Session 3: Wire Length Distribution

# Introduction to VLSI Interconnect Design

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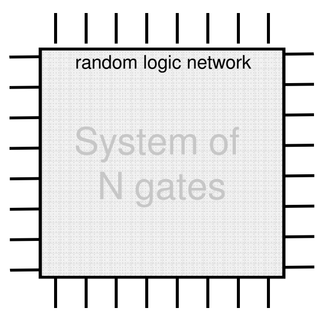
## Rent's Rule

Rent's Rule : wires emanating from a block of logic follow a Poisson distribution.

$$T = kN^p$$




p=0.6, k=4,

N=1E9,T= 1E7

T = Number of I/Os
N = Number of logic gates

empirical parameters:
p = Rent's exponent
k = Rent's coefficient

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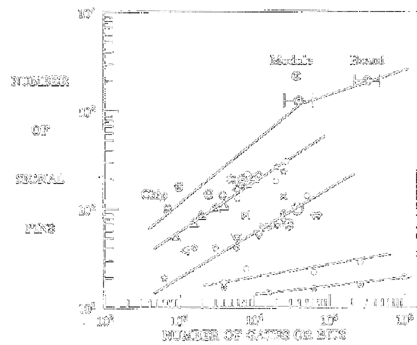
# Rent's Rule

TABLE 9.5 Rent's Constants for Various System Types

| System or Chip Type | Exponent $\beta$ | Multiplier $K_p$ |
|---|---|---|
| Static memory | 0.12 | 6 |
| Microprocessor | 0.45 | 0.82 |
| Gate array | 0.50 | 1.9 |
| High-speed computer | | |
| Chip and module level | 0.63 | 1.4 |
| Board and system level | 0.25 | 82 |

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# Reference

580 IEEE TRANSACTIONS ON ELECTRON DEVICES, VOL. 45, NO. 3, MARCH 1998

## A Stochastic Wire-Length Distribution for Gigascale Integration (GSI)—Part I: Derivation and Validation

Jeffrey A. Davis, Vivek K. De, and James D. Meindl, *Life Fellow, IEEE*

*(Invited Paper)*

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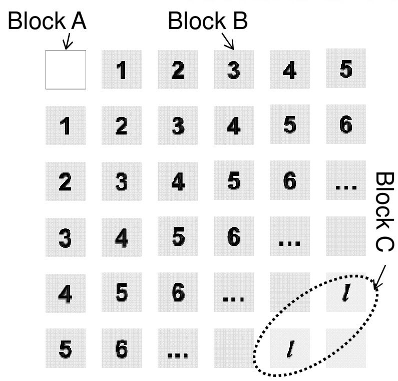
# Wiring Distributions




| VARIABLE | DEFINITION |
|---|---|
| $T_A$ | No. of I/Os for block A |
| $T_B$ | No. of I/Os for block B |
| $T_C$ | No. of I/Os for block C |
| $T_{A-to-B}$ | No. of I/Os connecting block A to B |
| $T_{A-to-C}$ | No. of I/Os connecting block A to C |
| $T_{B-to-C}$ | No. of I/Os connecting block B to C |
| $T_{AB}$ | No. of I/Os connecting block A+B |
| $T_{BC}$ | No. of I/Os connecting block B+C |
| $T_{ABC}$ | No. of I/Os connecting block A+B+C |

$$T_A + T_B + T_C = T_{A-B} + T_{A-C} + T_{B-C} + T_{ABC}$$

$$T_{A-B} = T_A + T_B - T_{AB}$$

$$T_{B-C} = T_B + T_C - T_{BC} \quad \rightarrow T_{A-C} = T_{AB} + T_{BC} - T_B - T_{ABC}$$

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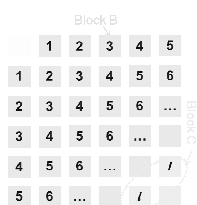
# Wiring Distributions




$$T_B = k(N_B)^p$$

$$T_{AB} = k(N_A + N_B)^p$$

$$T_{BC} = k(N_B + N_C)^p$$

$$T_{ABC} = k(N_A + N_B + N_C)^p$$

$$T_{A-C} = k\left[(N_A + N_B)^p + (N_B + N_C)^p - (N_B)^p - (N_A + N_B + N_C)^p\right]$$

point to point interconnects between A and C

$$I_{A-C} = \alpha T_{A-C}$$

where

$\alpha = f.o./f.o.+1$ $f.o.$ : Average Fan-Out of system

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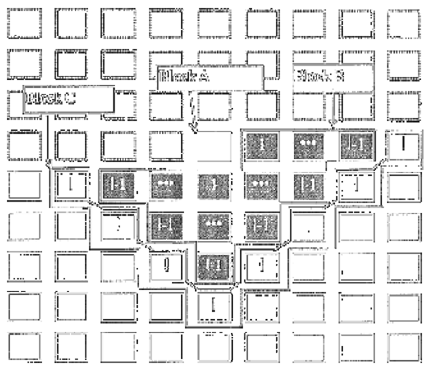
# Wiring Distributions

Algorithm for exact wire-length distribution calculation



$\Phi(i, j, l)$ = number of gates that are a distance $l$ away from the gate in the $i^{th}$ row and the $j^{th}$ column in a square array of gates

$$\Phi(i, j, r) \approx 2r$$

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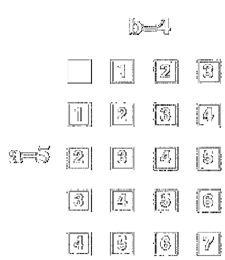
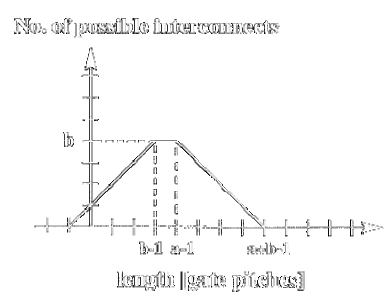
# Wiring Distributions

Number of interconnects of length $l$ for a corner interconnect




$$\delta_{ab} = (l+1)u(l+1) + (l-a-b+1)u(l-a-b+1) - (l-b+1)u(l-b+1) - (l-a+1)u(l-a+1)$$

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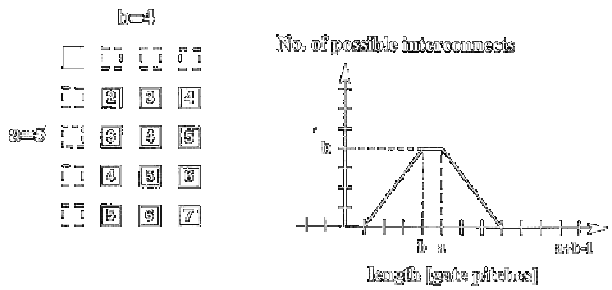
# Wiring Distributions

Number of interconnects of length $l$ away not in the same row or column




$$\delta'_{a'b'} = (l-1)u(l-1) + (l-a'-b'+1)u(l-a'-b'+1) - (l-b')u(l-b') - (l-a')u(l-a')$$

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# Wiring Distributions

By definition

$$\Phi(i,j,l) = \delta_{ab} + \delta'_{a'b'}$$

where

$$a = \sqrt{N} - i + 1$$

$$b = \sqrt{N} - j + 1$$

$$a' = \sqrt{N} - i + 1$$

$$b' = j$$

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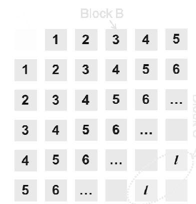
# Wiring Distributions

Knowing that:

$$N_A = 1$$

$$N_B = \sum_{r=1}^{l-1} \Phi(i,j,r)$$

$$N_C = \Phi(i,j,l)$$




remember

$$I_{A-C} = \alpha k \left[ (N_A + N_B)^p + (N_B + N_C)^p - (N_B)^p - (N_A + N_B + N_C)^p \right]$$

$$i(l) = \alpha k \sum_{i=1}^{\sqrt{N}} \sum_{j=1}^{\sqrt{N}} \left[ \begin{array}{l} \left(1 + \sum_{r=1}^{l-1} \Phi(i,j,r)\right)^p + \left(\sum_{r=1}^{l} \Phi(i,j,r)\right)^p \\ - \left(\sum_{r=1}^{l-1} \Phi(i,j,r)\right)^p - \left(1 + \sum_{r=1}^{l} \Phi(i,j,r)\right)^p \end{array} \right]$$

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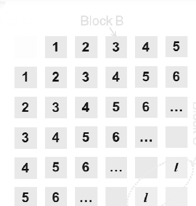
# Wiring Distributions

$$\Phi(i,j,r) \approx 2r$$

$$N_A = 1$$

$$N_B = \sum_{r=1}^{l-1} 2r = l(l-1)$$

$$N_C = 2l$$




$$\Gamma \triangleq \frac{I_{total}}{\int_{l=1}^{2\sqrt{N}} i(l)} = \frac{2N(1-N^{p-1})}{\frac{-N^p(1+2p-2^{2p-1})}{p(2p-1)(p-1)(2p-3)} - \frac{1}{6p} + \frac{2\sqrt{N}}{2p-1} - \frac{N}{p-1}}$$

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# Wiring Distributions

$$\Gamma = 2N(1-N^{p-1}) \Big/ \left( \frac{-N^p(1+2p-2^{2p-1})}{p(2p-1)(p-1)(2p-3)} - \frac{1}{6p} + \frac{2\sqrt{N}}{2p-1} - \frac{N}{p-1} \right)$$

$$I(a<l<b) = \int_a^b i(l)dl$$

Region I: $1 \le l < \sqrt{N}$

$$i(l) = \frac{\alpha k}{2}\Gamma\left(\frac{l^3}{3} - 2\sqrt{N}l^2 + 2Nl\right)l^{2p-4}$$

Region II: $\sqrt{N} \le l < 2\sqrt{N}$

$$i(l) = \frac{\alpha k}{6}\Gamma\left(2\sqrt{N} - l\right)^3 l^{2p-4}$$

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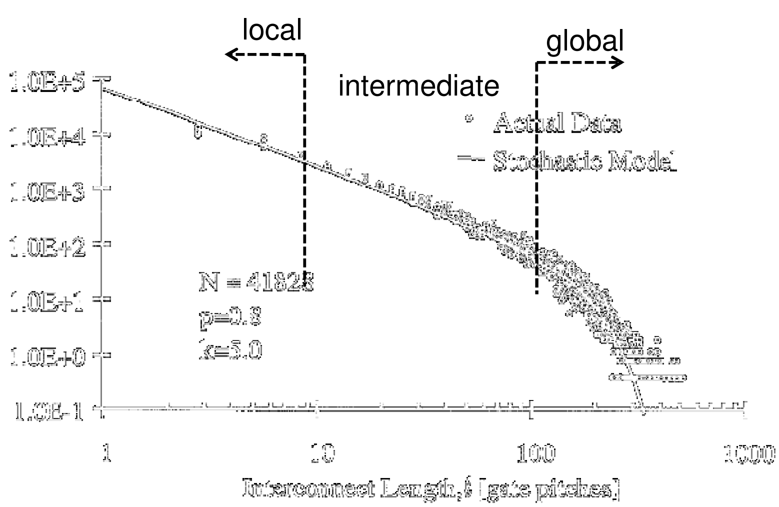
# Wiring Distributions

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