ECSE 425 – Tutorial 1

IC Fabrication and Reliability

Alexandre Raymond

alexandre.raymond@mail.mcgill.ca

Trends in Technology

IC transistor density : 35% / year

IC die size : 10-20% / year

=> 50-55% transistors / year

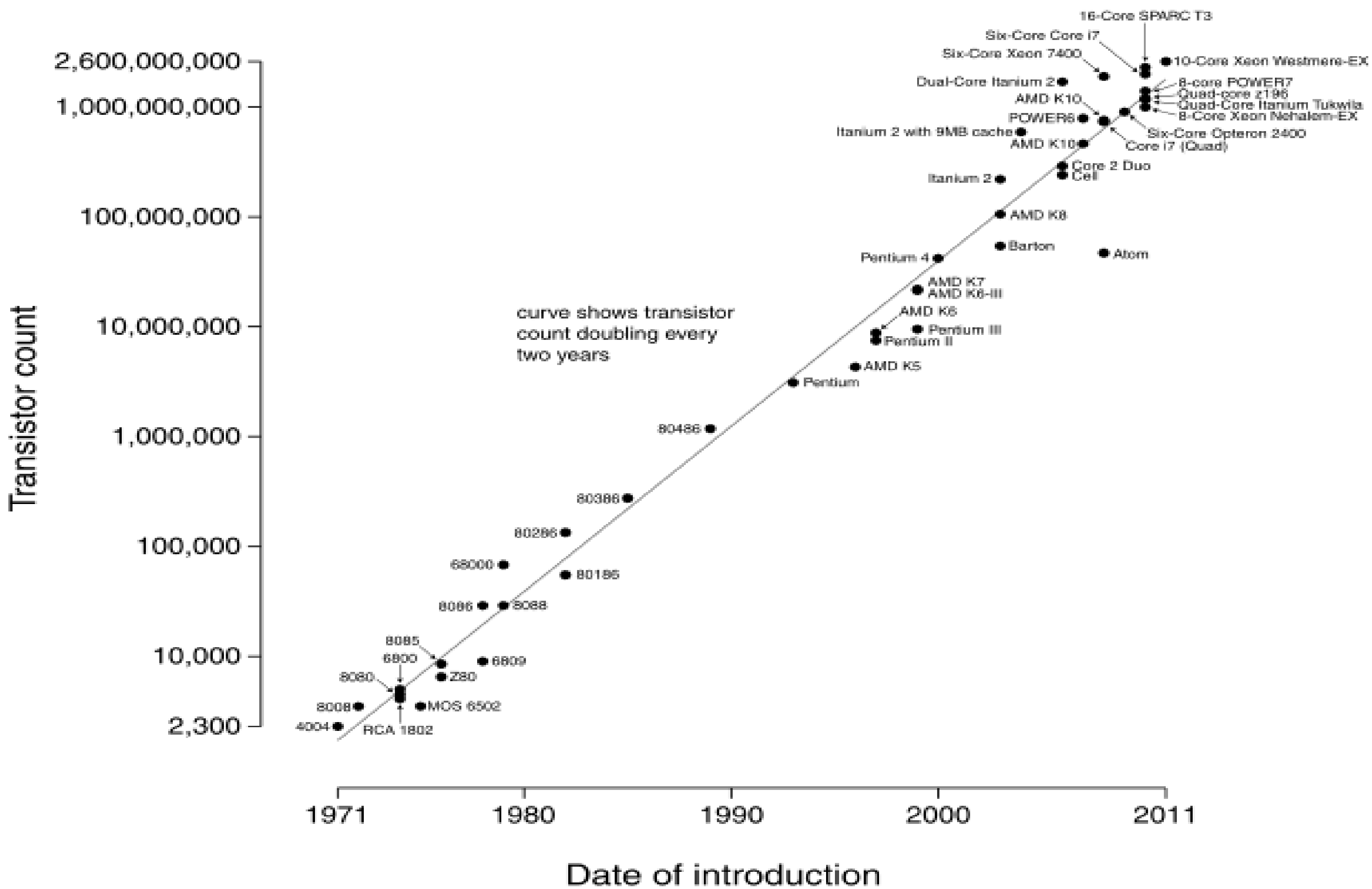
RAM : 40% / year

HDD : 30% / year

Exponential growth!

Trends in Technology

Microprocessor Transistor Counts 1971-2011 & Moore's Law



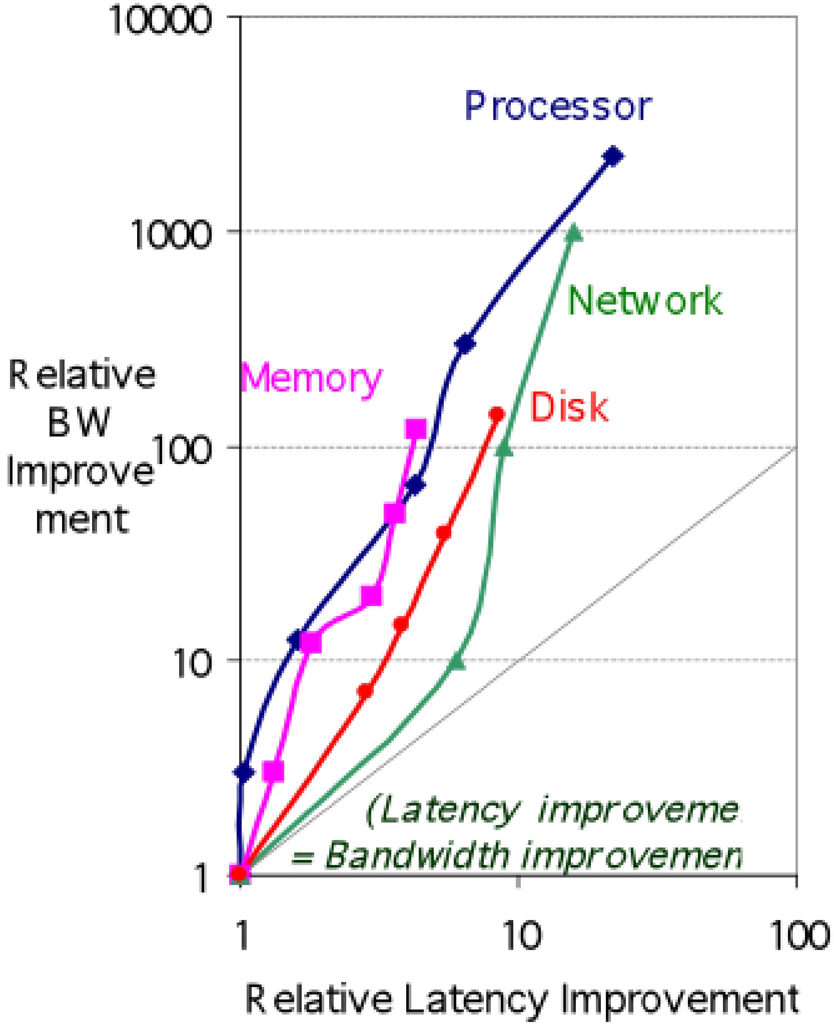
Credit: Wgsimon, Wikipedia

Trends in Technology

Bandwidth : how much information you can move on average per unit time (eg: bits/sec)

Latency : how long it takes to get data once it has been requested (eg: ms)

Trends in Technology



Bandwidth >> Latency

Cost of an Integrated Circuit

$$\text{ICCost} = \frac{\text{DieCost} + \text{DieTestCost} + \text{PackagingAndTestCost}}{\text{FinalYield}} \tag{1}$$

$$\text{DieCost} = \frac{\text{WaferCost}}{\text{DiesPerWafer x DieYield}} \tag{2}$$

$$\text{DiesPerWafer} = \frac{\pi \text{ x WaferRadius}^2}{\text{DieArea}} - \frac{\pi \text{ x WaferDiameter}}{\sqrt{2 \text{ x DieArea}}} \tag{3}$$

$$\text{DieYield} = \text{WaferYield x } \left(1 + \frac{\text{DefectDensity x DieArea}}{\alpha}\right)^{-\alpha} \tag{4}$$

Cost of an Integrated Circuit

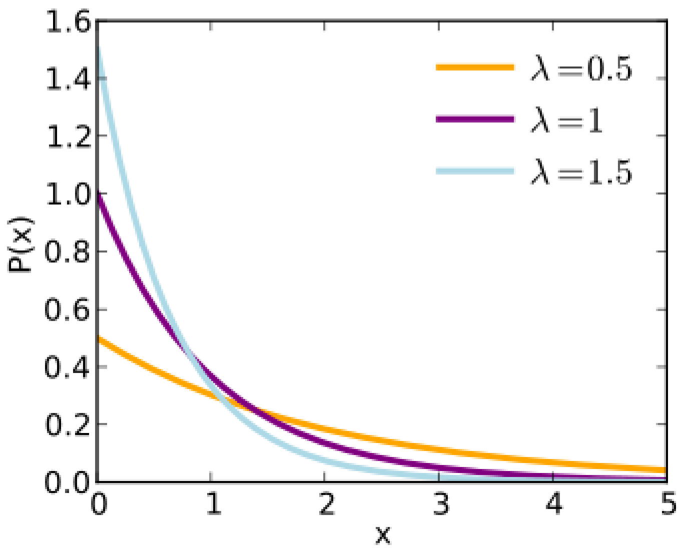
- Question: Number of dies per 300mm (30cm) wafer for a die that is 1.5cmx1.5cm?
  - Die area = $2.25cm^2$
  - Dies per wafer = …
- Find die yield under conditions above, and assuming defect density of 0.4 defect/cm^2 and α=4.
  - Die yield = …

Cost of an Integrated Circuit

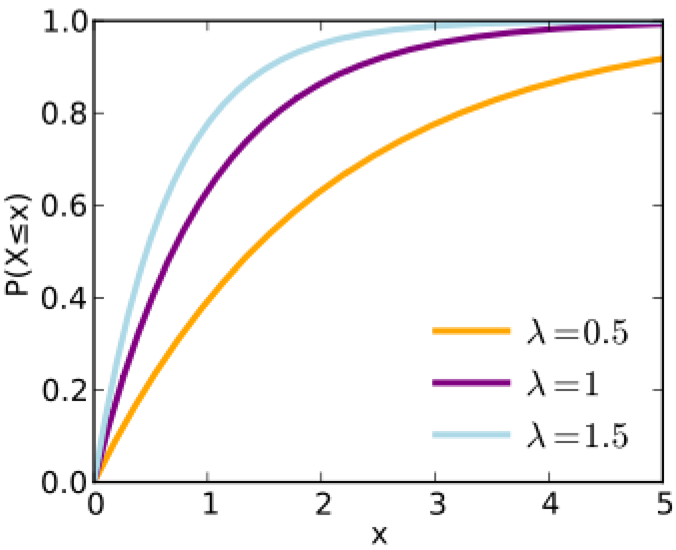
- Question:
  a) Find the probability of a defective core in a 4-core CPU chip, assuming die area of $3.1cm^2$, defect rate 0.6 defect/cm^2, α=4.
  – Equivalent to die yield for a die having ¼ the area.
- b) Find the probability that at least 3 out of 4 cores are working (so you can sell the chip as a 3-core CPU).

Reliability

- A system with **constant failure** rate λ has an exponentially distributed **lifetime** X, or "time to failure".
  - MTTF = E[X] = 1 / λ   FIT=10^9 λ



PDF= $\lambda e^{-\lambda x}$



CDF= $1 - e^{-\lambda x}$

Credit: Skbkekas, Wikipedia

Reliability

- If a system with lifetime Y fails whenever any of its *n* modules fails:
  - $Y = \min(X_1, \ldots, X_n)$
  - $\lambda_{system} = \text{sum}(\lambda_i)$
  - $MTTF_{system} = E[Y] = 1 / \lambda_{system} = 1 / (\lambda_1 + \ldots + \lambda_n)$

Reliability

- MTTR: Mean time to repair
- System or Module availability =
  MTTF / (MTTF + MTTR)
- Exercise: Assume a disk subsystem with the following components and MTTF:
  - 10 disks, each rated at 1,000,000-hour MTTF
  - 1 SCSI controller, 500,00-hour MTTF
  - 1 power supply, 200,000-hour MTTF
  - 1 fan, 200,000-hour MTTF
  - 1 SCSI cable, 1,000,000-hour MTTF

$$Failure\ rate_{system} = \frac{10 \times 1}{1,000,000} + \frac{1}{500,000} + \frac{1}{200,000} + \frac{1}{200,000} + \frac{1}{1,000,000} = \frac{23,000}{1,000,000,000\ hours}$$

$$MTTF_{system} = \frac{1}{Failure\ rate_{system}} = 43,500\ hours$$