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Low Power Digital System Design

On-chip Interconnects (Cont.)

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Low Power Encoding: Data Compression

- Data compression can be an efficient method to decrease the power dissipation of interconnects.

- Main Idea: The less data transmission, the less power dissipation.

Data Compression Encoding

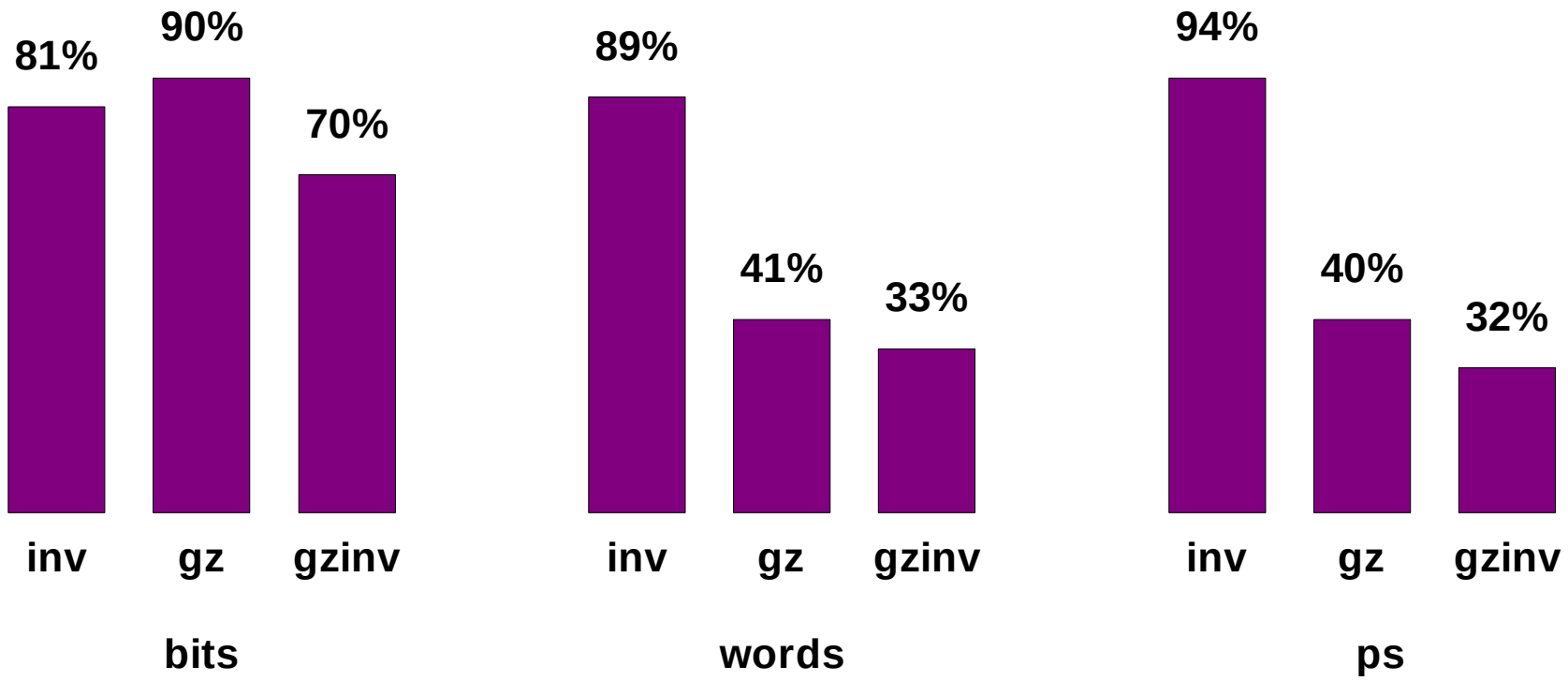
- Uniformly distributed random sequence of values:
  - Bus-invert method
- Auto-correlated sequence of values:
  - Data redundancy
    - compression can be used.
- Non-uniformity in the distribution of random sequence of values:
  - Data redundancy
    - compression can be used.

Auto-Correlated Sequence of Values

- By removing the redundancy, the data can be more accurately approximated as a random sequence.

- Conclusion: After the compression, the techniques used for random sequences can also be used.
  - e.g., Using a combination of compression and bus-invert methods.

Compression Impact on Interconnect Switching Activity



- **Example: 8-bit bus**

Inv: bus-invert **gz:** gzip method **gzinv:** gzip then bus-invert

- The contributions of bus-invert and gzip methods are independent of each other.

Auto-Correlated Sequence of Values (Cont.)

- Some low power encoding techniques benefit from the auto-correlation without any compression:

- Example: Gray code for address bus
  - Spatial correlation

Non-uniformity in Random Sequences

- Compression
  - Huffman Encoding is one of the well known techniques for compression when there is non-uniformity in a random sequence.
  - Can we use it for low-power encoding?

Assignment

- Huffman Encoding
  - Behavioral description of transition counter.
  - Behavioral description of Huffman encoder.
  - Analyze the impact of Huffman encoding on the number of transitions.
  - Target system:
    - a 2-bit adder with serial output
    - Adder input sequences are uniformly distributed
  - Do not consider the power dissipation of the encoder and decoder circuitries.

Level Signaling vs. Transition Signaling

- Transition signaling: a logic-1 is represented by a transition (positive or negative edge) while a 0 is represented by the lack of such a transition.

- Modulation Equation:

$$b(n) = v(n) \oplus b(n-1)$$

- Demodulation Equation:

$$v'(n) = b(n) \oplus b(n-1)$$

Transition Signaling

- will not reduce switching activity by itself.
- Main Idea: If we use transition signaling and at the same time we reduce the number of 1’s in the codewords we can directly reduce the switching activity on the bus.

Limited Weight Codes

- Definition:
  - *Weight[v(n)]* = the Hamming weight of *v(n)* = total number of 1's in *v(n)*.

- An *M*-limited weight code can be defined as having codewords with:

$$Weight[v(n)] \leq M$$

- The smaller *M* is, the lower the resulting bus switching activity will be (the worst-case number of transitions per cycle is *M*).