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Efficient Crosstalk Reduction Technique for Data Bus

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ABSTRACT

Crosstalk has become the great challenge to the design community in Deep-submicron (DSM) and Very Deep-submicron (VDSM) technologies. As the portion of silicon area for interconnects and buses is dominating, crosstalk effect also dominates in deciding the reliability and performance of the SoCs and many types of processors. These interconnect and buses are prone to errors due to crosstalk. The major part of the crosstalk is due to coupling transitions occurring on the data bus and interconnects when signals are transmitted. One of the favorable techniques to reduce the crosstalk is to reduce the coupling transitions. Bus encoding technique is the promising method to reduce the crosstalk. Hence an efficient Crosstalk reduction data bus encoding scheme is proposed which can reduce the 6C, 5C and 4C crosstalk for 64-bit data bus around 88%, 68% and 24% respectively, for 32-bit data bus around 89%, 74% and 32% respectively and 16-bit data bus by 93%, 71% and 19% respectively.

Keywords

Silicon, Data bus, Reliability, Efficient.

1. INTRODUCTION

Crosstalk is dominating the nanometer technology which causes errors on interconnects and data buses because the wires are packed ever closer to each other and the inter wire coupling capacitances dominates the portion of total capacitance. The crosstalk has become a major concern because of continuing decrease in transistor sizes and the corresponding increase in chip density and operating frequencies. It has become a deciding design factor on total power consumption and delay of on chip data busses. Unfortunately in nanometer and sub nanometer technologies the coupling capacitance dominates the load capacitance and its magnitude is several times larger than load capacitance. The characteristics of data buses and long interconnects such as wire spacing [8], coupling length ,wire length, wire width, wire material, driver strength, and signal transition time, etc. influences the coupling effect. These increased coupling effects on on-chip data buses and on long global interconnects not only increase the propagation delay but also deteriorate the signal integrity and increases the crosstalk due to the coupling capacitance. Hence the crosstalk depends on the magnitude of the coupling capacitance which occurs between data bus paths and between interconnects. As a results these busses and interconnects becoming more sensitive crosstalk caused effects [14, 16]. Crosstalk and delay faults can be reduced by reducing the coupling transitions [12]. The coupling capacitance not only depends on space between metal paths but also on the data dependent transitions and on the relative switching activity between adjacent bus wires [13].The total energy consumption and delay which determines maximum speed of the bus depends on crosstalk as given in [2,4].

On-chip data buses play an important role in reliable communication and high-performance chips. Crosstalk results due to charging and discharging of a coupling transition of a signal on data bus. Reducing the transition activity on the on-chip data buses is the one of the attractive way of reducing the crosstalk. On of the simplest method to eliminate crosstalk is by using passive shielding [5]. However it requires twice the number of wires which results to a 100% area overhead. In recent days it is discovered that encoding the data bus can eliminate or reduces the some classes of crosstalk with much low area overhead compare to the shielding techniques. Transition activity on the data bus can be reducing by employing bus encoding techniques. Several bus encoding techniques have been proposed to reduce power consumption during bus transmission in literature [1, 7].These techniques mainly relay on reducing the data bus activity. Reducing power consuming transition by encoding the data on the data buses leads to reducing the bus activity hence overall power consumption is reduced [9,10,11,15]. These techniques are not evaluated their performance for the crosstalk. The proposed technique reduces the coupling transitions and cross talk.

2. CROSSTALK

One of the important effects of coupling capacitances is that they may induce unwanted voltage spikes in neighboring bus wire. This is knows as Crosstalk. Figure 1 show the data bus model when no switching transition occurs. A wire on which a switching transition occurs is termed an *aggressor* and the wire on which it produces a noise spike is termed as a *victim*. Typically, an aggressor wire is physically adjacent to a victim wire and they may be modeled as being connected by a distributed coupling capacitance. Hence, a switching event in the aggressor wire while the victim wire is silent can result in the injection of at current into the victim wire, causing an electrical spike. However, a large coupling capacitance relative to the self-capacitance of the wire can cause a large inadvertent spike on the victim that may cause a spurious switching event, potentially leading to errors on victim wire.

Many interconnect and data bus factors affect the amount of crosstalk induced on a victim wire. The interconnect parameters that affect the crosstalk are: coupling capacitance C_C, total capacitance C_T and resistance R_{wire}. The larger the ratio of coupling capacitance to total capacitance (C_C / C_T) for a victim, the more susceptible it is to crosstalk [3]. The victim resistance and the physical location of the coupling with the aggressor also affect the crosstalk.

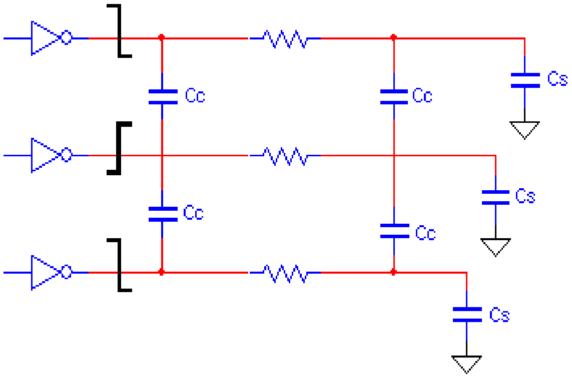

Fig 1: 3-bit Data bus model in DSM technology

The crosstalk can be classified into six types 1C, 2C, 3C, 4C, 5C and 6C according to the C_C of two wires [6] in 3-bit interconnect bus models. Table 2 defines the transition types of crosstalk. Let the crosstalk effect on a single wire *(victim)* depends on the signal transition of its neighboring wires *(aggressors)*. Reducing the 6C, 5C and 4C crosstalk reduces the power dissipation, delay and errors. To increase the reliability of high performance chips it is necessary to reduce the 6C, 5C and 4C crosstalk classes.

Table 1. Classification of Crosstalk classes

Class	Transition Patterns
1	---,--↑,↑--,--↓,↓--,↑-↑,↑-↓,↓-↑,↓-↑, ↓-↓
2	↑↑↑,↓↓↓
3	-↑↑,↑↑-,-↓↓,↓↓-
4	-↑-,-↓-,↓↓↑,↑↓↓,↑↑↓,↓↑↑
5	-↑↓,-↓↑,↓↑-,↑↓-
6	↓↑↓,↑↓↑

3. CROSSTALK REDUCTION ENCODING TECHNIQUE

The proposed crosstalk reduction technique called Bus regrouping with hamming distance (BRG-HD) is based on reduction of the number of coupling transitions occurring on the data bus when a new data is to be transmitted. In the following analysis assume n=32-bit data words. By using the following algorithm coupling transitions and self transitions can be reduced. The proposed algorithm for 32-bit Data bus is given as follows: Let 32-bit data bus be represented by

$a_0\ a_1\ a_2\ a_3\ a_4\ a_5\ a_6\ a_7\ a_8\ a_9\ a_{10}\ a_{11}\ a_{12}\ a_{13}\ a_{14}\ a_{15}\ a_{16}\ a_{17}\ a_{18}\ a_{19}\ a_{20}\ a_{21}\ a_{22}\ a_{23}\ a_{24}\ a_{25}\ a_{26}\ a_{27}\ a_{28}\ a_{29}\ a_{30}\ a_{31}$

- Calculate the number of CT (coupling transitions) of the present bus data with the previous bus data.
- Calculate 6C, 5C, 3C, 2C and 1C type crosstalk transitions between present bus data with the previous bus data.
- If CT >= (n/2) then
- Consider the grouping of the present bus data. Now arrange the data on the data bus as

  Odd Group: $a_0a_2a_4a_6a_8a_{10}a_{12}a_{14}\ a_{16}a_{18}a_{20}a_{22}a_{24}a_{26}a_{28}a_{30}$

  Even Group: $a_1a_3a_5a_7a_9a_{11}a_{13}a_{15}\ a_{17}a_{19}a_{21}a_{23}a_{25}a_{27}a_{29}a_{31}$
- The Hamming Distance between odd group of present data and odd group of previous data is calculated. This is represented as OHD = Odd bits Hamming Distance
- The Hamming Distance between even group of present data and even group of previous data is calculated. This is represented as EHD = Even bits Hamming Distance

  Transmit the data by following the below conditions:

  If OHD > EHD, flip the data in odd bit positions and append bit ‘1’ on the left and bit ‘0’ on the right side of the encoded data.

  If EHD > OHD, flip the data in even bit positions and append bit ‘0’ on the left and bit ‘1’ on the right side of the encoded data.

  If OHD = EHD, flip the entire data and append bit ‘1’ on the left and bit ‘1’ on the right side of the encoded data.
- If CT<n/2 is true then transmits the data as it is, append bit ‘0’ on the left and bit ‘0’ on the right side of the encoded data.
- Calculate coupling transitions, 6C, 5C, 4C, 3C, 2C and 1C type crosstalk transitions.

Table 2. Efficiency of encoding technique for Crosstalk 6C

Method	64-bit	32-bit	16-bit
BINV	-1.419028	6.601467	43.809666
DYNAMIC	86.228561	88.080685	89.23031
BRG	79.588373	88.500917	92.4821
NOVEL	89.575735	86.109413	90.214797
BRG-HD	88.846362	89.234413	93.153341
SHINV	16.371186	16.648839	60.396778
EESCT	55.338508	47.195905	78.475537

4. PERFORMANCE EVALUATION

The effectiveness of proposed data bus technique for crosstalk reduction is evaluated by using a VHDL code. The simulations are performed on 64-bit, 32-bit and 16-bit data bus by applying 10000 data vectors. Coupling transitions, 6C type, 5C type, 4C type, 3C type, 2C type, and 1C type crosstalk are considered as metric parameters. The proposed technique performance is compared with the other existing six techniques namely Bus invert (BINV), Dynamic bus coding (DYNAMIC) Bus regrouping method (BRG), Novel data encoding (NOVEL), Shift invert coding (SHINV) and Energy efficient special encoding (EESCT) technique.

Table 3. Efficiency of encoding technique for Crosstalk 5C

Method	64-bit	32-bit	16-bit
BINV	13.692649	22.031255	8.2297806
DYNAMIC	33.541854	31.099484	24.717745
BRG	45.089982	42.409647	58.69488
NOVEL	70.523381	69.527704	55.733864
BRG-HD	68.189907	74.694203	71.40524
SHINV	12.584616	16.064313	16.814599
EESCT	31.19187	36.449634	29.056309

Table 4. Efficiency of encoding technique for Crosstalk 4C

Method	64-bit	32-bit	16-bit
BINV	26.74735	35.97949	34.299941
DYNAMIC	-25.60695	-1.043055	-22.634739
BRG	-21.01667	17.52452	-32.293497
NOVEL	7.43769	18.93798	13.246924
BRG-HD	24.8162	32.19841	19.478617
SHINV	14.73731	21.32337	14.960457
EESCT	-9.431594	26.02898	-3.04628

Table 5. Efficiency of encoding technique for Crosstalk 3C

Method	64-bit	32-bit	16-bit
BINV	-9.7765363	2.7801911	55.018762
DYNAMIC	-156.58215	-215.18679	-68.925891
BRG	-181.81493	-332.84101	-176.87617
NOVEL	-271.15743	-317.65421	-228.89306
BRG-HD	-240.47414	-315.46481	-220.23921
SHINV	-12.662942	-58.731538	-32.973734
EESCT	-42.522561	-66.046916	-70.473734

The proposed technique reduces the 6C, 5C and 4C crosstalk for 64-bit data bus around 88%, 68% and 24% respectively as shown in Tables 2, Table 3 and Table 4, for 32-bit data bus around 89%, 74% and 32% respectively as shown in Table 2, Table 3 and Table 4 and for 16-bit data bus by 93%, 71% and 19% respectively as shown in Table 2, Table 3 and Table 4. The proposed method efficiency in reducing the worst case crosstalk i.e 6C crosstalk is around 88% to 93%. Its efficiency in reducing the crosstalk is high comparing with the others. Table 6 and Table7 shows that the proposed technique converts the most of the crosstalk 6C, 5C, 4C and 3C to 2C and 1C crosstalk which does not causes any errors or delay. Hence proposed technique's overall efficiency is better compare to other techniques. The proposed technique's performance is evaluated by varying data bus width. This is shown in Figures 2, 3, 4 and 5.

Table 6. Efficiency of encoding technique for Crosstalk 2C

Method	64-bit	32-bit	16-bit
BINV	0.5411255	27.210884	73.57513
DYNAMIC	-104.16667	-91.666667	-22.797927
BRG	-455.03247	-792.17687	-241.45078
NOVEL	-1109.4697	-1637.585	-399.87047
BRG-HD	-1333.8745	-1639.7959	-314.37824
SHINV	-56.818182	-86.734694	-52.720207
EESCT	-66.937229	-149.65986	31.476684

Table 7. Efficiency of encoding technique for Crosstalk 1C

Method	64-bit	32-bit	16-bit
BINV	-12.413515	-25.247874	-28.85911
DYNAMIC	-2.4648947	-9.2710645	-8.0378076
BRG	-6.6817476	-20.423791	-26.282668
NOVEL	-11.453307	-25.417185	-31.734163
BRG-HD	-16.47996	-33.739081	-42.306458
SHINV	-16.120784	-25.808396	-41.082402
EESCT	-17.98585	-39.504637	-39.917574

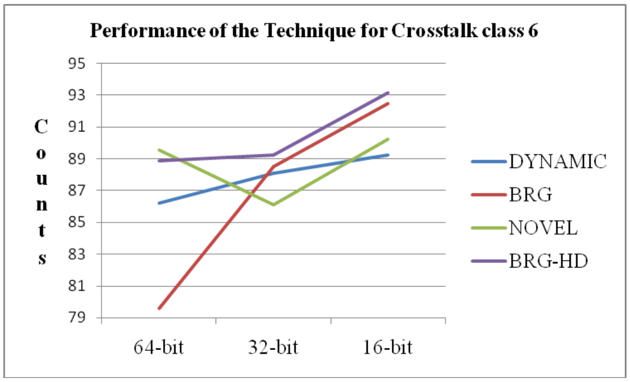

Fig 2:Performance of different techniques for 6C Crosstalk

The crosstalk reduction efficiency of encoding method is calculated by using the following formula:
Efficiency= (Crosstalk before encoding – Crosstalk after encoding) / Crosstalk before encoding X 100.

5. CONCLUSION

The Proposed crosstalk reduction technique for data bus is based on reducing coupling transitions. These transitions are reduced based on Hamming Distance. The main aim of the proposed technique is to reduce 6C, 5C and 4C crosstalk transitions. The reduction in worst case crosstalk reduces the overall energy consumption and delay on data bus to transfer data. The simulation results show that the proposed technique reduces the 6C, 5C and 4C type crosstalk for 64-bit data bus around 88%, 68% and 24% respectively, for 32-bit data bus around 89%, 74%

and 32% respectively and for 16-bit data bus by 93%, 71% and 19% respectively.

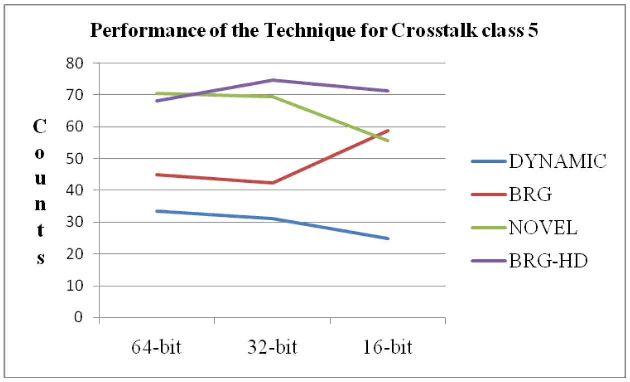

Fig 3: Performance of different techniques for Class 5 crosstalk

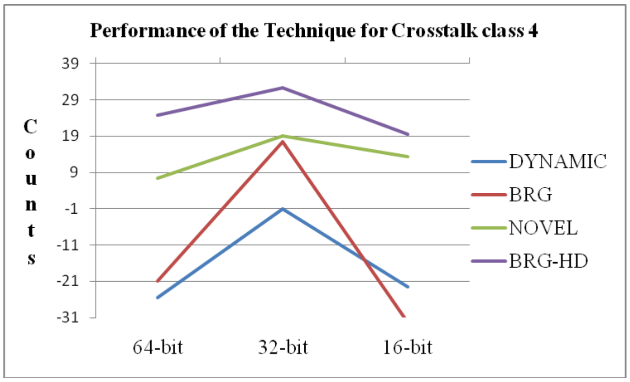

Fig 4: Performance of different techniques for Class 4 crosstalk

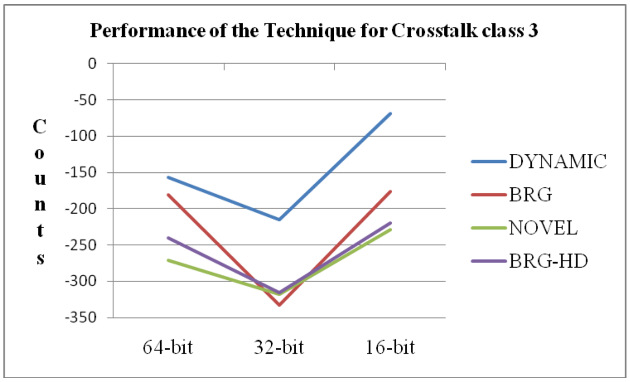

Fig 5: Performance of different techniques for Class 3 crosstalk

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