Sharif University of Technology
Department of Computer Engineering

Low Power
Digital System Design

On-chip Interconnects (Cont.)

A. Ejlali

On-chip interconnects: Low Power Encoding

- On-chip interconnects dissipate power mainly because of switching activity.

$$P_{SW} = \alpha \cdot f \cdot C_L \cdot V_{SW}^2$$

- Solution 2:
  - Logic level techniques vs. Circuit level techniques
  - Lowe Power Encoding

Low Power Encoding: The Main Idea

- Code the data in order to decrease α on the large C_L side even at the expense of slightly increasing α on the low C_L side.

- Large C_L side: Long Interconnects
- Low C_L side: Short Interconnects

Low Power Encoding: Bus-Inverting

- Uses one extra control bit called *invert*.
  - *Invert*=0 => *bus-value* = *data-value*
  - *Invert*=1 => *bus-value* =~*data-value*

- Compute D_H between the present bus value and the next data value.
  - also count the present invert line.
  - D_H = Hamming Distance

If D_H <n/2 then

Invert*=0, *bus-value = data-value

else

Invert*=1, *bus-value = ~ data-value

Bus-Inverting: Impact on Peak Power

- Assumption: Uniformly distributed sequence of values are transferred.

- The maximum number of transitions per time-slot is reduced from n to $n/2$.
  - Peak power dissipation is reduced by half.

Bus-Inverting: Impact on Average Power

- Average power dissipation is reduced by up to 25%.
- Binomial distribution for D_H of the next data value.
  - $P(i)$ = Probability of $D_H = i$.

$$P(i) = \binom{n}{i} \left(\frac{1}{2}\right)^n$$

Impact on Average Power (Cont.)

- Expected value of D_H
  - When $n=2k$

$$E(D_H) = K \cdot P(K) + 2\sum_{i=0}^{K-1} i \cdot P(i)$$

  - When $n=2k+1$

$$E(D_H) = 2\sum_{i=0}^{K} i \cdot P(i)$$

Impact on Average Power (Cont.)

- Example: n=4
  - Bus-Inverting
    - $P(0)=1/16$, $P(1)=4/16$, $P(2)=6/16$, $P(3)=4/16$,$P(4)=1/16$
    - $E(D_H)=20/16$
  - Without any encoding technique
    - P(0)=1/8, P(1)=3/8,P(2)=3/8,P(3)=1/8
    - $E'(D_H)=12/8$
  - Transition reduction:
    - $E(D_H)/E'(D_H)=10/12$

Partitioned Bus Inverting

- As n increases the term corresponding to $n/2$ in the binomial distribution becomes dominant.

$$P(i) = \binom{n}{i}(\frac{1}{2})^n$$

- Example: Consider the variation of $r(n)$ as n changes:

$r(4)=6/4=1.5$

$r(8)=10/4=2.5$

$r(16)=99/14=7.07$

$$r(n) = \frac{\binom{n}{n/2}}{\binom{n}{n/4}}$$

Partitioned Bus Inverting (Cont.)

- Conclusion: As *n* increases the decrease in average power dissipation becomes smaller.

- Solution: Partitioned bus inverting
  - partitioning the bus into several narrower *sub-buses.*
  - Bus-inverting is applied to each sub-bus independently.

Data Compression Encoding

- Bus-Inverting: used when uniformly distributed sequence of values are transferred.

- New assumption: Non-uniformity in the distribution of transferred values.
  - There is a data redundancy hence data compression can be used.