

## Cost Analysis

$$\text{IC cost} = \frac{\text{Die cost} + \text{Testing cost} + \text{Packaging cost}}{\text{Final test yield}}$$

$$\text{Die cost} = \frac{\text{Wafer cost}}{\text{Dies per wafer} \times \text{Die yield}}$$

$$\text{Dies per wafer} = \frac{\pi \times (\text{Wafer\_diam}/2)^2}{\text{Die area}} - \frac{\pi \times \text{Wafer\_diam}}{\sqrt{2} \times \text{Die area}} - \text{Test dies}$$

$$\text{Die yield} = \text{Wafer yield} \times \left\{ 1 + \frac{\text{Defect\_per\_unit\_area} \times \text{Die\_area}}{\alpha} \right\}^{-\alpha}$$

## Real World Examples

Chip	Metal layers	Line width	Wafer cost	Defect/cm <sup>2</sup>	Area mm <sup>2</sup>	Dies/wafer	Yield	Die Cost
386DX	2	0.90	\$900	1.0	43	360	71%	\$4
486DX2	3	0.80	\$1200	1.0	81	181	54%	\$12
PowerPC 601	4	0.80	\$1700	1.3	121	115	28%	\$53
HP PA 7100	3	0.80	\$1300	1.0	196	66	27%	\$73
DEC Alpha	3	0.70	\$1500	1.2	234	53	19%	\$149
SuperSparc	3	0.70	\$1700	1.6	256	48	13%	\$272
Pentium	3	0.80	\$1500	1.5	296	40	9%	\$417

From “Estimating IC Manufacturing Costs,” by Linely Gwennap, *Microprocessor Report*, August 2, 1993, p. 15.

## Other Costs

$$\text{Die test cost} = \frac{\text{Test jig cost} \times \text{Avg. test time}}{\text{Die yield}}$$

Packaging cost: depends on pins, heat dissipation, beauty, etc.

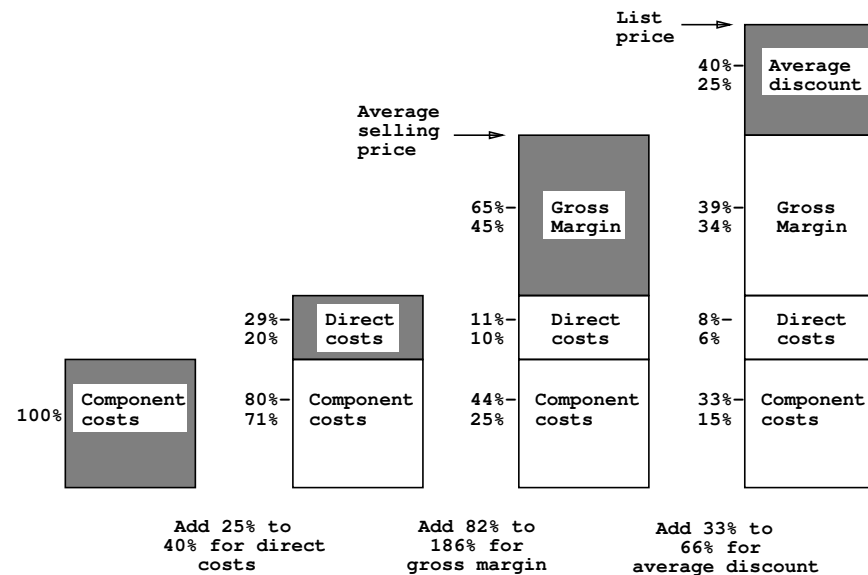
Chip	Die cost	Pins	Package type	Cost	Test and assembly	Total
386DX	\$4	132	QFP	\$1	\$4	\$9
486DX2	\$12	168	PGA	\$11	\$12	\$35
PowerPC 601	\$53	304	QFP	\$3	\$21	\$77
HP PA 7100	\$73	504	PGA	\$35	\$16	\$124
DEC Alpha	\$149	431	PGA	\$30	\$23	\$202
SuperSparc	\$272	293	PGA	\$20	\$34	\$326
Pentium	\$417	273	PGA	\$19	\$37	\$473

## Cost vs. Price

What is relationship of cost to price?

- Component costs
- Direct costs (add 25% to 40%) recurring costs: labor, purchasing, scrap, warranty
- Gross margin (add 82% to 186%) non-recurring costs: R&D, marketing, sales, equipment maintenance, rental, financing cost, pre-tax profits, taxes
- Average discount to get List Price (add 33% to 66%): volume discounts and/or retailer mark-up

## Cost vs. Price



## Volume vs. Cost

- Rule of thumb on applying learning curve to manufacturing:  
 “When volume doubles, costs reduce 10%”  
 A DEC View of Computer Engineering by C. G. Bell, J. C. Mudge, and J. E. McNamara, Digital Press, Bedford, MA., 1978.
- High-end systems need more R&D, but fewer systems are sold
  - Amortize R&D costs over a fewer number of systems  $\Rightarrow$  higher margins
- 40 MPPs at 200 nodes = 8,000 nodes/year vs. 100,000 workstations/year
  - $12.5X \approx 2^{3.6} \Rightarrow (0.9)^{3.6} = 0.68$
  - Cost should be 1/3 less for same components
- What about PCs vs. workstations?