EE 3755

Computer Arithmetic

Handout #10

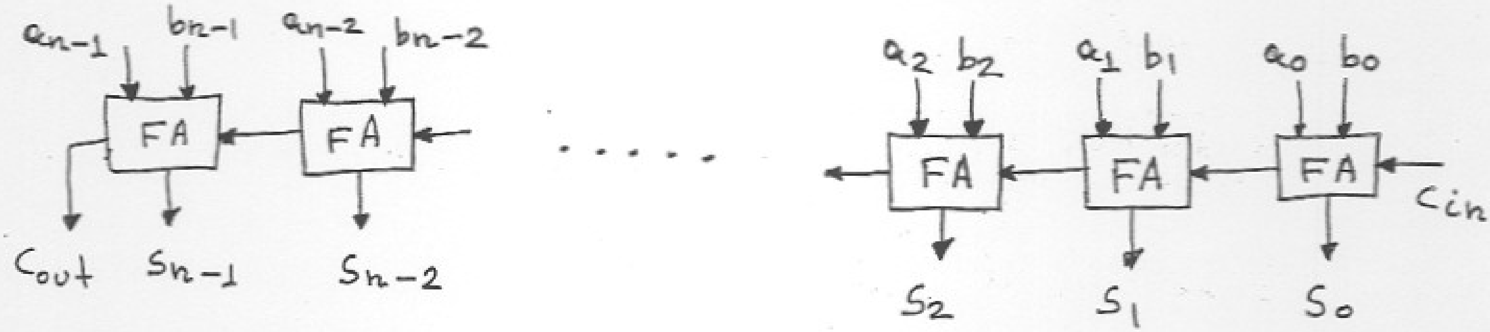
EE 3755

Ripple Carry Adder

Consider two n-bit binary numbers

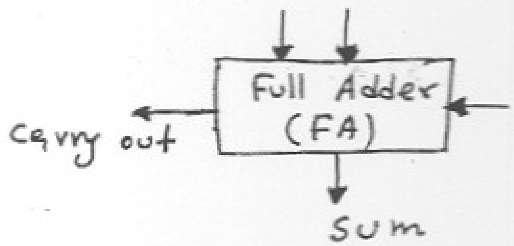
$A = (a_{n-1} a_{n-2} \cdots a_1 a_0)_2$; $B = (b_{n-1} b_{n-2} \cdots b_1 b_0)_2$

One two-operand adder (adding A and B) is the ripple carry adder shown below:



where

FA indicates Full Adder



The delay through an n-bit ripple carry adder is $n \times D_{FA}$ where D_{FA} is the delay through a Full Adder

Unsigned array multipliers

Consider two 5-bit unsigned numbers $A = a_4 a_3 a_2 a_1 a_0$ and $B = b_4 b_3 b_2 b_1 b_0$ where a_4 and b_4 are the most significant bits of A and B while a_0 and b_0 are the least significant bits of A and B respectively.

The table below describes the multiplication operation.

$$
\begin{array}{cccccccccccc}
 & & & & & & a_4 & a_3 & a_2 & a_1 & a_0 & = A \\
 & & & & & \times) & b_4 & b_3 & b_2 & b_1 & b_0 & = B \\
\hline
 & & & & & & a_4b_0 & a_3b_0 & a_2b_0 & a_1b_0 & a_0b_0 & \\
 & & & & & a_4b_1 & a_3b_1 & a_2b_1 & a_1b_1 & a_0b_1 & & \\
 & & & & a_4b_2 & a_3b_2 & a_2b_2 & a_1b_2 & a_0b_2 & & & \\
 & & & a_4b_3 & a_3b_3 & a_2b_3 & a_1b_3 & a_0b_3 & & & & \\
 & +) & a_4b_4 & a_3b_4 & a_2b_4 & a_1b_4 & a_0b_4 & & & & & \\
\hline
 & P_9 & P_8 & P_7 & P_6 & P_5 & P_4 & P_3 & P_2 & P_1 & P_0 & = P \\
\hline
\end{array}
$$

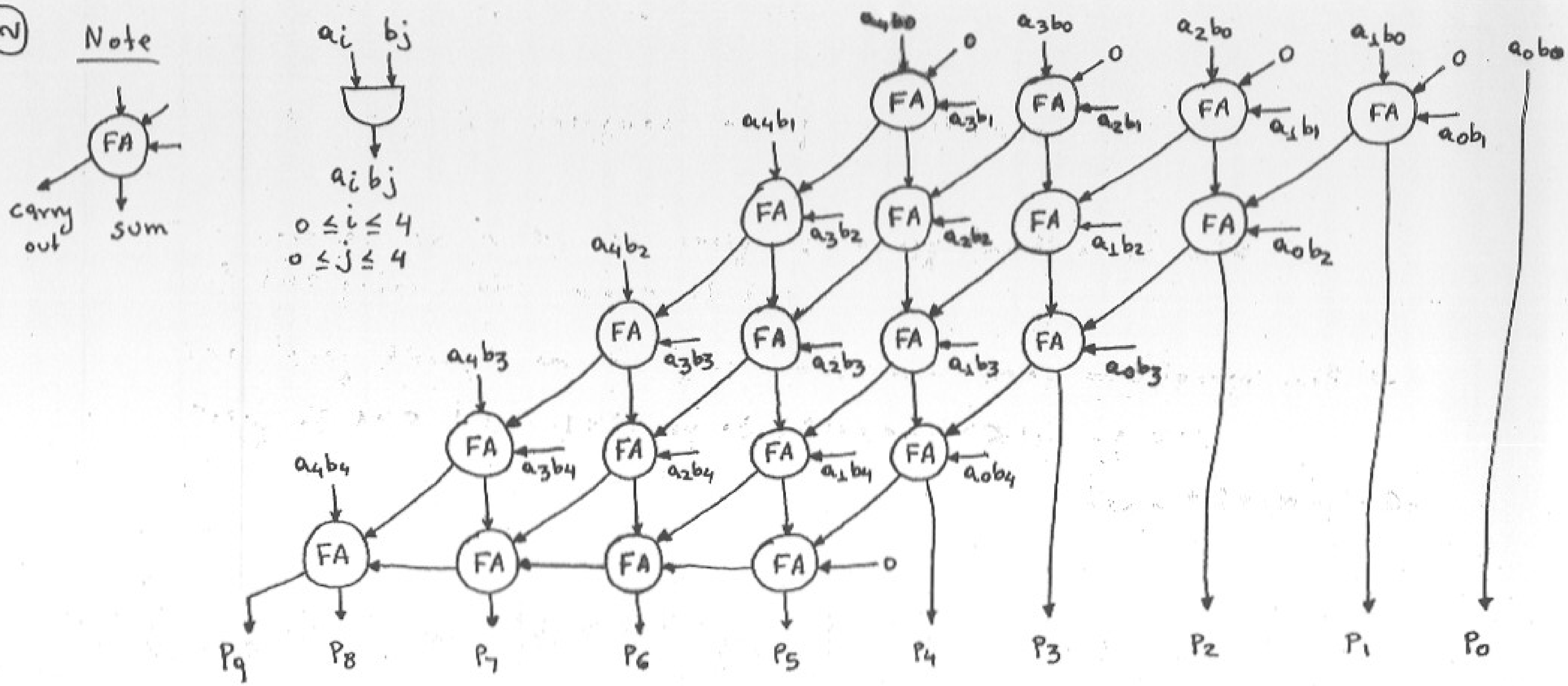
Summand matrix describing the add-shift operations in a 5-by-5 unsigned multiplication

- In the above, every term $a_i b_j$ denotes the AND operation between bits a_i and b_j. Each term $a_i b_j$ is called a summand.

•• P_9 and P_0 are the most significant and least significant bits of the product respectively.

(2)

Note

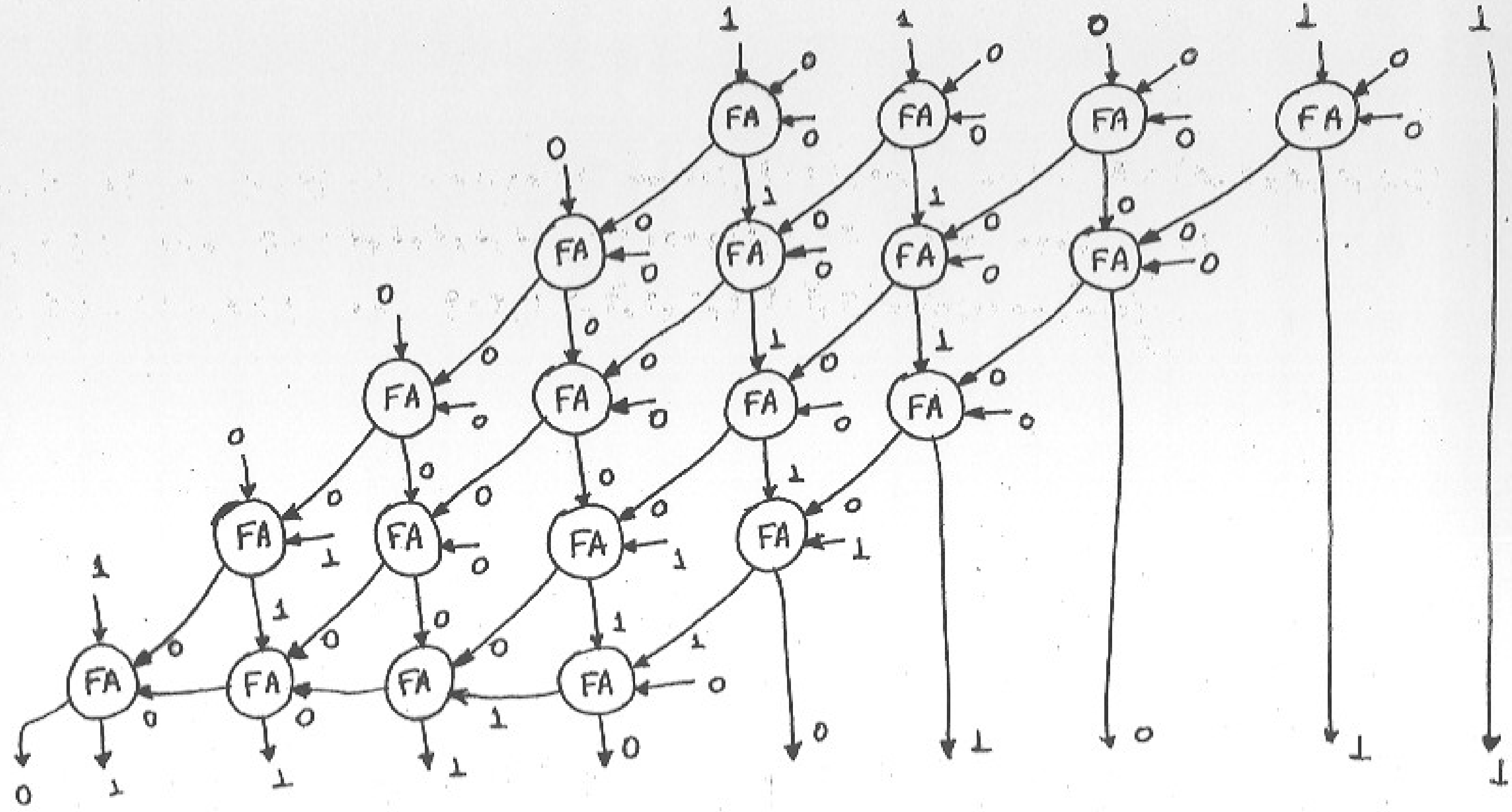


A 5-by-5 unsigned array multiplier.

- The cost of an n-by-n unsigned array multiplier will be n^2 AND gates plus $n \times (n-1)$ FAs

•• The delay through an n-by-n unsigned array multiplier will be Delay of AND + $(n-1) \times$ Delay of FA + $(n-1) \times$ Delay of FA =

$$= D_{AND} + 2 \times (n-1) \times D_{FA}.$$



An example of a 5-by-5 unsigned multiplication with $A = (a_4 a_3 a_2 a_1 a_0)_2 = (11011)_2 = 27$ and $B = (b_4 b_3 b_2 b_1 b_0)_2 = (10001)_2 = 17$. The product is $P = A \times B = 27 \times 17 = 459$ or $P = P_9 P_8 P_7 P_6 P_5 P_4 P_3 P_2 P_1 P_0 = (0111001011)_2$.