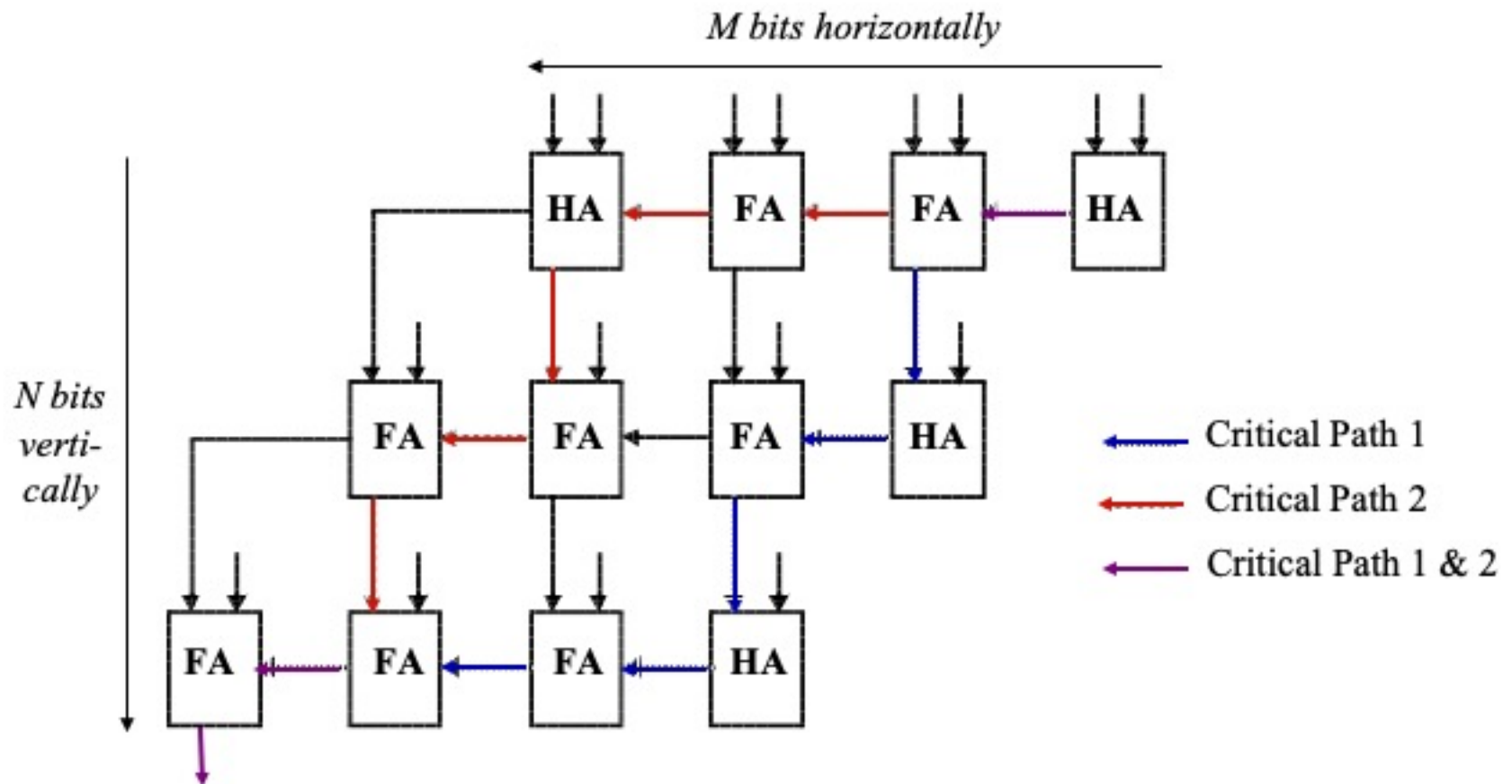


Digital ICs — Lectures

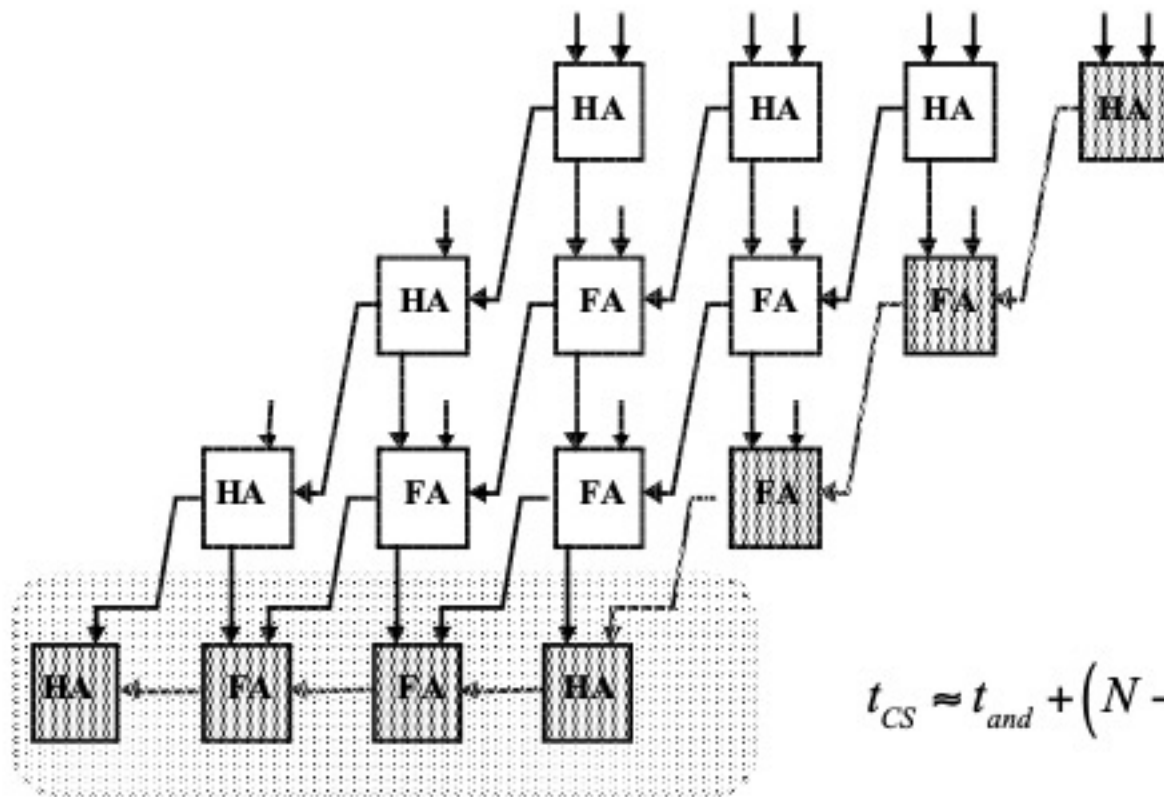
1) Introduction [Ch. 1]	TSEI03/TSTE86
2) Devices [Ch. 3, 4]	TSEI03/TSTE86
3) Interconnect [Ch. 4, 9]	TSTE86
4) Circuits [Ch. 5]	TSEI03/TSTE86
5) Combinational logic [Ch. 6]	TSEI03/TSTE86
6) Sequential circuits [Ch. 7]	TSEI03/TSTE86
7) Synchronization [Ch. 10]	TSTE86
8) Adders [Ch. 11]	TSEI03/TSTE86
9) Multipliers [Ch. 11]	TSTE86
10) Memory [Ch. 12]	TSEI03/TSTE86
11) Manufacturing [Ch. 2]	TSTE86
12) System design [Ch. 8]	TSTE86

Array Multiplier



$$t_{array} \approx t_{and} + \left[(M-1) + (N-2) \right] \cdot t_{carry} + (N-1) \cdot t_{sum}$$

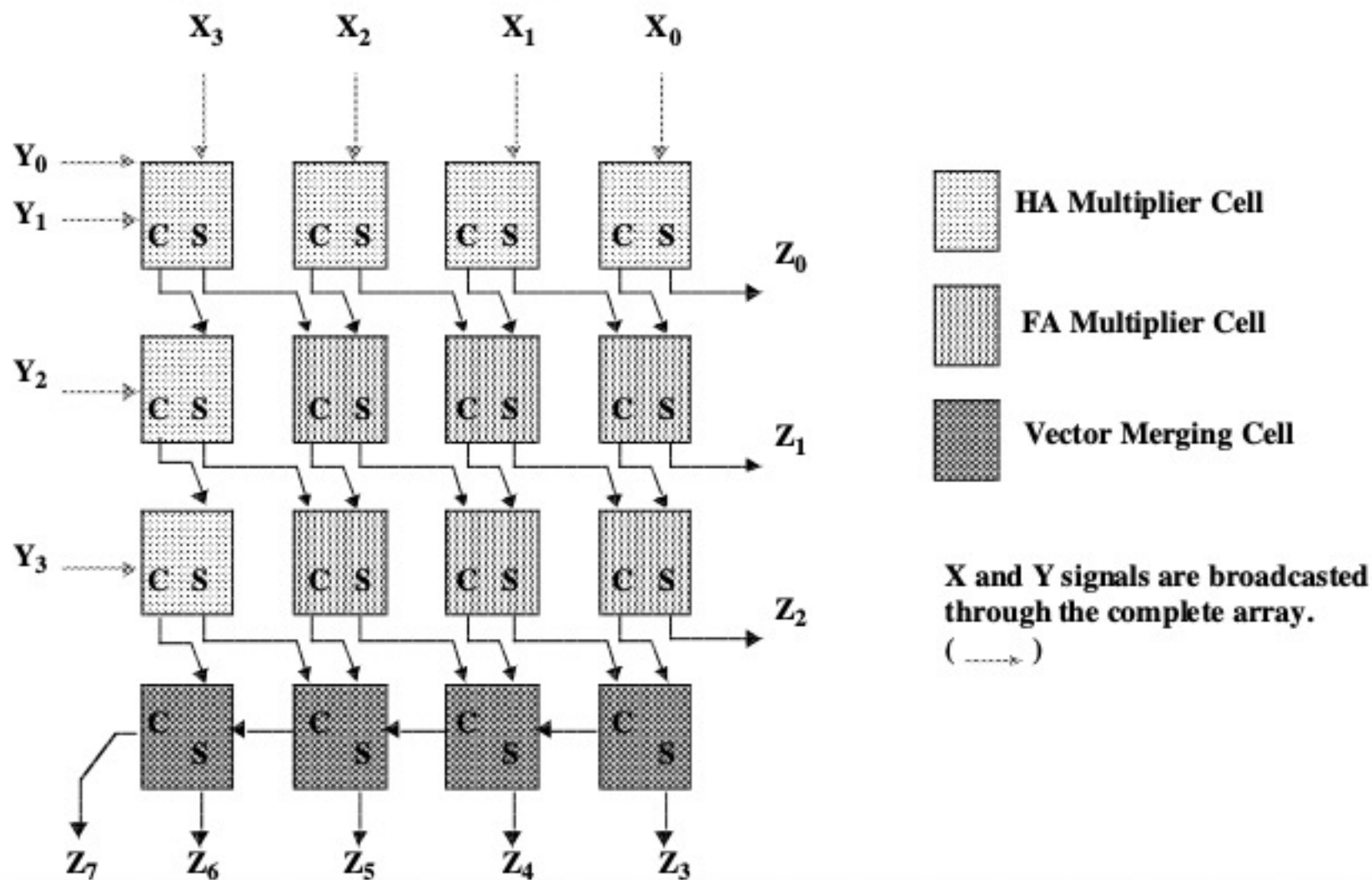
Carry-Save Multiplier



Vector Merging Adder

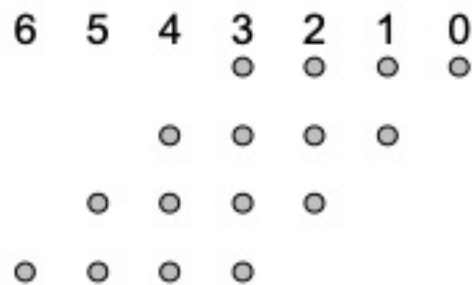
$$t_{CS} \approx t_{and} + (N - 1) \cdot t_{FA} + t_{merge}$$

Multiplier Floorplan



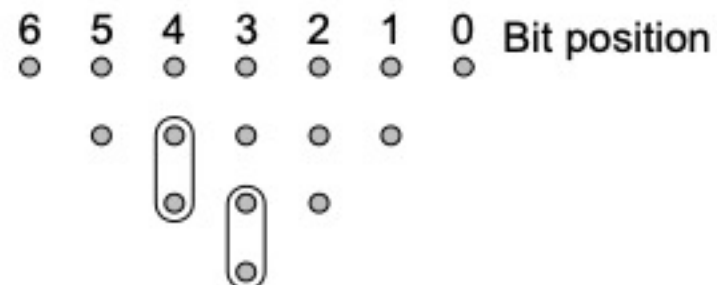
Wallace-Tree Multiplier

Partial products



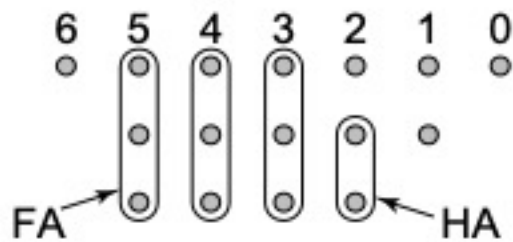
(a)

First stage



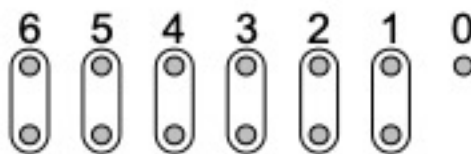
(b)

Second stage



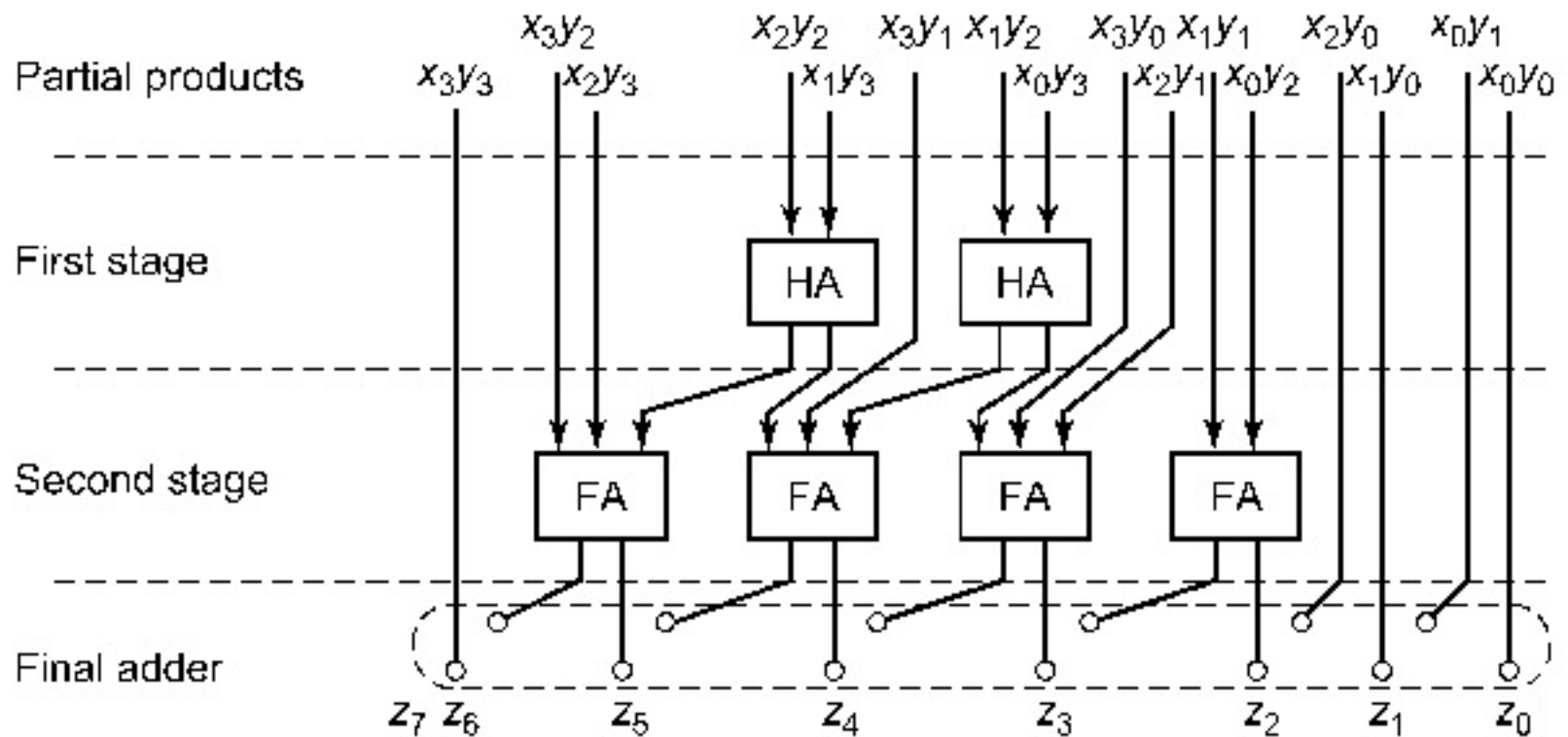
(c)

Final adder (VMA)



(d)

Wallace-Tree Multiplier



Two's Complement Multiplication

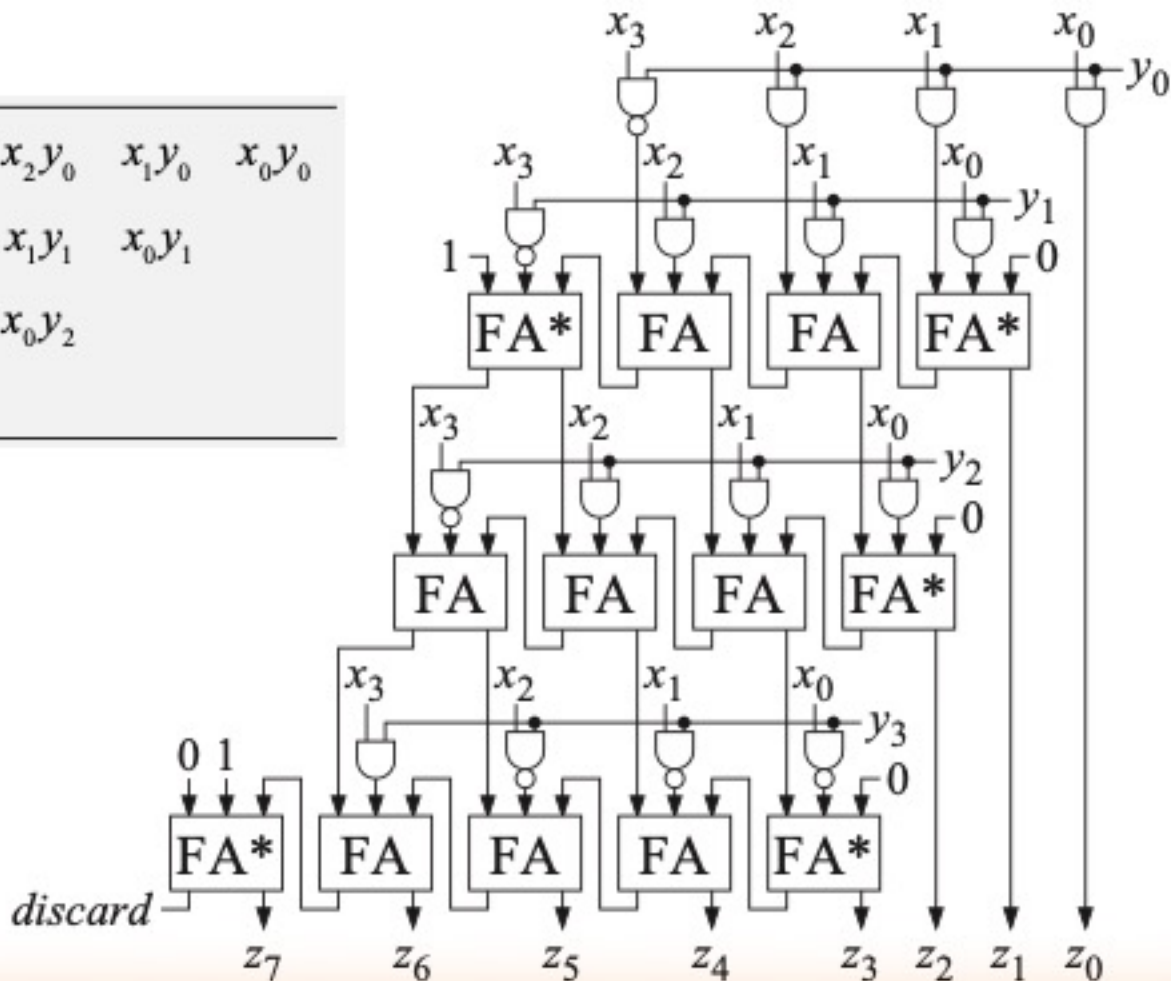
$$\begin{aligned}
 XY &= \left(-x_{M-1}2^{M-1} + \sum_{i=0}^{M-2} x_i 2^i \right) \left(-y_N 2^{N-1} + \sum_{j=0}^{N-2} y_j 2^j \right) = \\
 &= x_{M-1}y_{N-1}2^{M+N-2} + \sum_{i=0}^{M-2} \sum_{j=0}^{N-2} x_i y_j 2^{i+j} - \sum_{j=0}^{M-2} x_{M-1} y_j 2^{M-1+j} - \sum_{i=0}^{N-2} x_i y_{N-1} 2^{i+N-1}
 \end{aligned}$$

						y_3	y_2	y_1	y_0	X
		×				x_3	x_2	x_1	x_0	Y
						$x_3 y_3$				$x_{M-1} y_{N-1} 2^{M+N-2}$
							$x_2 y_0$	$x_1 y_0$	$x_0 y_0$	$x_i y_j 2^{i+j}$
							$x_2 y_1$	$x_1 y_1$	$x_0 y_1$	⋮
							$x_2 y_2$	$x_1 y_2$	$x_0 y_2$	⋮
		$\bar{0}$	$\bar{0}$	$\overline{x_3 y_2}$	$\overline{x_3 y_1}$	$\overline{x_3 y_0}$	$\bar{0}$	$\bar{0}$	$\bar{0}+1$	$-x_{M-1} y_j 2^{M-1+j}$
M, N		$\bar{0}$	$\bar{0}$	$\overline{x_2 y_3}$	$\overline{x_1 y_3}$	$\overline{x_0 y_3}$	$\bar{0}$	$\bar{0}$	$\bar{0}+1$	$-x_i y_{N-1} 2^{i+N-1}$
$= 4 \Rightarrow$		z_7	z_6	z_5	z_4	z_3	z_2	z_1	z_0	Z

Two's Complement Multiplier

Reorganize bit products

		1	x_3y_0	x_2y_0	x_1y_0	x_0y_0
		x_3y_1	x_2y_1	x_1y_1	x_0y_1	
		x_3y_2	x_2y_2	x_1y_2	x_0y_2	
+	1	x_3y_3	x_2y_3	x_1y_3	x_0y_3	



FA* can be simplified