XCircuit



Load = 20fF at S0, S1, S2, S3, C4

Equations

$$C_1 = G_0 + P_0 C_0$$

$$C_2 = G_1 + P_1 C_1 = G_1 + P_1 G_0 + P_1 P_0 C_0$$

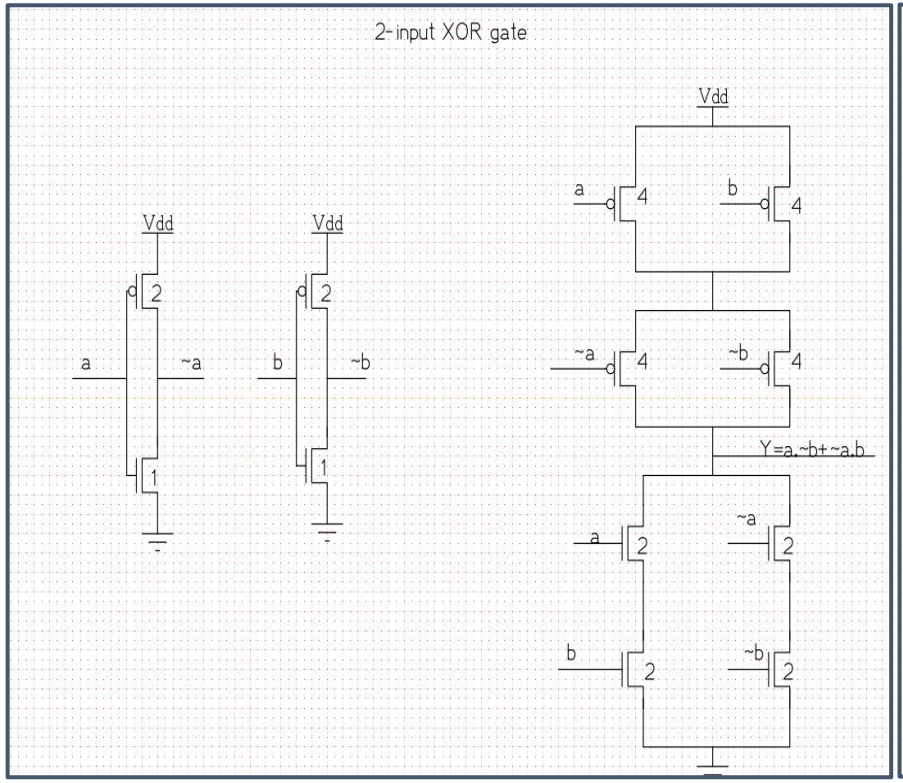
$$C_3 = G_2 + P_2 C_2 = G_2 + P_2 G_1 + P_2 P_1 G_0 + P_2 P_1 P_0 C_0$$

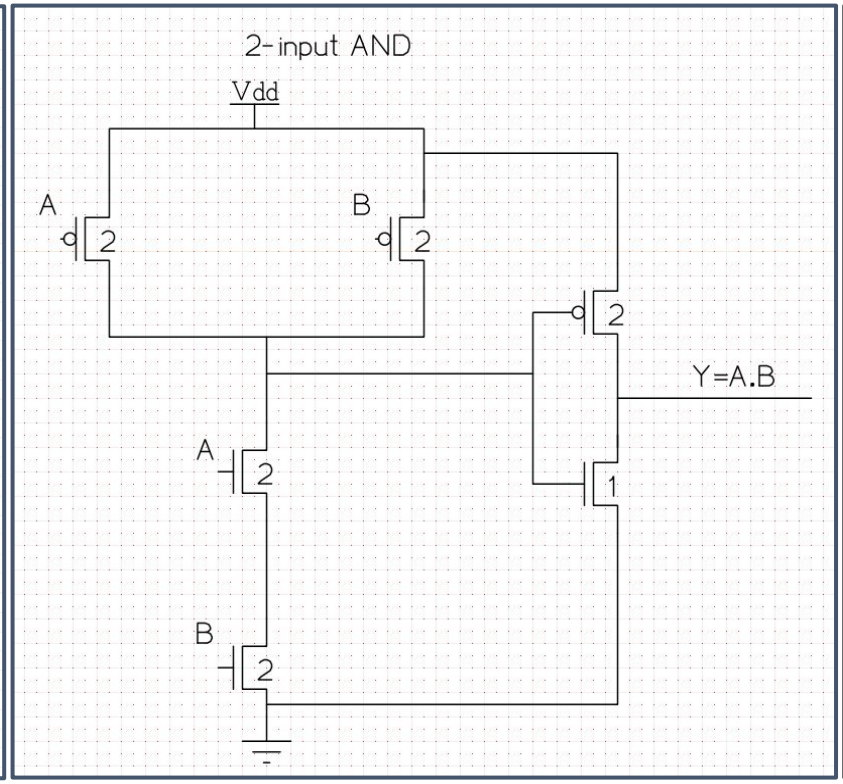
$$C_4 = G_3 + P_3 C_3 = G_3 + P_3 G_2 + P_3 P_2 G_1 + P_3 P_2 P_1 G_0 + P_3 P_2 P_1 P_0 C_0$$

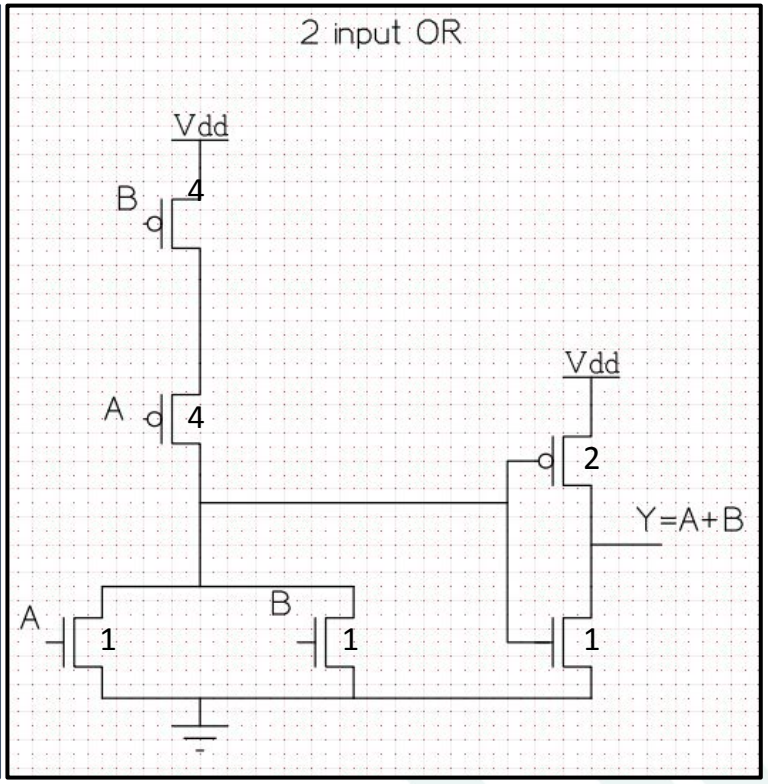
$$G_n = A_n B_n \qquad P_n = A_n \oplus B_n \qquad S_n = P_n \oplus C_n$$

Source: ALL ABOUT ELECTRONICS (2022). *Carry Look Ahead Adder (CLA) Explained*. *YouTube*. Available at: https://www.youtube.com/watch?v=SQKdnxysXnw

Schematic – CMOS Gates

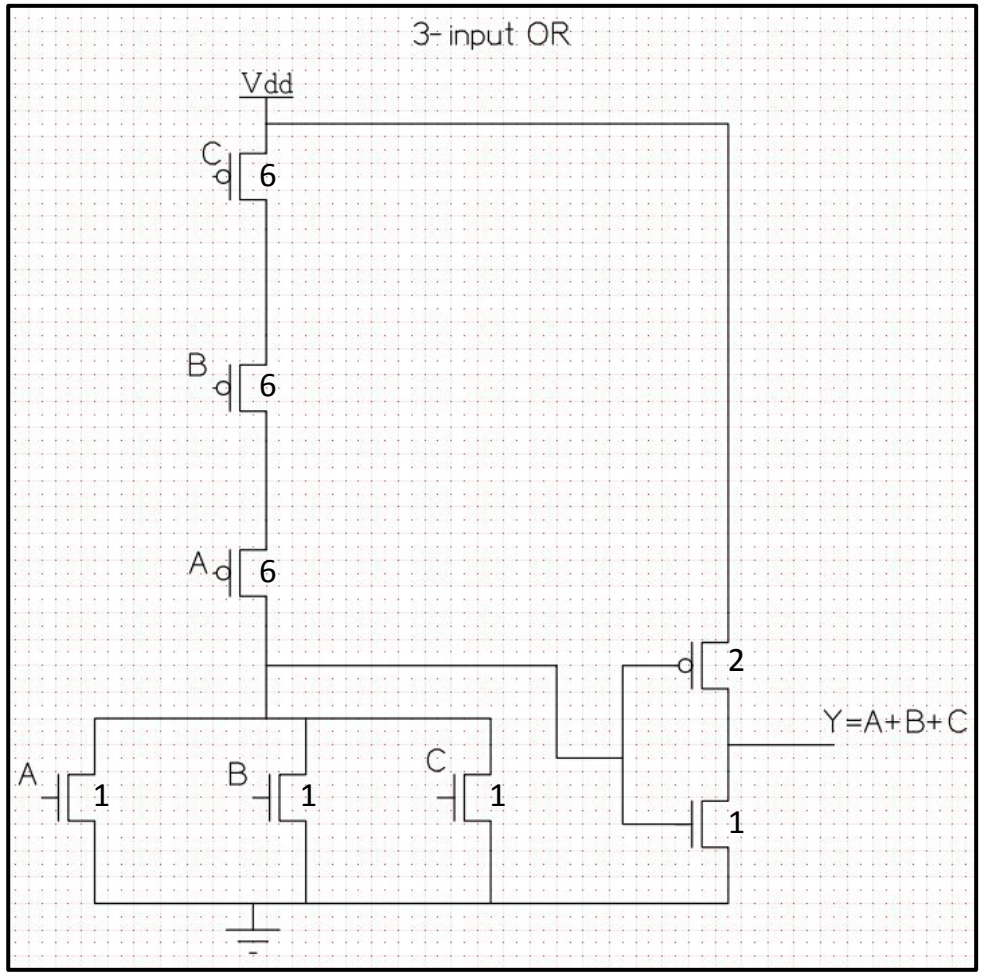


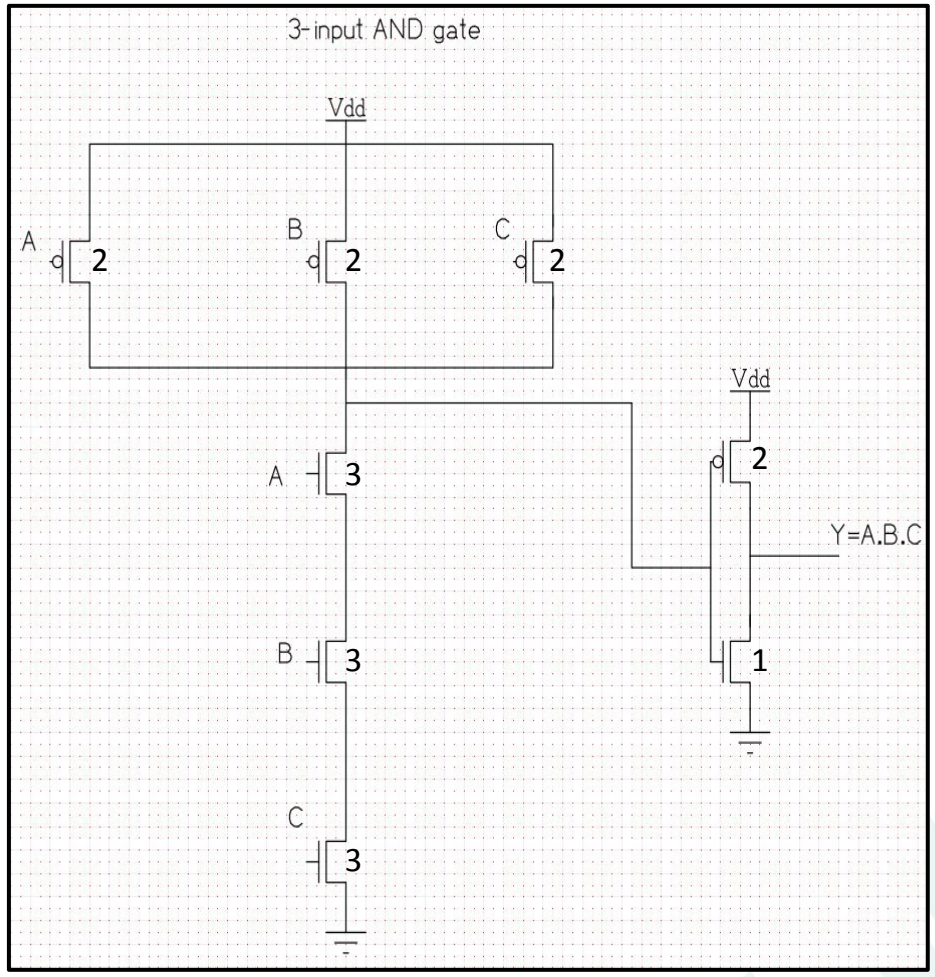




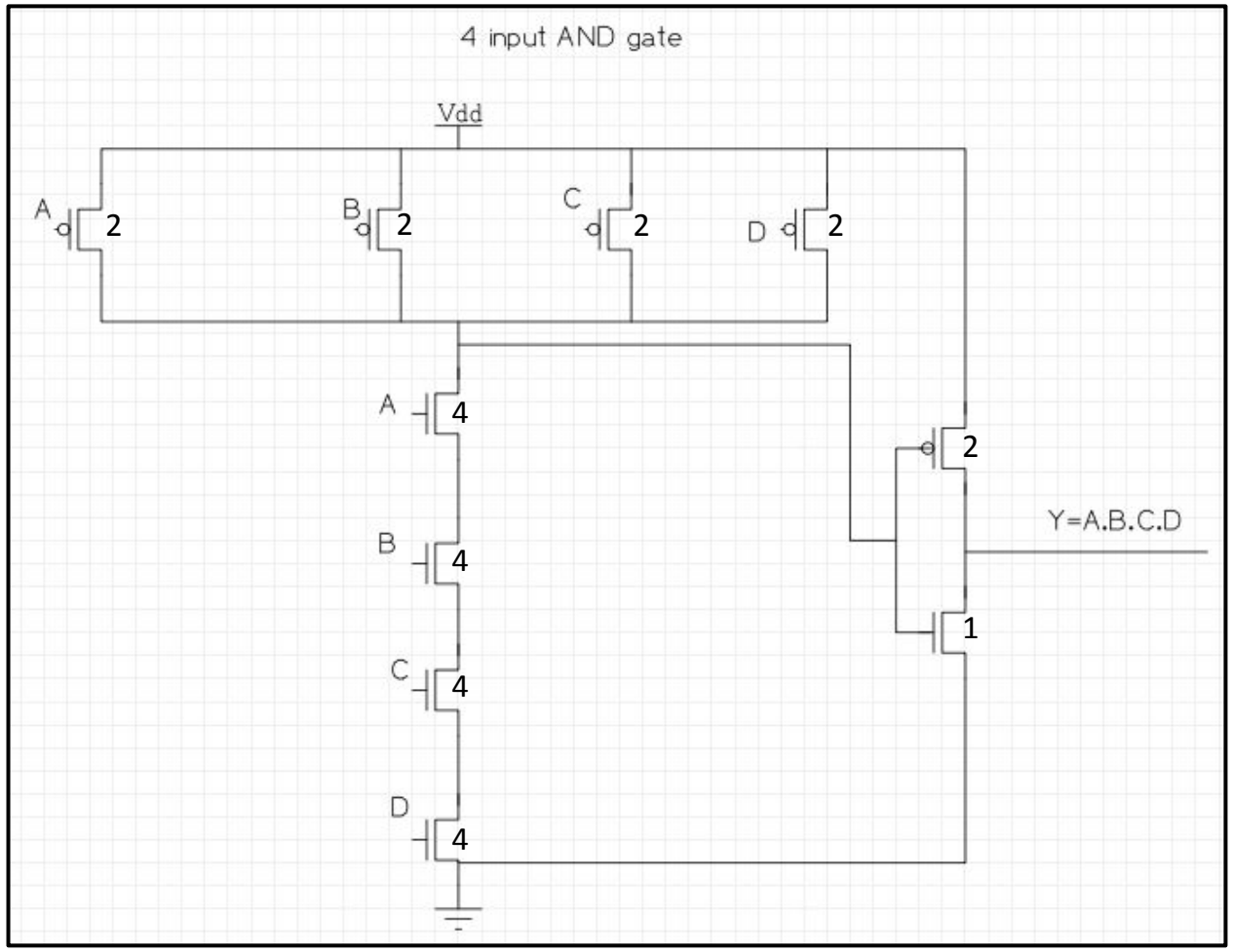
All logic gates are sized to match the worst case resistance of a unit inverter.

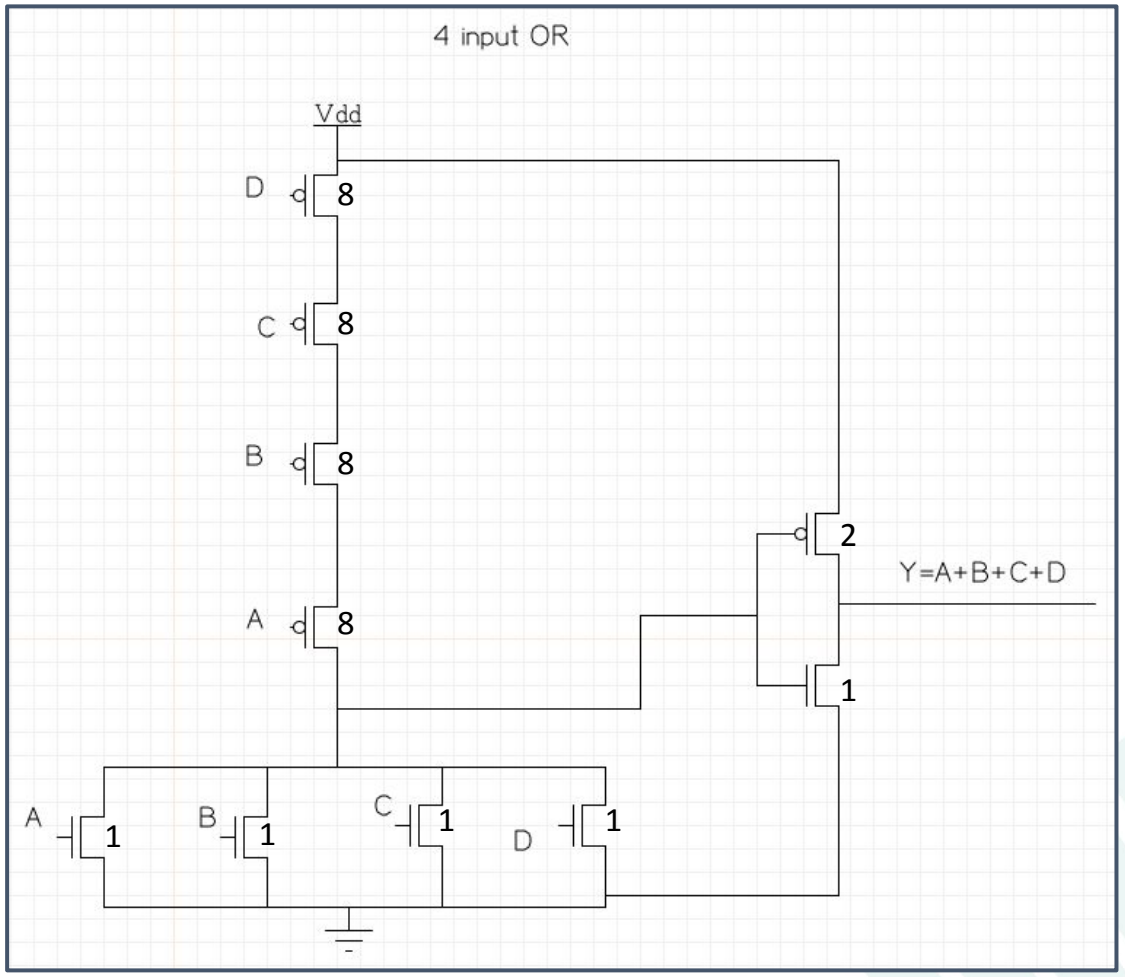
Schematic – CMOS Gates



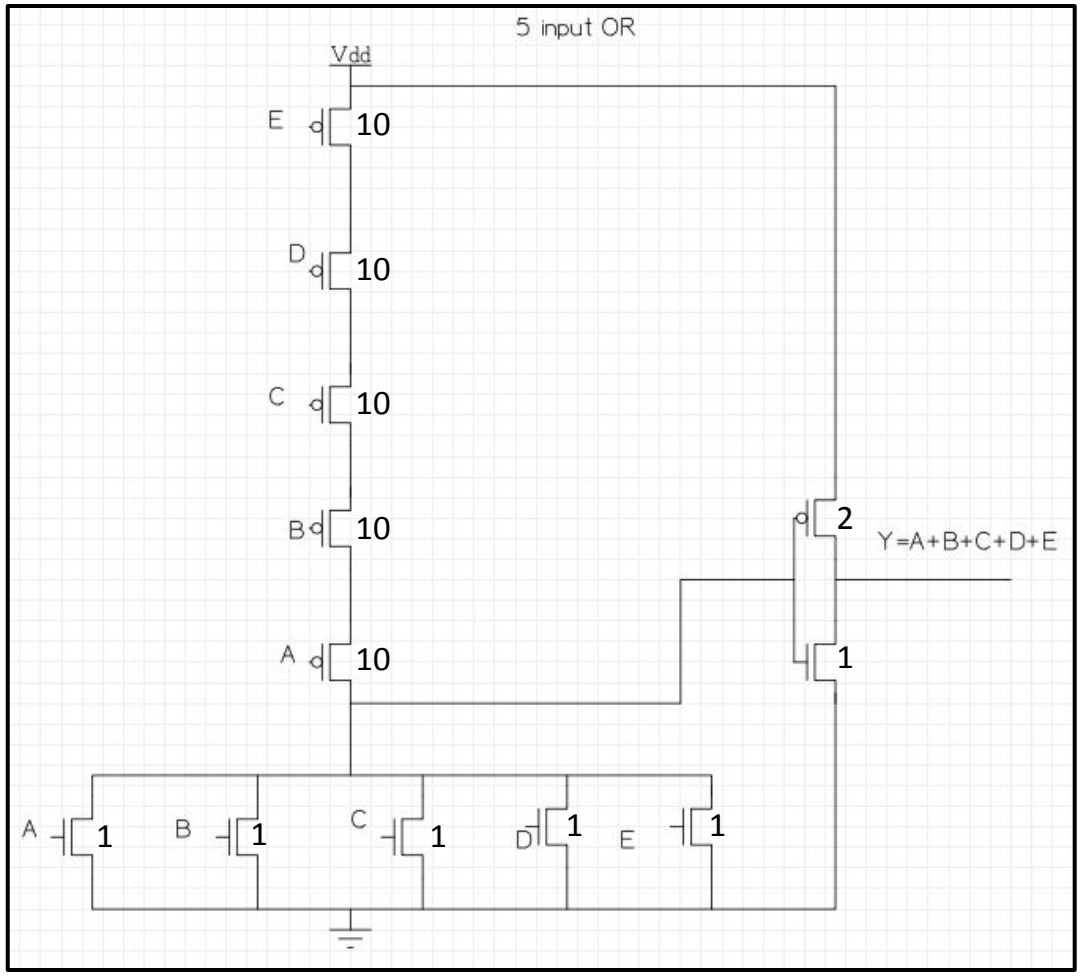


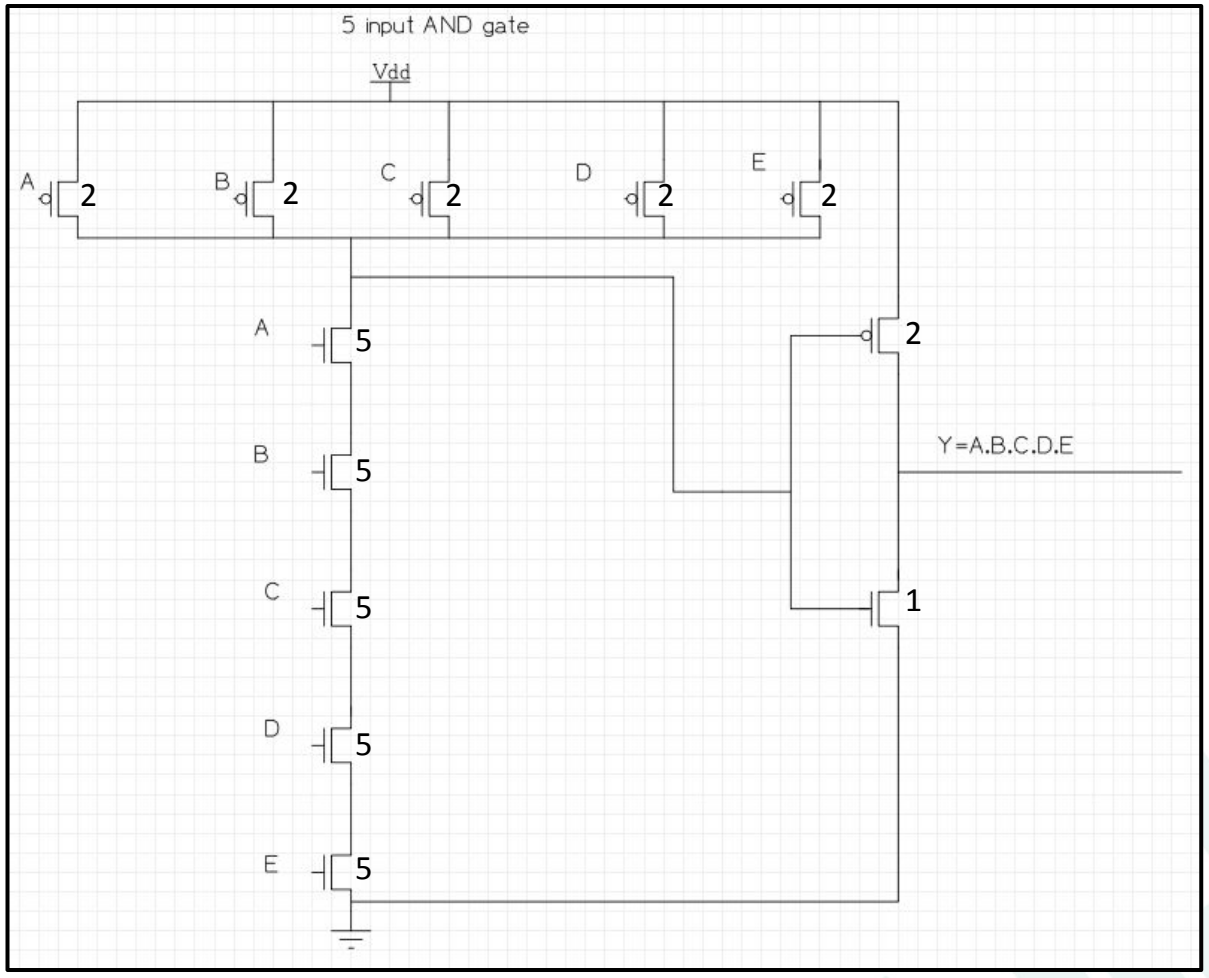
Schematic – CMOS Gates





Schematic – CMOS Gates





Total Number of Transistors

Logic Gate	Number of Transistors in NMOS stack	Number of Transistors in PMOS stack	Total Number of Transistors	Number of Instances within Schematic
2 input XOR gate	6	6	12	8
2-input AND gate	3	3	6	8
2-input OR gate	3	3	6	1
3-input AND gate	4	4	8	3
3-input OR gate	4	4	8	1
4-input AND gate	5	5	10	2
4-input OR gate	5	5	10	1
5-input AND gate	6	6	12	1
5-input OR gate	6	6	12	1
				236

Truth Table

A	B	C_i	S	C_o	*Carry status*
0	0	0	0	0	delete
0	0	1	1	0	delete
0	1	0	1	0	propagate
0	1	1	0	1	propagate
1	0	0	1	0	propagate
1	0	1	0	1	propagate
1	1	0	0	1	generate
1	1	1	1	1	generate

G L Suma Lata (2020). *Generatr,propagate,delete the three important terms in full adder*. YouTube. Available at: https://www.youtube.com/watch?v=dyVS5t3TGmQ

Static and Dynamic Power Dissipation (Typical)

Process Corner: TT Voltage = 1.2 V Temperature = 25 C

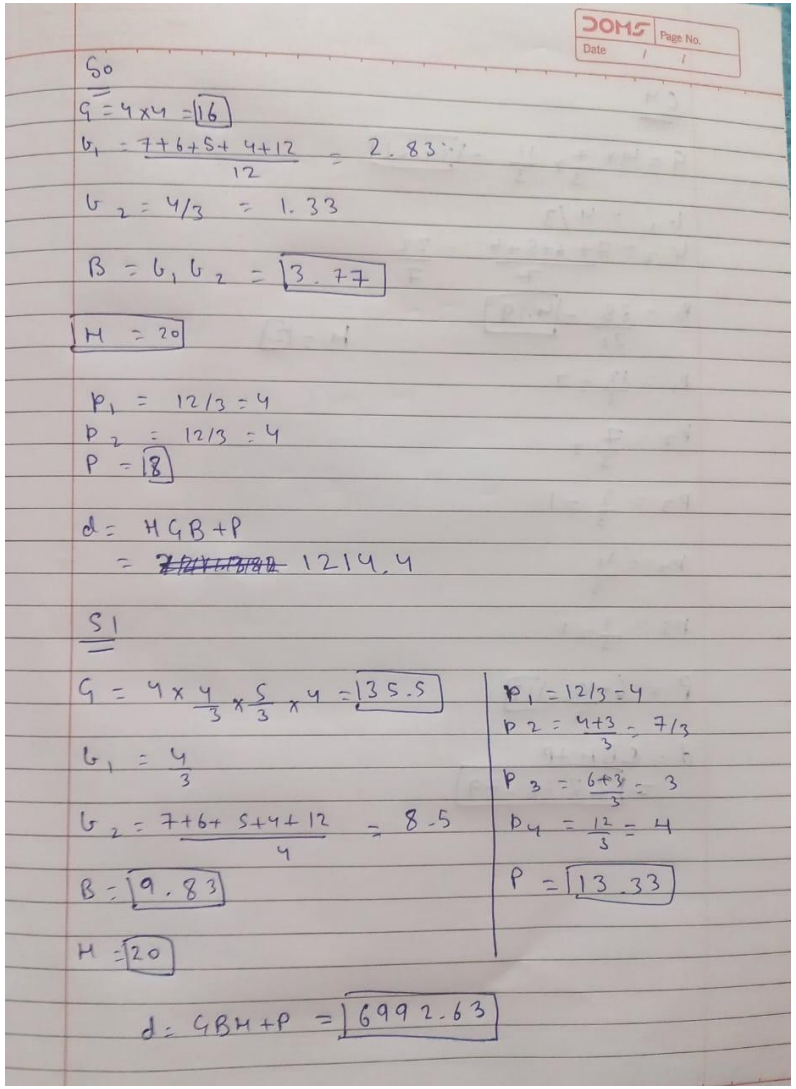
Input Stimuli								Output Toggled (0 to 1)	Leakage Current (Ampere)	Static Power (Watts)	Dynamic Power (Watts)
A0	B0	A1	B1	A2	B2	A3	B3				
1 to 0	1	0	0	0	0	0	0	S0	7.1427E-08	8.5712E-08	9.0932E-06
0	0	1 to 0	1	0	0	0	0	S1	6.8506E-08	8.2208E-08	9.2709E-06
0	0	0	0	1 to 0	1	0	0	S2	5.4038E-08	6.4846E-08	9.2763E-06
0	0	0	0	0	0	1 to 0	1	S3	2.8873E-08	3.4648E-08	8.4421E-06
0	0	0	0	0	0	0 to 1	1	C4	2.8873E-08	3.4648E-08	8.4421E-06

Leakage Current (Maximum)

Process Corner: FF Voltage = 1.32 V Temperature = 125 C

Input Stimuli								Output Toggled (0 to 1)	Leakage Current (Ampere)	Static Power (Watts)	Dynamic Power (Watts)
A0	B0	A1	B1	A2	B2	A3	B3				
1 to 0	1	0	0	0	0	0	0	S0	6.9552E-07	9.1808E-07	1.1392E-05
0	0	1 to 0	1	0	0	0	0	S1	7.1608E-07	9.4523E-07	1.1609E-05
0	0	0	0	1 to 0	1	0	0	S2	6.8902E-07	9.0951E-07	1.1574E-05
0	0	0	0	0	0	1 to 0	1	S3	6.3229E-07	8.3462E-07	1.0501E-05
0	0	0	0	0	0	0 to 1	1	C4	6.3229E-07	8.3462E-07	1.0501E-05

Path Effort



Go

$G = 4 \times 4 = 16$

$b_1 = \frac{7+6+5+4+12}{12} = 2.83$

$b_2 = 4/3 = 1.33$

$B = b_1 b_2 = 3.77$

$H = 20$

$P_1 = 12/3 = 4$

$P_2 = 12/3 = 4$

$P = 8$

$d = HGB + P$

$= 1214.4$

S1

$G = 4 \times \frac{4}{3} \times \frac{5}{3} \times 4 = 35.5$

$b_1 = \frac{4}{3}$

$b_2 = \frac{7+6+5+4+12}{4} = 8.5$

$B = 9.83$

$H = 20$

$d = GBH + P = 6992.63$

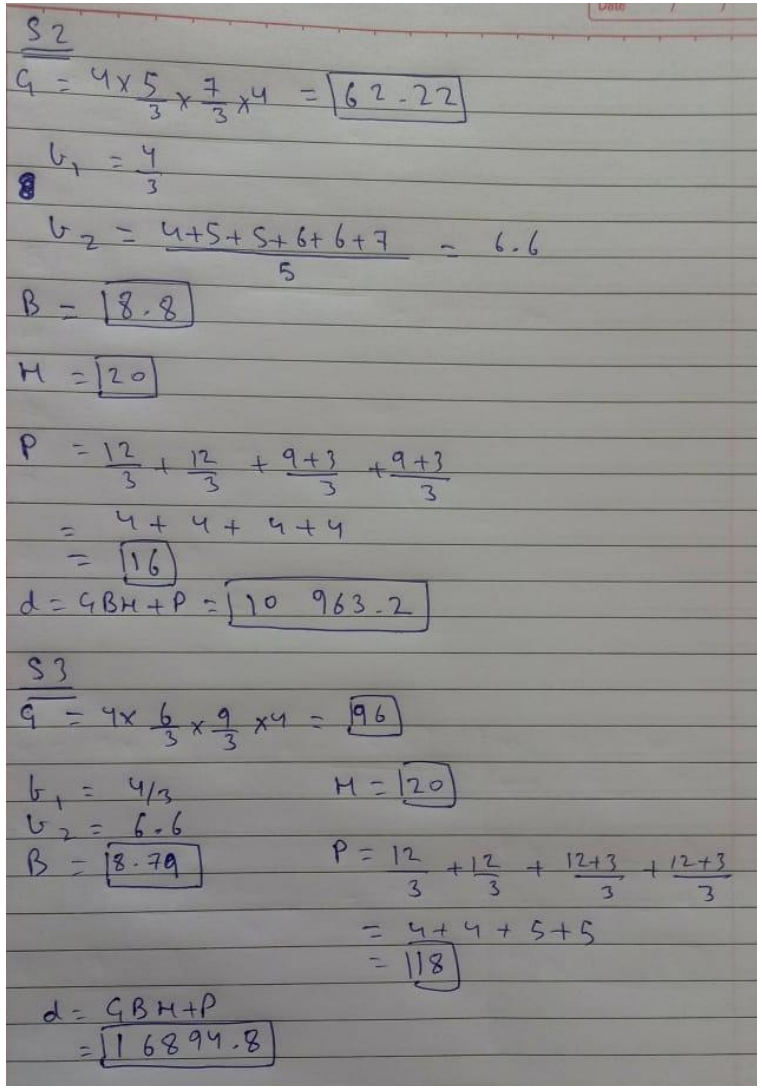
$P_1 = 12/3 = 4$

$P_2 = \frac{4+3}{3} = 7/3$

$P_3 = \frac{6+3}{3} = 3$

$P_4 = \frac{12}{3} = 4$

$P = 13.33$



S2

$G = 4 \times \frac{5}{3} \times \frac{7}{3} \times 4 = 62.22$

$b_1 = \frac{4}{3}$

$b_2 = \frac{4+5+5+6+6+7}{5} = 6.6$

$B = 8.8$

$H = 20$

$P = \frac{12}{3} + \frac{12}{3} + \frac{9+3}{3} + \frac{9+3}{3}$

$= 4 + 4 + 4 + 4$

$= 16$

$d = GBH + P = 10\,963.2$

S3

$G = 4 \times \frac{6}{3} \times \frac{9}{3} \times 4 = 96$

$b_1 = 4/3$

$b_2 = 6.6$

$B = 8.79$

$H = 20$

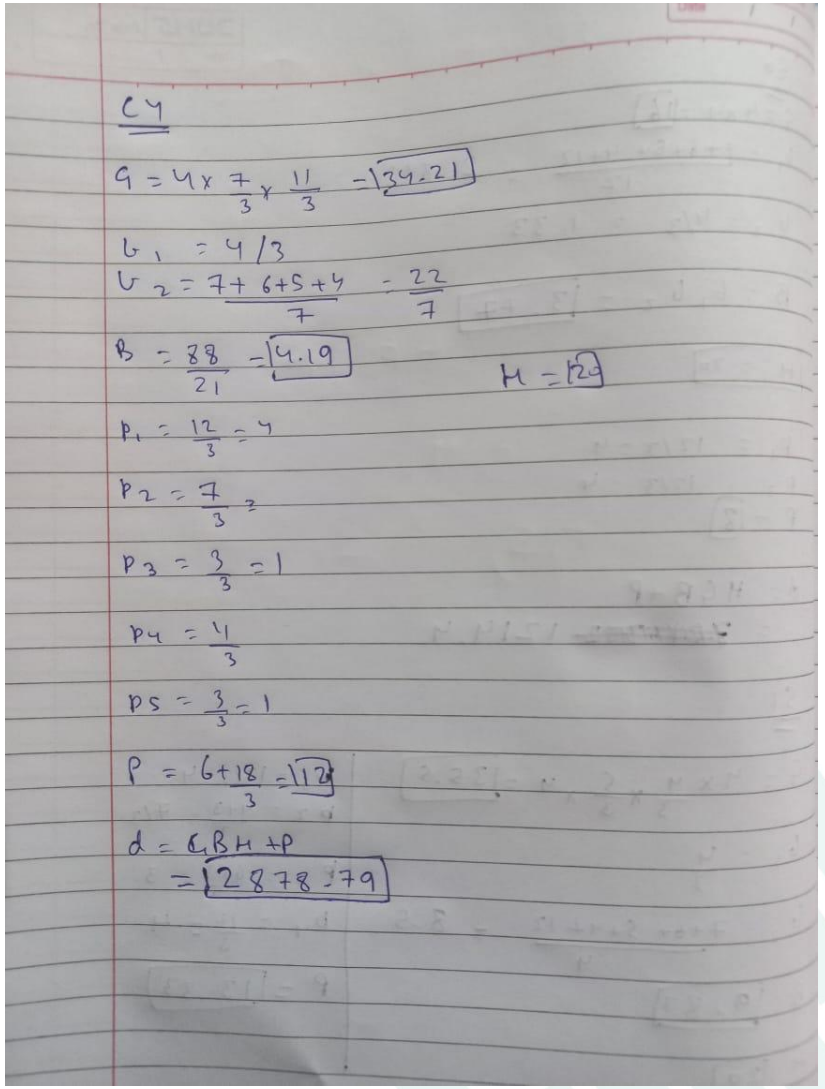
$P = \frac{12}{3} + \frac{12}{3} + \frac{12+3}{3} + \frac{12+3}{3}$

$= 4 + 4 + 5 + 5$

$= 118$

$d = GBH + P$

$= 16894.8$



CY

$G = 4 \times \frac{7}{3} \times \frac{11}{3} = 34.21$

$b_1 = 4/3$

$b_2 = \frac{7+6+5+4}{7} = \frac{22}{7}$

$B = \frac{88}{21} = 4.19$

$H = 20$

$P_1 = \frac{12}{3} = 4$

$P_2 = \frac{7}{3} =$

$P_3 = \frac{3}{3} = 1$

$P_4 = \frac{4}{3}$

$P_5 = \frac{3}{3} = 1$

$P = \frac{6+18}{3} = 12$

$d = GBH + P$

$= 2878.79$

Propagation Delay

Process Corner: SS Voltage = 1.08 V Temperature = 125 C

Input Stimuli								Output Toggled	Propagation Delay (Seconds)
A0	B0	A1	B1	A2	B2	A3	B3		
PULSE	1	0	0	0	0	0	0	S0	4.3992E-10
0	0	PULSE	1	0	0	0	0	S1	4.6625E-10
0	0	0	0	PULSE	1	0	0	S2	4.6805E-10
0	0	0	0	0	0	PULSE	1	S3	4.4550E-10
0	0	0	0	0	0	PULSE	1	C4	3.6596E-10

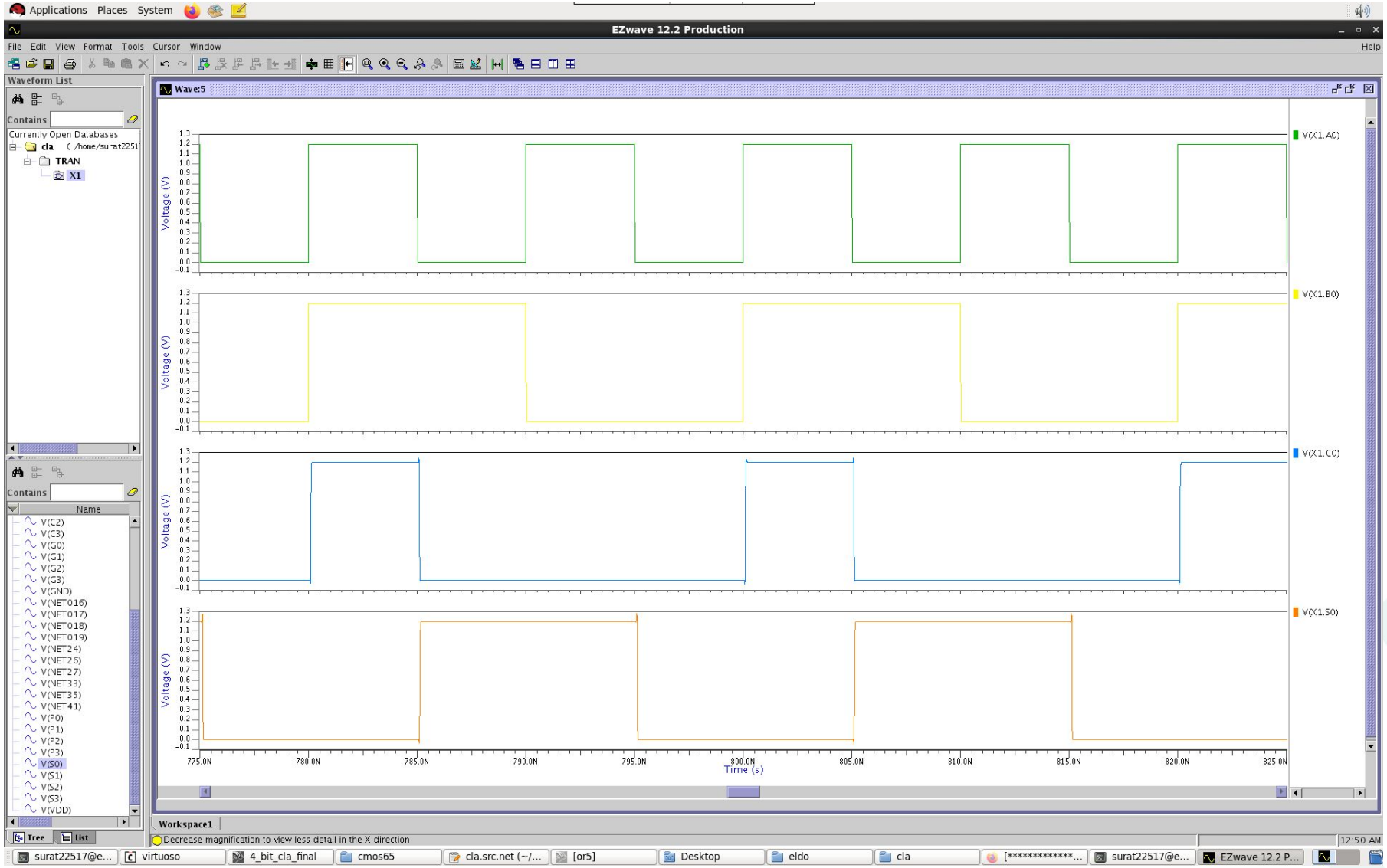
Activity Factor

```
P(S0) = 0.5, AF(S0) = 0.25
P(C1) = 0.4375, AF(C1) = 0.24609
P(S1) = 0.5, AF(S1) = 0.25
P(C2) = 0.41406, AF(C2) = 0.24261
P(S2) = 0.5, AF(S2) = 0.25
P(C3) = 0.40527, AF(C3) = 0.24103
P(S3) = 0.5, AF(S3) = 0.25
P(C4) = 0.40198, AF(C4) = 0.24039
```

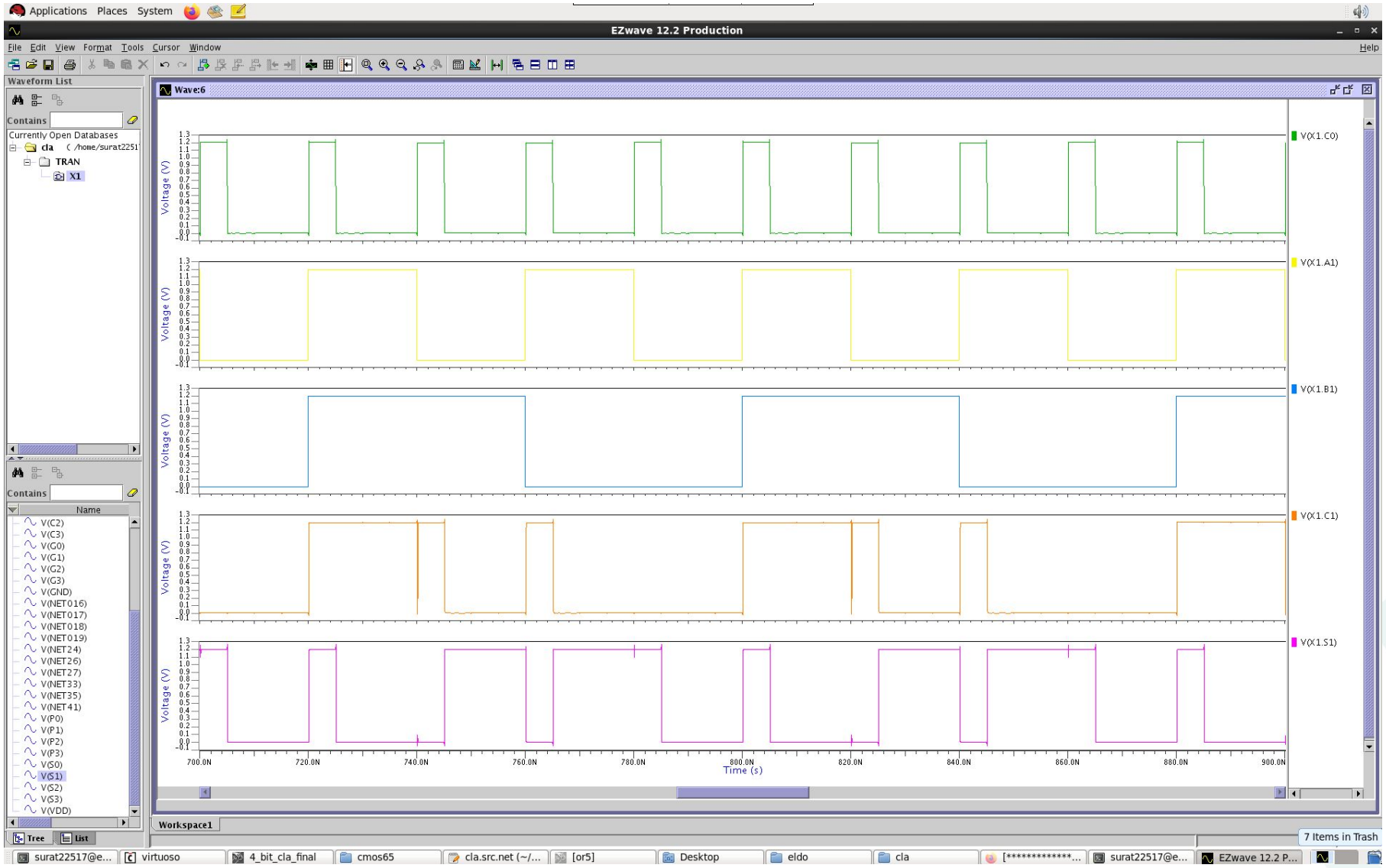
```
function activityFactor = computeActivityFactor(probability)
    % computeActivityFactor Computes the activity factor given a probability
    % Input:
    %   probability - The probability value (scalar, 0 <= probability <= 1)
    % Output:
    %   activityFactor - The computed activity factor, p * (1 - p)

    % Validate the input
    if probability < 0 || probability > 1
        error('Probability must be in the range [0, 1].');
    end

    % Calculate the activity factor
    activityFactor = probability * (1 - probability);
end

function p_ci = compute_pci(p_gi, p_pi, p_ci_prev)
    % compute_pci Computes the probability of carry out (c(i+1))
    % Inputs:
    %   p_gi - Probability of generate (g(i))
    %   p_pi - Probability of propagate (p(i))
    %   p_ci_prev - Probability of carry in (c(i))
    % Output:
    %   p_ci - Probability of carry out (c(i+1))

    p_pic_prev = p_pi * p_ci_prev;
    p_ci = 1 - ((1 - p_gi) * (1 - p_pic_prev));
end

function p_si = compute_psi(p_pi, p_ci)
    % compute_psi Computes the probability of sum (s(i))
    % Inputs:
    %   p_pi - Probability of propagate (p(i))
    %   p_ci - Probability of carry in (c(i))
    % Output:
    %   p_si - Probability of sum (s(i))

    p_si = (p_pi * (1 - p_ci)) + ((1 - p_pi) * p_ci);
end
```

```
% pi = ai xor bi
% gi = ai and bi
p_p0 = 1/2; p_p1 = 1/2; p_p2 = 1/2; p_p3 = 1/2;
p_g0 = 1/4; p_g1 = 1/4; p_g2 = 1/4; p_g3 = 1/4;

% Initial carry-in probability
p_c0 = 1/2;

% Compute carry probabilities
p_c1 = compute_pci(p_g0, p_p0, p_c0);
p_c2 = compute_pci(p_g1, p_p1, p_c1);
p_c3 = compute_pci(p_g2, p_p2, p_c2);
p_c4 = compute_pci(p_g3, p_p3, p_c3);

% Compute sum probabilities
p_s0 = compute_psi(p_p0, p_c0);
p_s1 = compute_psi(p_p1, p_c1);
p_s2 = compute_psi(p_p2, p_c2);
p_s3 = compute_psi(p_p3, p_c3);

% Compute activity factors
af_s0 = computeActivityFactor(p_s0);
af_s1 = computeActivityFactor(p_s1);
af_s2 = computeActivityFactor(p_s2);
af_s3 = computeActivityFactor(p_s3);
af_c1 = computeActivityFactor(p_c1);
af_c2 = computeActivityFactor(p_c2);
af_c3 = computeActivityFactor(p_c3);
af_c4 = computeActivityFactor(p_c4);

% Display results
disp("P(S0) = " + num2str(p_s0) + ", AF(S0) = " + num2str(af_s0));
disp("P(C1) = " + num2str(p_c1) + ", AF(C1) = " + num2str(af_c1));
disp("P(S1) = " + num2str(p_s1) + ", AF(S1) = " + num2str(af_s1));
disp("P(C2) = " + num2str(p_c2) + ", AF(C2) = " + num2str(af_c2));
disp("P(S2) = " + num2str(p_s2) + ", AF(S2) = " + num2str(af_s2));
disp("P(C3) = " + num2str(p_c3) + ", AF(C3) = " + num2str(af_c3));
disp("P(S3) = " + num2str(p_s3) + ", AF(S3) = " + num2str(af_s3));
disp("P(C4) = " + num2str(p_c4) + ", AF(C4) = " + num2str(af_c4));
```

Functionality Verification



Functionality Verification



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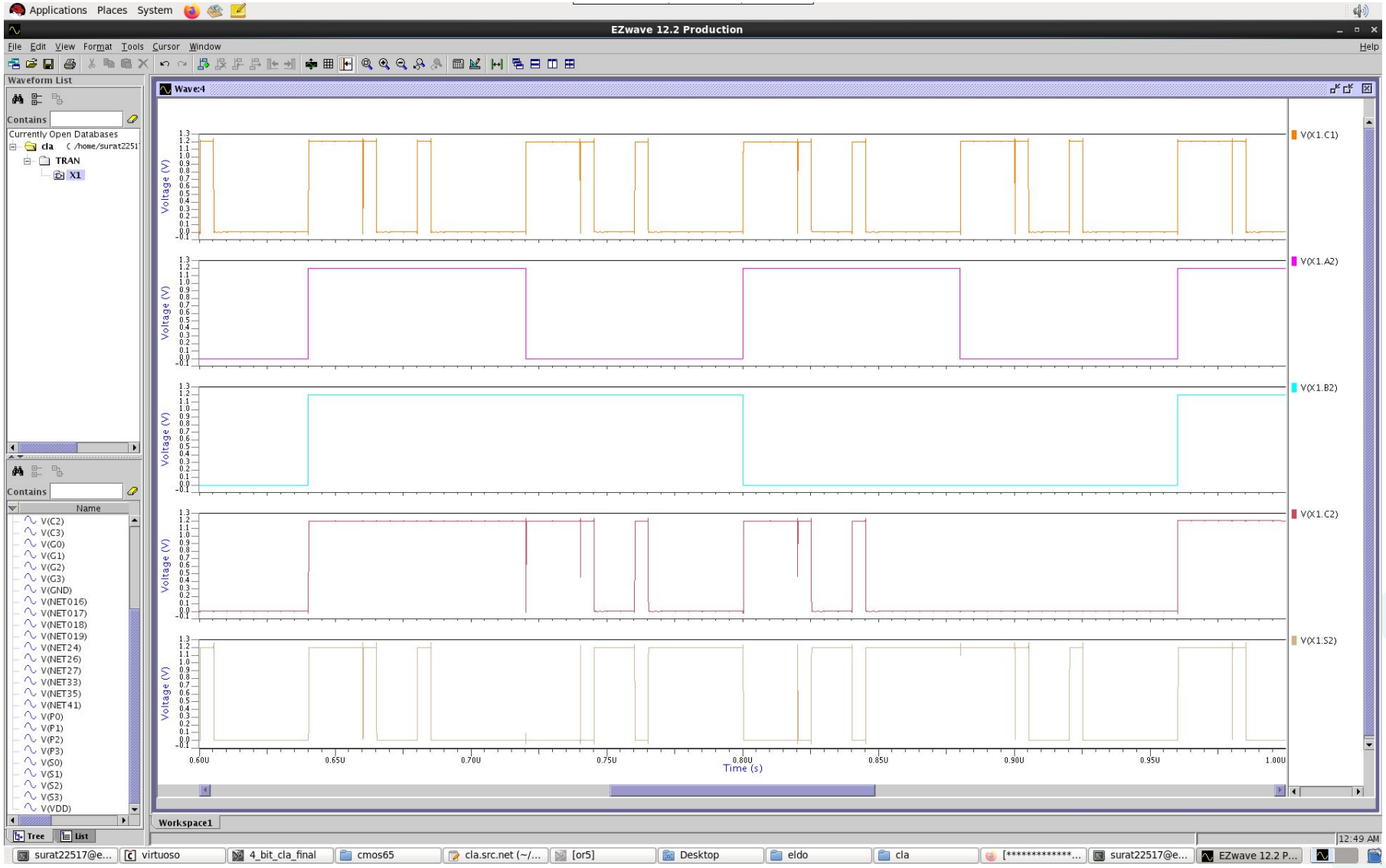

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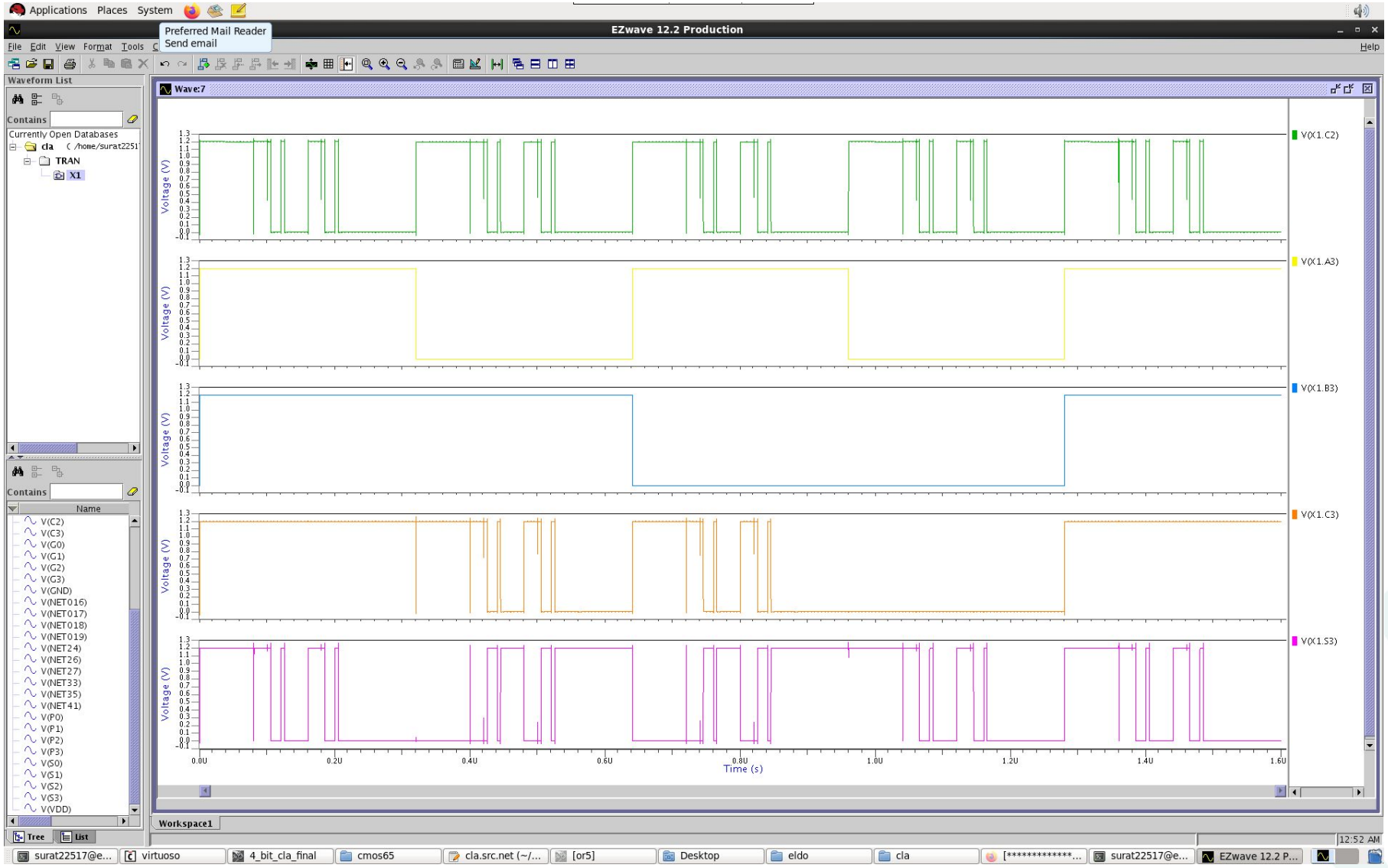

Work Distribution

- Surat Sathi Samanta (2022517) - Virtuoso Schematic, Stimuli Design, Path Effort, Functionality Verification
- Annika Sinha (2022082) - XCircuit Schematic , Transistor Count, Truth Table, Timing Analysis
- Riya Sachdeva (2022411) - Equations, Power Dissipation, Leakage Current, Activity Factor