Estimation of Power Consumption in Encoded Data Buses

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Abstract

Because of the increasing importance of cross coupled capacitances in deep submicron technologies [1], it is of great interest to extend the existing high-level power estimation techniques by considering the spatial correlation between adjacent lines. This work addresses the modeling and estimation of power dissipation in on-chip buses based on the statistical properties of data sequences. Using the derived models, a power estimation technique is proposed and evaluated for various coding schemes. For different DSP applications, our results depict less than 5 % discrepancy with precise bit level estimations.

1. Introduction

In this work we analyze the relation between the word-level statistics of the data being transmitted over a bus and its energy consumption. In addition to two's complement (K2), we will consider two more coding schemes: K1, where each bit is xored with the MSB and K0 where each bit is xored with the previous one.

2. Bus and data model

A bus of length L can be modeled as a distributed circuit with unit length capacitance c_t to ground and c_e between adjacent lines. Assuming a synchronous and complete toggling of the lines [3], the energy consumption can be calculated by:

$$\hat{E}_i = \frac{V_{dd}^2\, L}{2} \{c_t\, t_t + 2c_e\, t_e\}$$

where:

$$t_t = 2\mathcal{E}\left[b_i^+ \Delta b_i\right]$$
$$t_e = \mathcal{E}\left[b_i^+ (2\Delta b_i - \Delta b_{i+1} - \Delta b_{i-1})\right]$$

are respectively the temporal and the equivalent spatial transition activity. b_i^+ represents the current value of the bus signal. In a wide spectrum of DSP applications the data distribution can be assumed to be Gaussian [2] with correlation factor ρ and variance σ^2. In this case, the total signal activity T_t and T_e can be very accurately estimated by:

$$T_{t\_K2} \approx B/2 - dt_m \log_2(k\sigma_n) - \beta \frac{dt_m^\gamma}{\sqrt{t_m}}$$
$$T_{others} \approx 0.5\ \log_2(k\sigma) - \beta \frac{dt_m^\gamma}{\sqrt{t_m}}$$

with parameters:

		k	β	γ
K2	T_t	3.40	0.73	1.5
	T_e	3.25	0.48	1
K1	T_t	1.90	0.84	2
	T_e	2.15	1.15	2.5
K0	T_t	2.10	0.80	1.5
	T_e	1.72	1.05	2

$$\sigma_n = \frac{\sigma}{2^B}$$
$$t_m = \frac{\arccos(\rho)}{\pi}$$
$$dt_m = 0.5 - t_m$$

3. Experimental results

In order to determine the applicability of the approximations described in the previous section, we compare them with the temporal and equivalent spatial transition obtained by bit precise simulation. In our experiments we use signals coming from the FFT input of a OFDM receiver over different channel models, male voice and classical music records, and pressure measurements from a ignition knock detector. The analysis shows that the errors (smaller than 5% for any of the encoding schemes) are similar to those obtained by simulation of random generated Gaussian distributed data. The small discrepancy is induced then by the assumption of a normal distribution.

References

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