Delayed-ABC SOI for crosstalk noise repair

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Abstract: Crosstalk repair by gate sizing often increases the noise on adjacent wires, and results in cyclical iterations of noise repair. We propose a Delayed Actively Body-bias Controlled (D-ABC) SOI scheme for crosstalk noise repair by providing delayed forward bias to drivers. The delay between gate and body suppresses the crosstalk noise on adjacent wires. The proposed D-ABC SOI scheme has reduced the crosstalk noise by 48.5%, with 4.3% increase in the crosstalk noise on adjacent wires.

Keywords: crosstalk, noise, signal integrity, SOI, body-bias

Classification: Integrated circuits

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1 Introduction

Crosstalk noise has become one of the critical design issues, because of high coupling capacitances and low supply voltages in nanometer era. To repair crosstalk noise, a lot of techniques have been proposed [1, 2, 3].

Gate sizing is a practical crosstalk noise reduction technique in the post route design stage. The difficulty in gate sizing for noise reduction is that, by increasing a driver size, noise at the driver output is reduced, but noise injected by that driver on other nets is increased. This can create cyclical dependencies between nets in the circuit with noise violations [2]. Hence, many researchers have proposed heuristic post-route gate sizing algorithm that uses a graph representation of the noise dependencies between nodes. However, solving those post-route gate sizing problems is difficult. In this paper, we focus on correcting crosstalk noise by gate sizing. Our goal is to suppress the noise on adjacent wires and to break the cyclical dependencies between nets.

To achieve the goal, we make use of body bias control of Partially Depleted Silicon On Insulator (PD-SOI). The threshold value of PD-SOI devices can be controlled dynamically by its body bias, and a lot of approaches about body bias control have been proposed [4, 5, 6, 7]. Dynamic Threshold MOSFET (DTMOS) [4] uses gate signal for body bias control. The Look-Ahead type Active Body Biasing (LA-ABB) [5] uses a looked ahead body biasing signal, and lowers V_{th} beforehand to accelerate switching of the transistor. The Actively Body-bias Controlled (ABC) SRAM controls the body biases of the access and driver transistors by the potential of the word line, and realizes low voltage operation while improving write margin [6, 7]. Conventional body bias control approaches realize high speed operation by forward bias to the switching transistors, and realize low leakage power by zero bias to the others. The key factor of these approaches is to give sufficient forward bias while the transistors switch from off to on. In cross talk repair, conventional body bias control approaches works as well as gate sizing.

In this paper, we propose a novel body bias control method named D-ABC SOI for crosstalk noise repair. Our approach suppresses forward bias while switching, and realizes the low noise injection to adjacent wires. The delayed forward bias with the switching increases the drivability and reduces the noise induced by adjacent wires. Therefore, we are able to improve the

noise tolerance by suppressing the influence on adjacent wires. Furthermore, we evaluate the effect by selecting optimum body contact resistance.

2 Delayed-ABC approach

2.1 The circuit configuration

Figure 1 shows crosstalk glitch repair situations by controlling drivability. The driver cells, A1, B1, C1, and receiver cells, A2, B2, C2, are connected to N_{A1} , N_{B1} , N_{C1} , respectively. N_{A1} , N_{B1} and N_{C1} have crosstalk noises caused by coupling capacitances. We assume that the supply voltage is below 0.6 V, so the gate and body can be connected directly.

Now, we are going to improve the crosstalk noise at N_{A1} as shown in Fig. 1 (a). Figure 1 (b) shows a conventional body-tie and upsizing approach. Figure 1 (c) is the body bias approach with DTMOS, in which N_{A0} and body_{A1p}, N_{A0} and body_{A1n}, are connected. Figure 1 (d) shows the proposed D-ABC in which N_{A0} and the body are connected by the high resistance body contacts, R_{A1p} and R_{A1n} .

Fig. 1. Crosstalk noise repair by controlling drivability and waveforms of N_{A1}

The features of our approach are the following two points.

1. crosstalk noise reduction by forward bias (N_{A1} is a victim)
2. low noise injection to neighboring wire by delayed forward bias (N_{A1} is an aggressor)

We use the body bias control for noise reduction. Quick change of body voltage is important for high speed operation. Slow change of body voltage, which caused by high resistance, is not effective in achieving the high drivability that is the conventional body bias control objective. However, we make use of the insufficient forward bias for suppressing the noise to neighboring wire. After the switching, the forward bias increases gradually, and our approach achieving improves the noise tolerance.

2.2 The operation mechanism

Without loss of generality, we explain the operations of the N_{A1} for a fall glitch noise in both cases when N_{A1} is a victim and an aggressor. The explanation of the rise glitch case, because it is similar to the fall glitch one. Typical voltage waveforms of N_{A1} and body_{A1n} for body-tie, upsizing, DT-MOS, and D-ABC are shown in Fig. 1 (f)–(k). Initially, N_{A0} is L, A1p is on and A1n is off. N_{A1} , N_{B1} and N_{C1} are H.

Figure 1 (f) and (g) are the cases when N_{A1} is a victim. When N_{B1} and N_{C1} change into L, the fall glitch noise occurs to N_{A1} . By the upsizing repair, the noise at N_{A1} is improved, because the transistor size of A1p is larger than body-tie. In case of using DTMOS, when N_{A0} is L, body_{A1p} is L and A1p has a forward bias. Therefore, the drivability of A1p is increased and the glitch of N_{A1} is reduced compared with body-tie, where body_{A1p} is H and A1p has a zero bias. In case of D-ABC, body_{A1p} is L or moving from H to L. As A1p has a forward bias, the noise at N_{A1} is reduced in comparison with body-tie. If N_{A1} changed to H and remains at H for a long time, body_{A1p} is L and A1p has the maximum forward bias.

Figure 1 (h)–(k) are the cases when N_{A1} is an aggressor. When N_{A1} changes into L, the fall glitch noise occurs to N_{B1} and N_{C1} . In upsizing repair, N_{A1} changes more rapidly than body-tie, N_{A1} injects a bigger noise to N_{B1} . In DTMOS repair, when N_{A0} is L, A1n has a zero bias. When N_{A0} changes into H from L, body_{A1n} follows N_{A0} and A1n has a forward bias. As a result, N_{A1} changes more rapidly and makes a bigger noise to N_{B1} than body-tie. In D-ABC repair, when N_{A0} is L, A1n has a zero bias. When N_{A0} changes into H from L, body_{A1n} follows N_{A0} as well as DTMOS. However, it rises slowly, because R_{A1n} has a high resistance value. While the N_{A1} transition period, body_{A1n} does not have a sufficient forward bias. Thus, our approach suppresses the noise on N_{B1} and N_{C1} , with improving the noise at N_{A1} .

3 Implementation and Simulation Results

In this section, we present the circuit simulation results for a fall glitch noise

(a) Circuit and layout

(b) The noise relationships between the cases N_{A1} is an aggressor and a victim.

Fig. 2. The experimental circuit and the noise relationships

with 90 nm SOI technology. The supply voltage is 0.5 V. Figure 2 (a) shows the circuit for simulation. The minimum spacings between N_{A1} and N_{B1} , N_{A1} and N_{C1} are 0.14 μm . The interconnect length between A1 and A2 is 802.01 μm . The coupling part is routed with metal 5, and coupling length is 795.30 μm . We have changed the drivability of A1 among x2, x3, x4, x6, and x8, and changed the body contact resistance, among 200 k Ω , 1 M Ω , and 10 M Ω . The highest resistance with body contact is 100 M Ω by Schottky barrier effect. The threshold voltages of transistors are set to $V_{th,n}=0.305$ V, and $V_{th,p}=0.386$ V, respectively. The resistance values of body for $V_g=0$ V are set to $R_{body,n}=71.3$ k Ω , and $R_{body,p}=131.2$ k Ω , while $R_{body,n}=33.3$ k Ω , and $R_{body,p}=42.1$ k Ω for $V_g=0.5$ V. The gate widths of x1 buffer are $W_n=0.54$ μm ,

Fig. 3. Voltage waveforms of (a) victim N_{A1} , and aggressor N_{B1} , (b) aggressor N_{A1} , victim N_{B1} , and (c) $body_{A1n}$

$W_p=0.82$ μm , respectively.

Figure 3 (a), (b), and (c) show N_{A1} , N_{B1} and $body_{A1n}$ voltage waveforms for body-tie, upsizing from x4 to x8, DTMOS, and D-ABC, when A1 size is x4. Here, 200 k Ω , 1 M Ω , and 10 M Ω in Fig. 3 are the body contact resistance values of D-ABC. When A1 is a victim, we assume that N_{A1} changed to H and remains at H for a long time. Upsizing(x8), DTMOS, 200 k Ω , 1 M Ω and 10 M Ω improve the noise by 43.6%, 46.7%, 47.5%, 48.1% and 48.5%, respectively. When A1 is an aggressor, upsizing(x8), DTMOS, 200 k Ω , 1 M Ω and 10 M Ω make crosstalk noise increase by 79.0%, 60.5%, 51.1%, 27.2% and 4.3%, respectively. When N_{A0} voltage is 250 mV, the $body_{A1n}$ voltages of DTMOS, 200 k Ω , 1 M Ω , and 10 M Ω are 181.6 mV, 106.9 mV, 57.7 mV and 40.6 mV, respectively. Insufficient forward bias for A1n during switching period suppresses the increment of induced noise.

Figure 2 (b) shows the noise relationships between the cases N_{A1} is a

victim and an aggressor. The more the resistance of body_{A1n} gets larger, the less N_{A1} has glitch noise, if the N_{B1} glitch value is same. However, the effects at 10 M Ω and 100 M Ω are almost equal, and 10 M Ω resistance is sufficient. We compare the conventional gate sizing method at x8, and D-ABC at x4. 10 M Ω and 1 M Ω cases have improved the N_{A1} 's noise by 8.7% and 8.1% in victim case, respectively. Also those cases improve the N_{B1} 's noise by 41.7% and 28.9% in aggressor case, respectively. In both victim and aggressor cases, D-ABC has improved crosstalk noises more than conventional upsizing method.

The optimum resistance value is concerned with the required circuit speed. Too high resistance hinders the preparation for the next crosstalk noise caused by N_{B1} and N_{C1} . From Fig. 3 (b), we find that the N_{A1} transition time is about 2 ns. Assume that N_{B1} and N_{C1} switch from H to L 2 ns after N_{A1} has just moved from L to H. Compared with body-tie at x4, DTMOS, 200 k Ω , 1 M Ω and 10 M Ω have improved the noise by 48.9%, 49.4%, 47.4% and 14.3%, respectively. In this case, we judge 1 M Ω as effective. If more slow speed is requested, over 1 M Ω cases are effective.

4 Conclusion

In this paper, we have proposed the D-ABC SOI scheme with the resistance for delay between gate and body to improve a crosstalk noise. A D-ABC SOI driver works as an effective crosstalk repair solution, by increasing the drivability in victim case and by suppressing it in aggressor case.

The simulation results at 0.5 V operation have shown that the 10 M Ω body contact improves the crosstalk noise by 48.5%, with the noise increase on adjacent wire only by 4.3%. Compared with conventional gate sizing method, D-ABC has reduced the crosstalk noise when N_{A1} is a victim and an aggressor by 8.7% and 41.7%, respectively. In our exploration about frequency signal changes for wire those transition time is 2 ns, we have indicated that 1 M Ω or lower resistance effective.