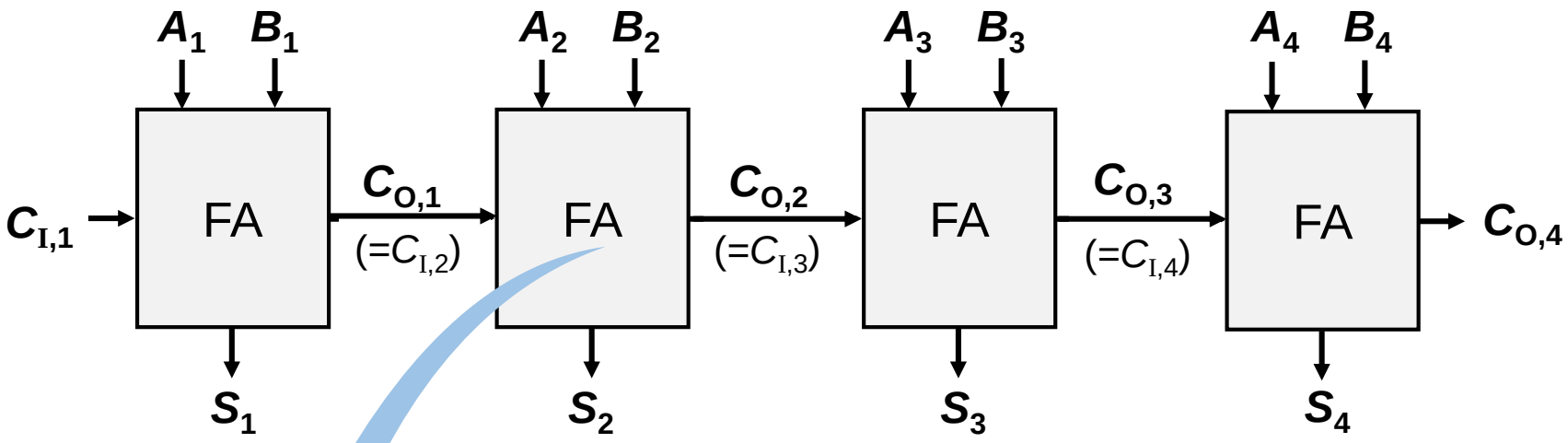
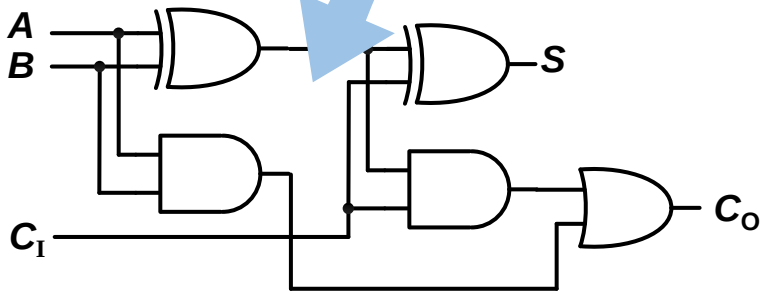
Multibit Data Addition; 4bit
Carry Ripple Adder

- $A_4A_3A_2A_1 + B_4B_3B_2B_1 = C_{O,4}S_4S_3S_2S_1$





Adder Delay t_{Adder}=?

$t_{Adder} = (N-1)t_{Carry} + t_{Sum}$

Can't we make this faster?

Any other structures than tree adders?

Adder Circuits (2)

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Carry Lookahead Adder

- For each stage *k*,

$$C_{O,k} = A_kB_k + C_{I,k}(A_k \oplus B_k)$$

- If we define P_k and G_k at k^{th} stage,

$$P_k = A_k \oplus B_k,\ G_k = A_kB_k,$$

$$C_{O,k} = G_k + P_kC_{I,k}$$

- Thus,

$C_{O,1} = G_1 + P_1C_{I,1} = C_{I,2}$

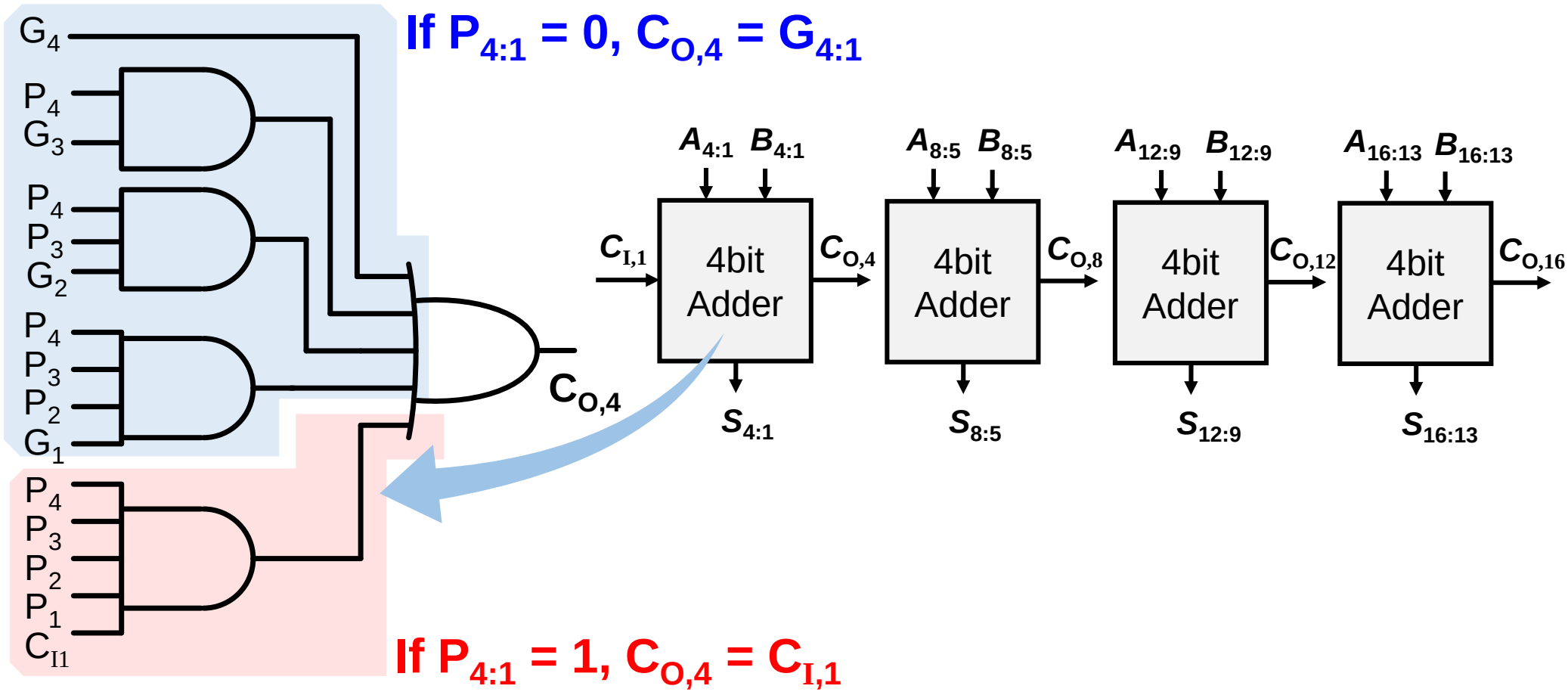
$C_{O,2} = G_2 + P_1C_{I,1} = C_{I,3} = G_2 + P_2(\mathbf{G_1 + P_1C_{I,1}})$

$C_{O,3} = G_3 + P_3C_{I,2} = C_{I,4} = G_3 + P_3(G_2 + P_2C_{I,2})$

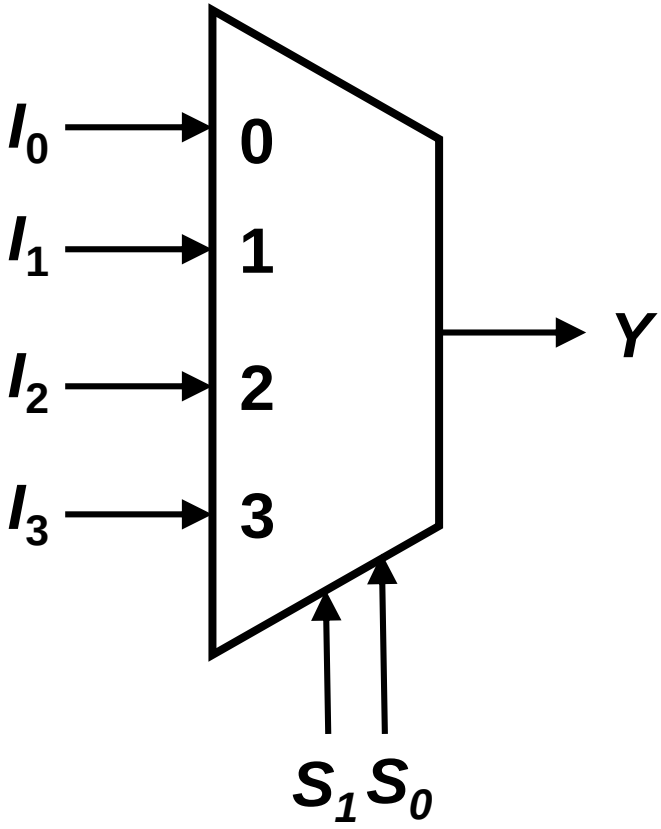
$= G_3 + P_3G_2 + P_3P_2G_1 + P_3P_2P_1C_{I,1}$

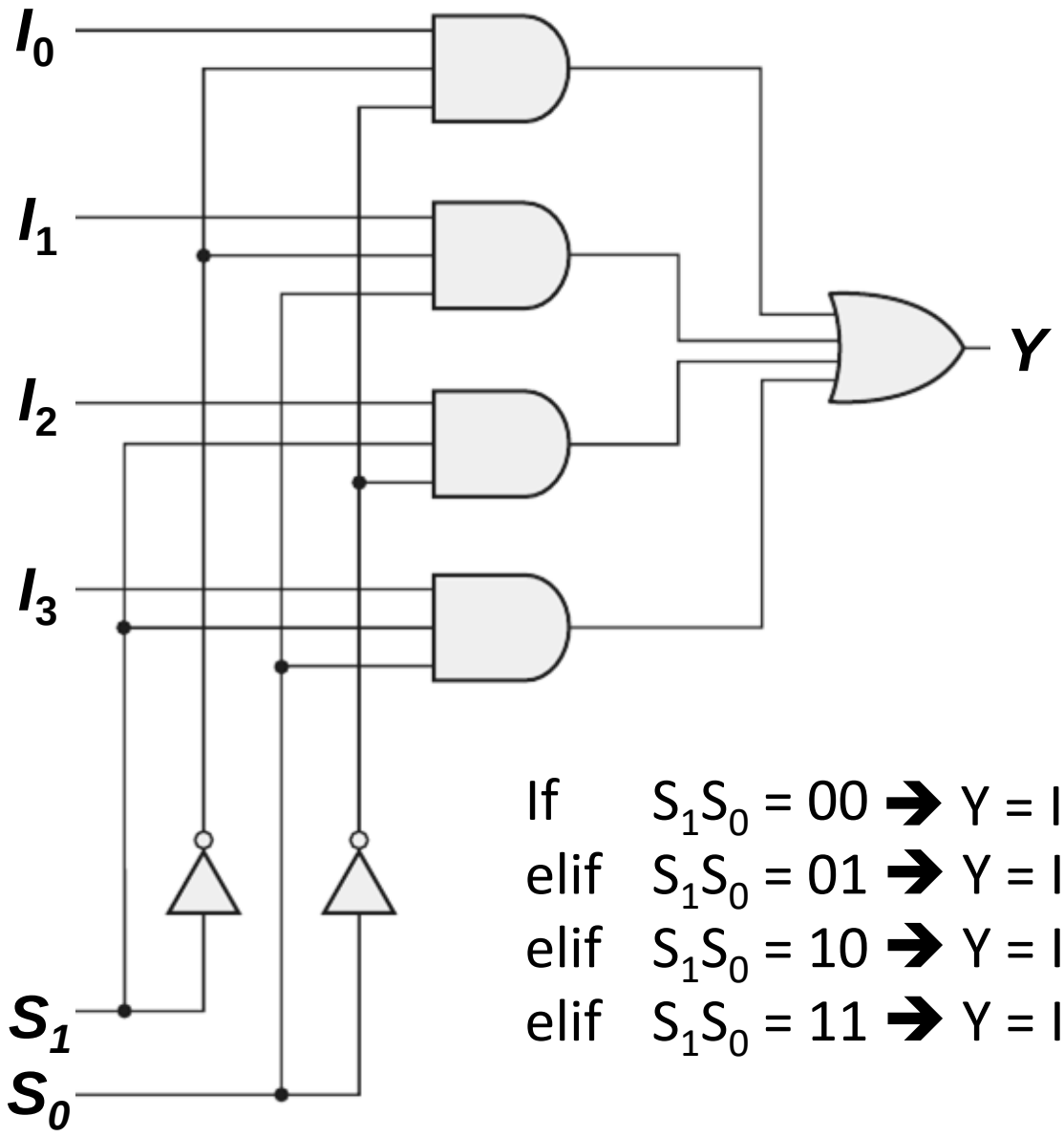
$C_{O,4} = G_4 + P_4G_3 + P_4P_3G_2 + P_4P_3P_2G_1 + P_4P_3P_2P_1C_{I,1}$

Four 4bit Adders for 16 Bit Addition



Revisit MUX





If $S_1S_0 = 00 \rightarrow Y = I_0$

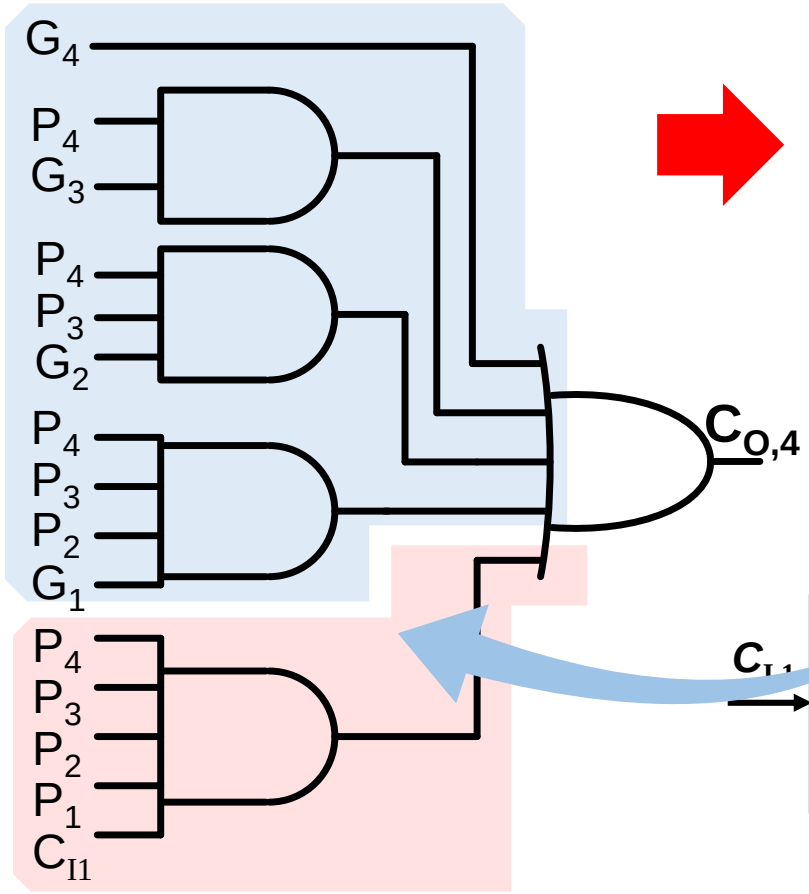
elif $S_1S_0 = 01 \rightarrow Y = I_1$

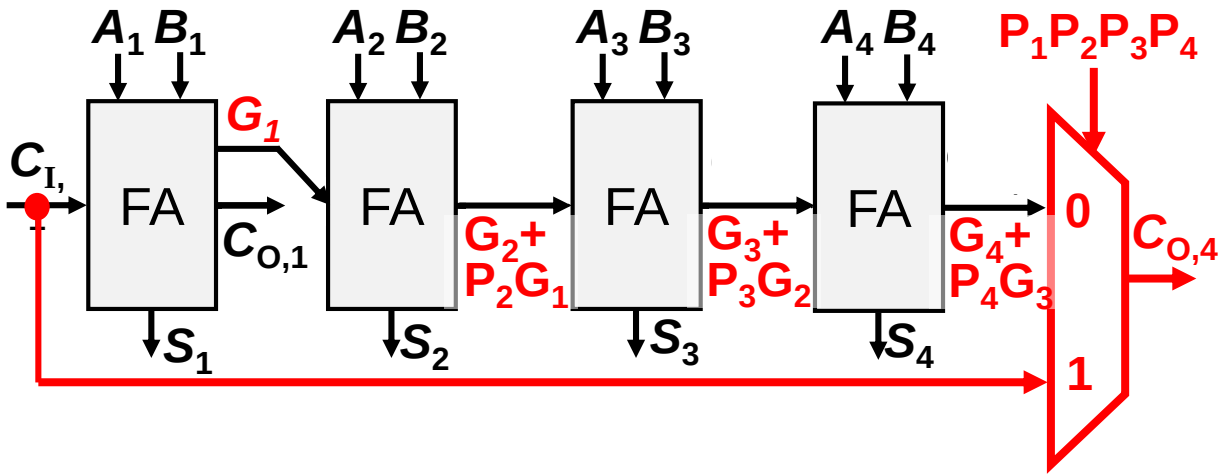
elif $S_1S_0 = 10 \rightarrow Y = I_2$

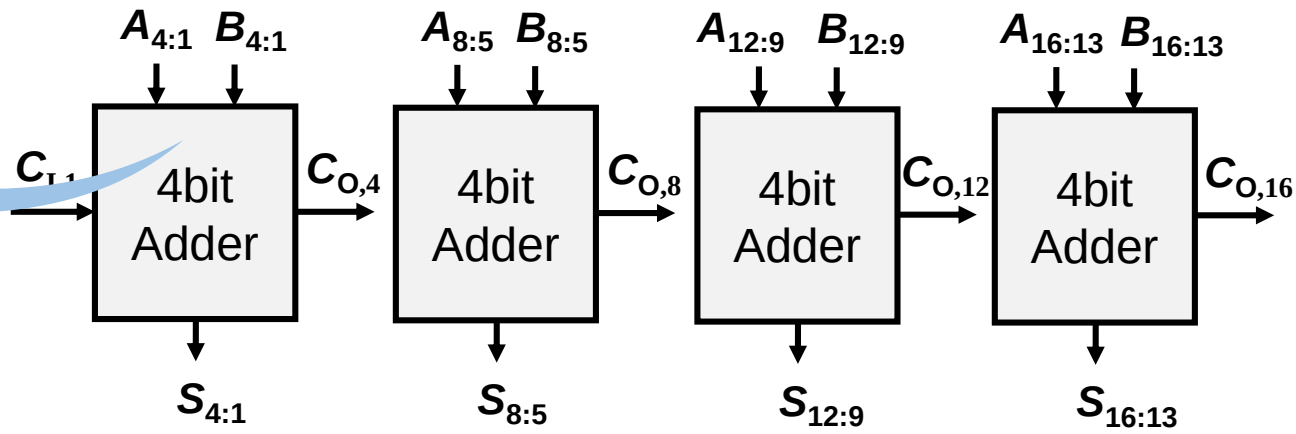
elif $S_1S_0 = 11 \rightarrow Y = I_3$

MUX Implementation of Carry Lookahead Adder

If $P_{4:1} = 0$, $C_{O,4} = G_{4:1}$

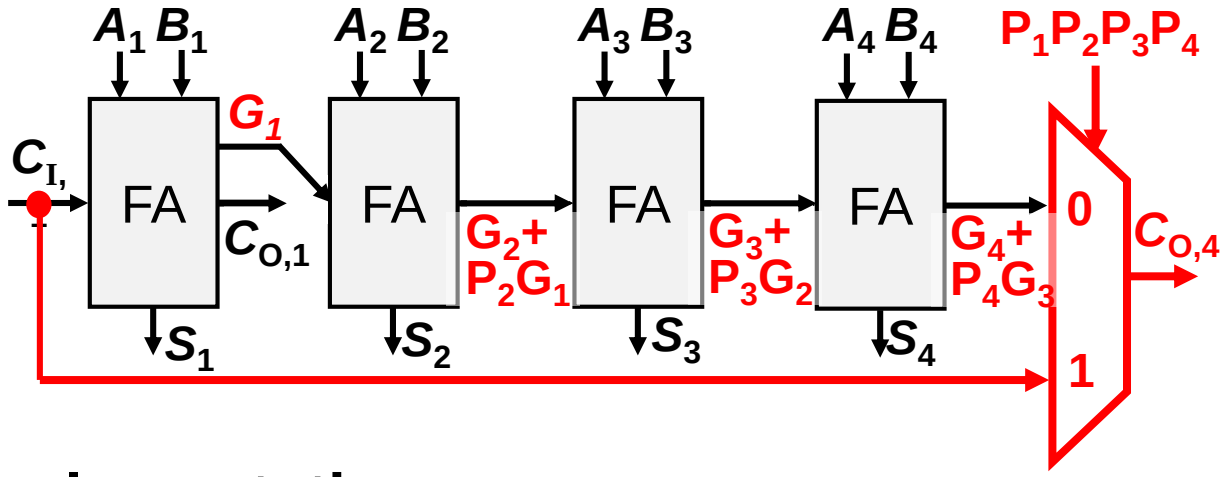




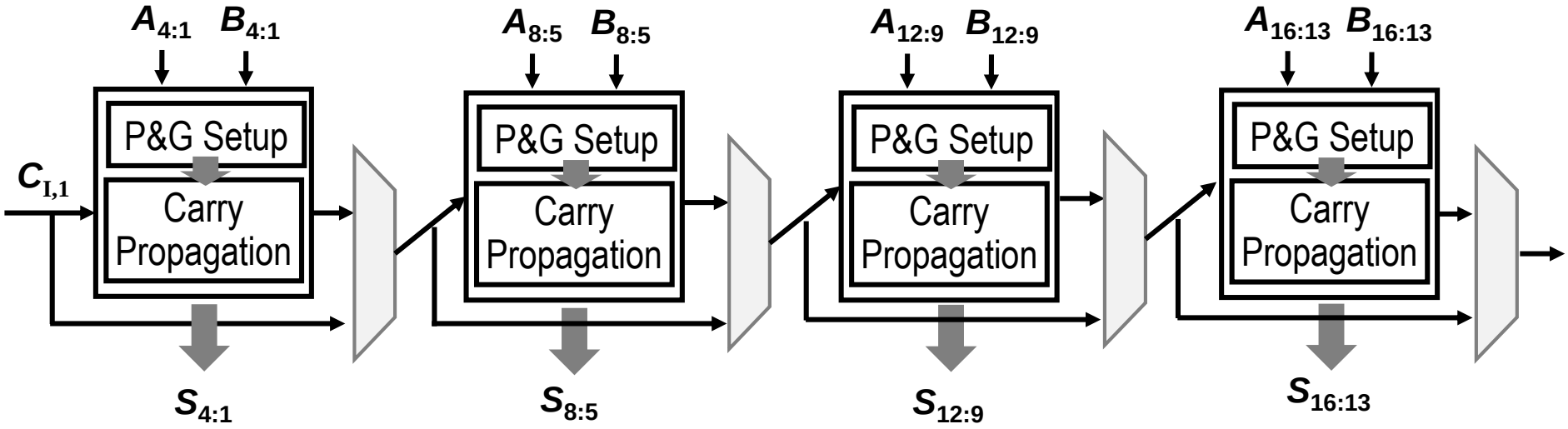


If $P_{4:1} = 1$, $C_{O,4} = C_{I,1}$

Carry Skip Adder



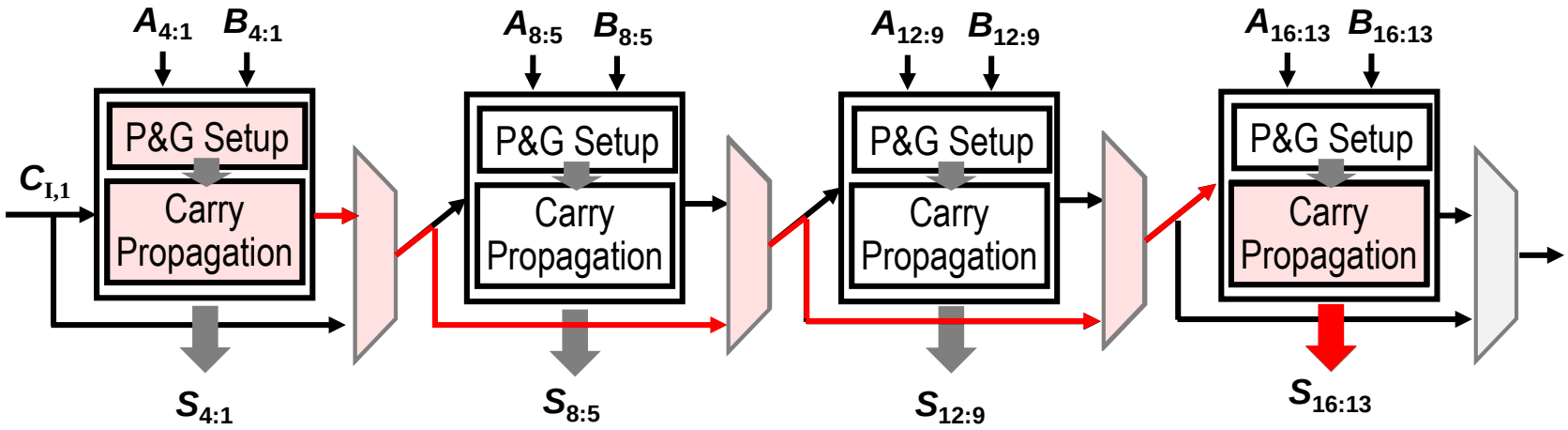
16bit Adder Implementation:



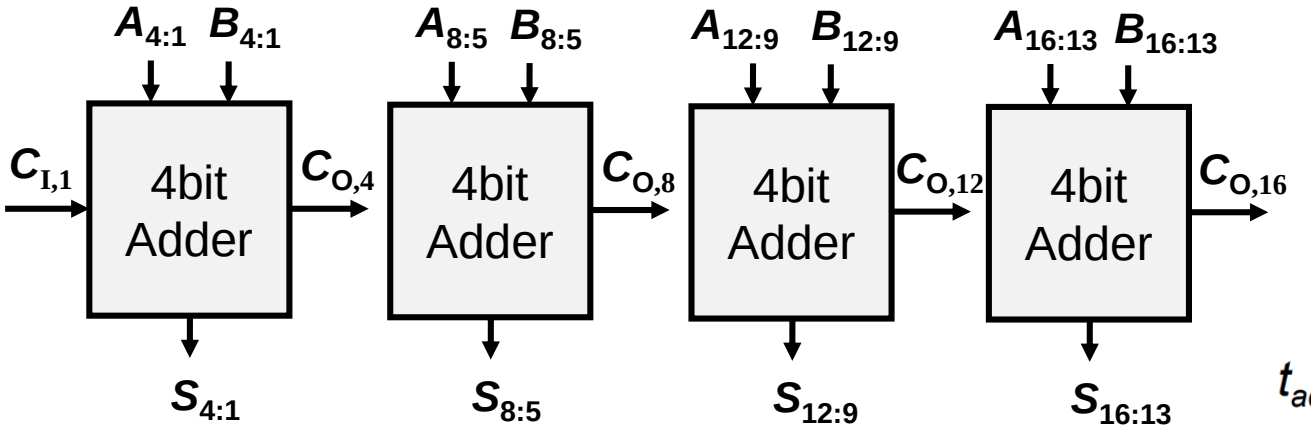
Critical Path Comparison

- Carry lookahead adder:

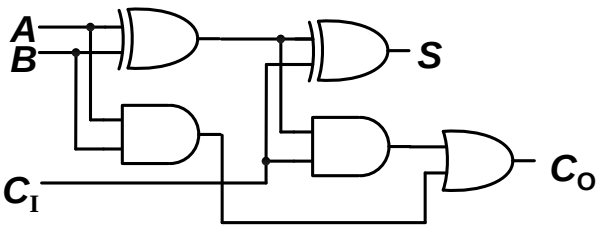
$$t_{adder} = t_{setup} + M_{tcarry} + (N/M - 1)t_{bypass} + (M - 1)t_{carry} + t_{sum}$$



- Carry ripple adder

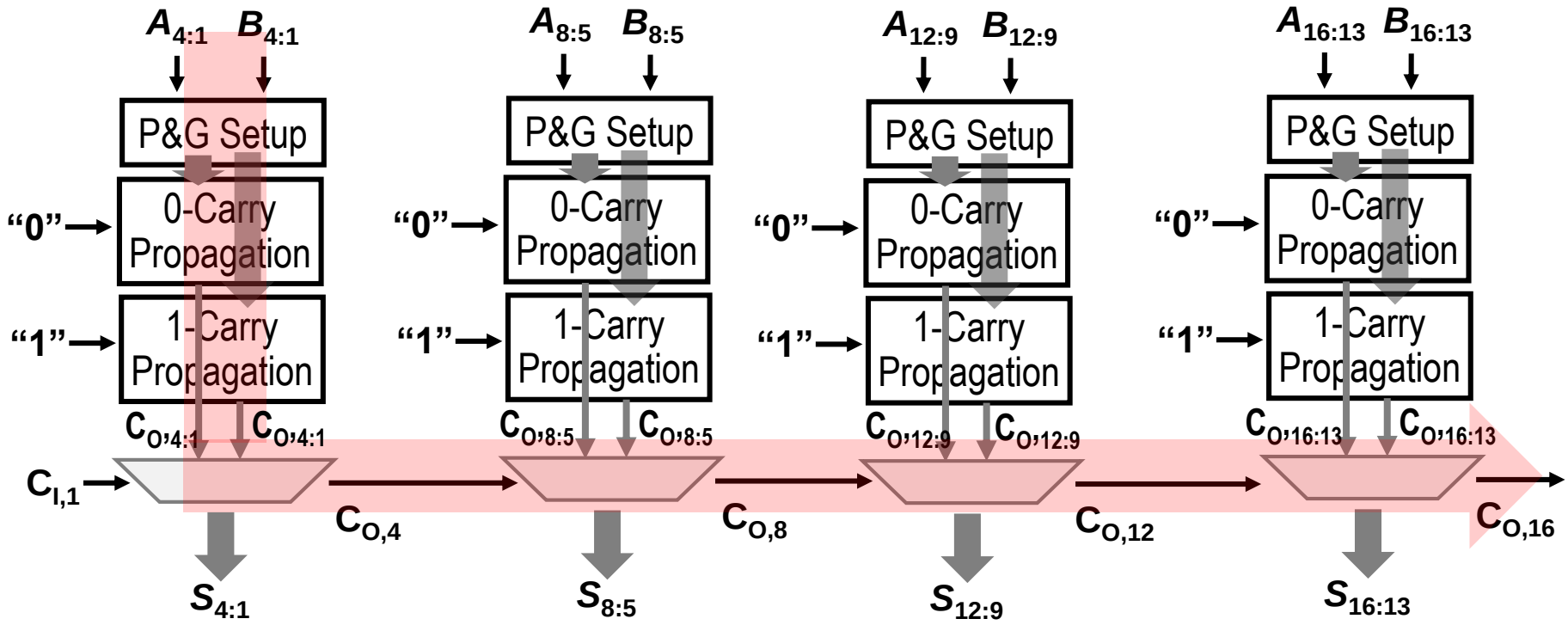


FA:



$$t_{adder} = (N\text{-}1)t_{carry} + t_{sum}$$

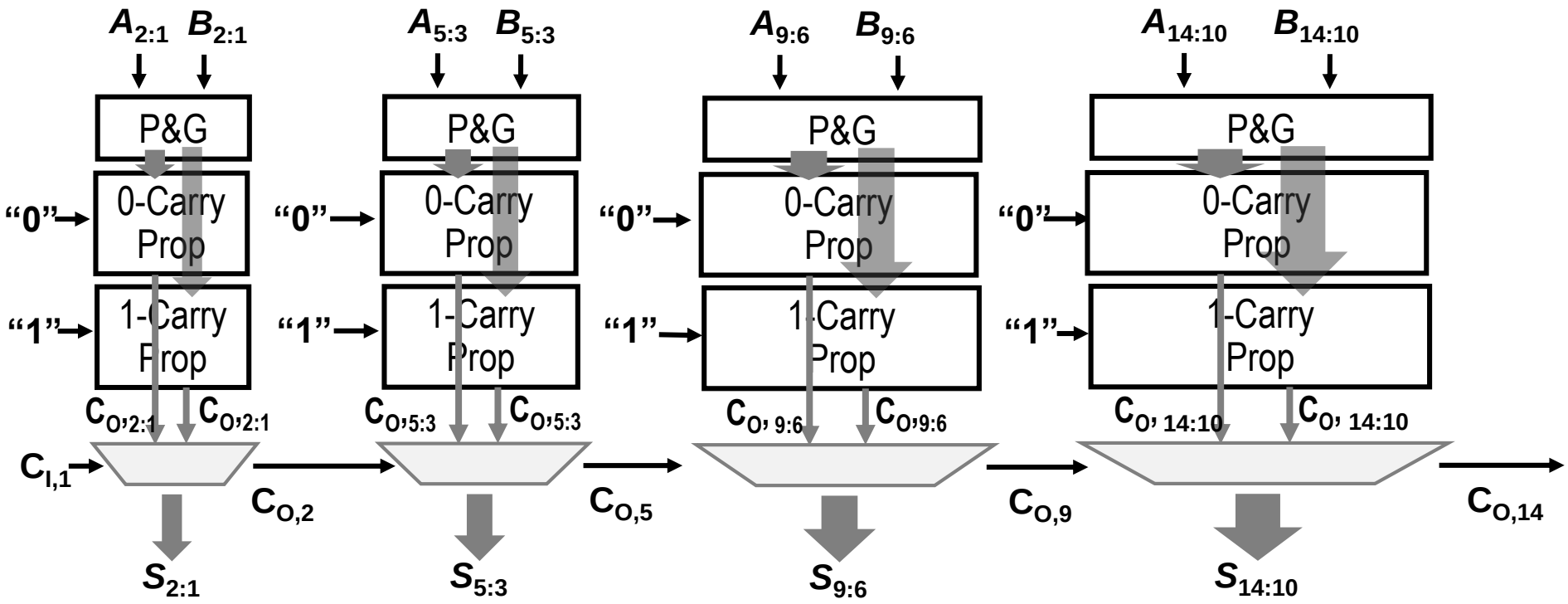
Carry Select Adder



Can you specify the critical path?

$t_{add} = t_{setup} + (N/M)t_{carry} + Mt_{mux} + t_{sum}$

Gradual Bit-Length Carry Select Adder



Checkpoints

- ✓Carry skip (bypass) adder
- ✓Carry select adder