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Research on electromagnetic interference resistance performance of three kinds of CMOS inverters

Key words: Voltage-mode complementary metal oxide semiconductor (CMOS); MOS current-mode logic (MCML); Current-mode CMOS; Electromagnetic interference (EMI); Inverter

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Motivation

1. The increasingly complex electromagnetic environment affects the normal operation of integrated circuits (ICs), leading to malfunctions in electronic systems.

2. As IC technology progresses, featuring smaller chip geometries, higher clock frequencies, and lower operating voltages, ICs inherently become more vulnerable to EMI.

3. There is a lack of circuit design at the level of circuit structure for EMI resistance, while the current-mode CMOS circuits exhibit several advantages, including high speed, low power consumption, and superior noise immunity in the deep submicron process.

Main idea

1. Three circuits such as the voltage-mode CMOS, the MCML, and the current-mode CMOS are selected to study their EMI resistance performance.

2. Compare the effect of injecting disturbing signals from the power pin, signal input pin, and output pin of the circuits on the output results of the circuits, respectively.

3. Compare the EMI resistance performance of three inverters to interference signals of different waveforms and frequencies.

4. Compare the EMI resistance performance of three inverters at different temperatures and manufacturing processes.

5. The relationship between input resistance of the current-mode CMOS and circuits' EMI resistance performance is investigated.

Method

1. Simulations with Cadence Virtuoso software are performed to study the effect of EMI on three inverters.
2. The study employs the use of direct injection of EMI signals into the circuits in simulation.
3. The disturbance level factor *λ* is defined to compare the EMI resistance performance of voltage-mode and current-mode circuits.

Major results

1. Effect of EMI signal injection terminal on the circuits

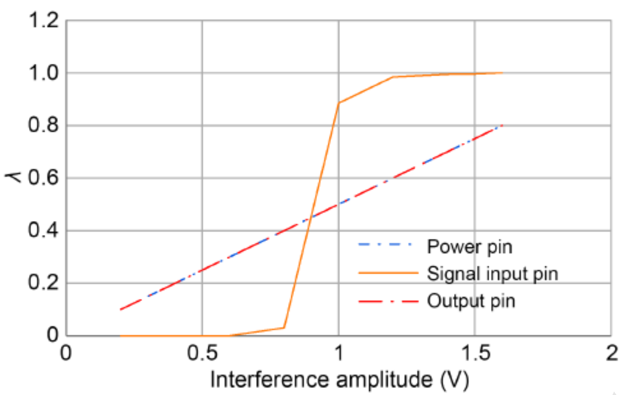

Fig. 4 Variation of λ of voltage-mode CMOS NOT gate with injection terminal and amplitude of sine wave interference signal

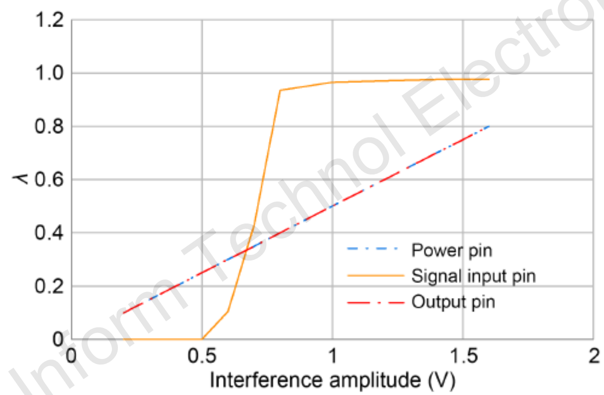

Fig. 6 Variation of λ of MCML NOT gate with injection terminal and amplitude of sine wave interference signal

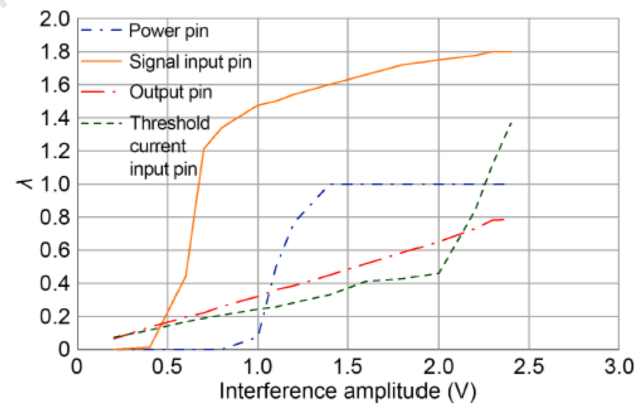

Fig. 8 Variation of λ of current-mode CMOS NOT gate with injection terminal and amplitude of sine wave interference signal

Major results

2. Effects of EMI waveforms and frequencies on circuits

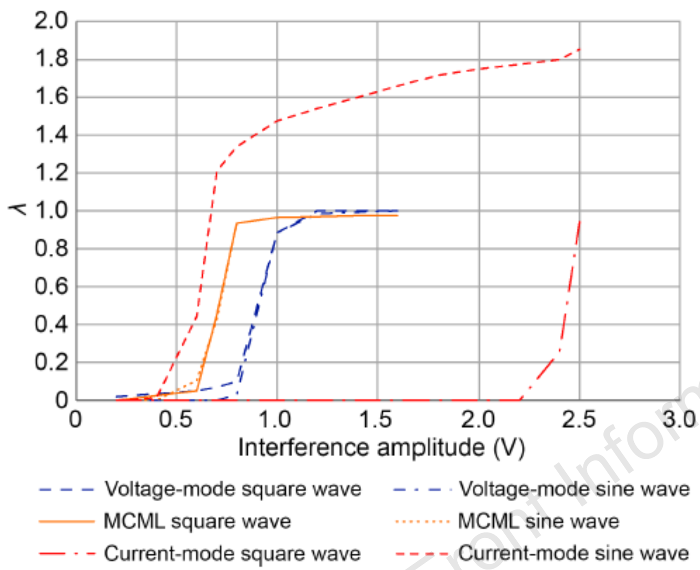

Fig. 10 Variation of λ of the three NOT gates with the waveform and amplitude of the interference signal

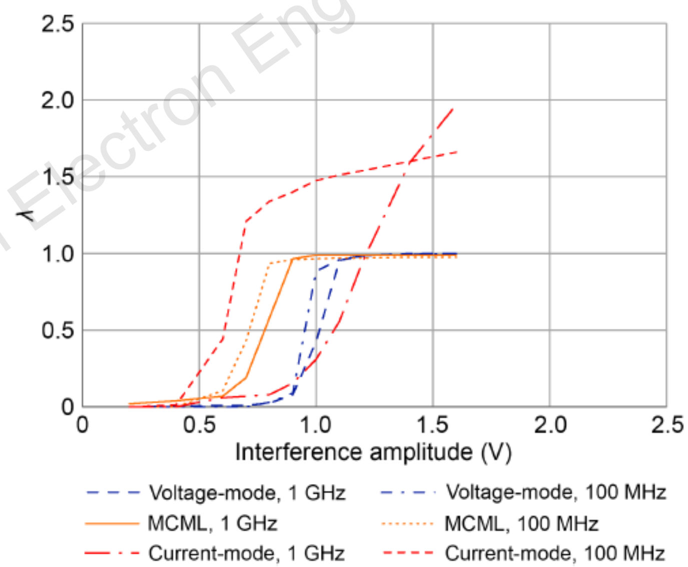

Fig. 12 Variation of λ of three kinds of NOT gates with the frequency and amplitude of the sine wave interference signal

Major results

3. Effects of temperatures and processes on circuits

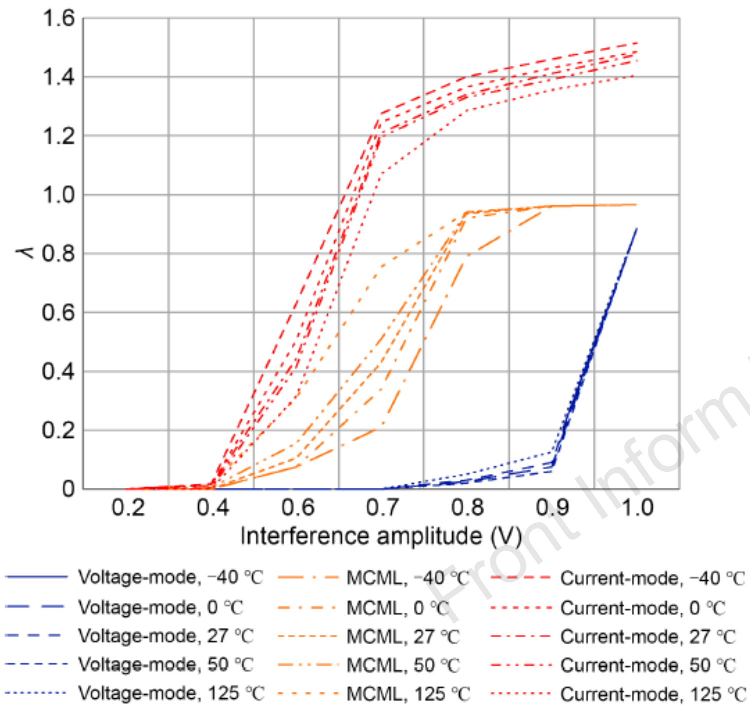

Fig. 14 Variation of λ of three kinds of NOT gates with temperatures and amplitude of the sine wave interference signal

Table 8 Voltage amplitude required by the three circuits to have logic errors and η values in different processes

NOT gate	V_{noise} (V)		η	
	28 nm	65 nm	28 nm	65 nm
Voltage-mode	0.50	1.00	0.50	0.50
MCML	0.40	0.80	0.40	0.40
Current-mode	0.80	0.70	0.80	0.35

Major results

4. Effect of resistance values on current-mode CMOS circuits

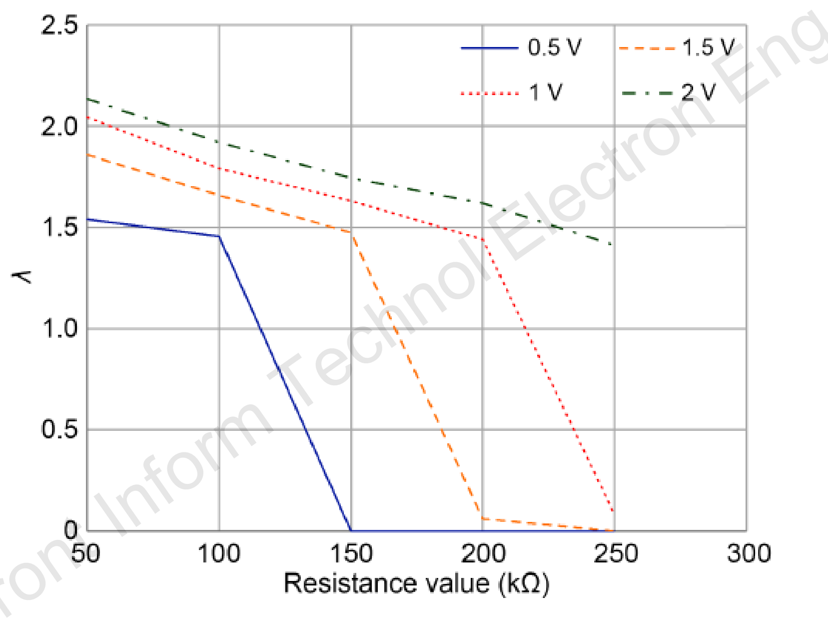

Fig. 15 Variation of λ of current-mode CMOS circuit with amplitude of sine interference signal and resistance value

As modern processes become more advanced, the internal capacitance of the circuit becomes smaller, the input impedance of the circuit becomes larger, and the resistance performance of the current-mode CMOS circuit will become better.

Conclusions

1. It is found that the EMI has a greater effect on the circuits if it is injected from the input of the signals from the simulation results.

2. For high-frequency EMI, the current-mode CMOS circuits have better resistance performance than the other two kinds of circuits.

3. In the square wave interference, the current-mode CMOS circuit interference resistance ability is significantly stronger than that of the other two kinds of circuits.

Conclusions

4. In the temperature range of −40 to 125 ℃, the higher the temperature, the weaker the immunity of voltage-mode CMOS and MCML circuits, and the stronger the immunity of current-mode CMOS circuits.
5. In the 28 nm process, the current-mode CMOS circuit interference resistance ability is relatively stronger than that of the other two kinds of circuits.

Jizhong SHEN received the Ph.D. degree in electrical engineering from Zhejiang University, Hangzhou, China, in 2001. He is currently a Full Professor with the College of Information Science and Electronic Engineering, Zhejiang University, Hangzhou, China. He has authored or coauthored more than 190 refereed technical articles on digital circuits design, low-power design, brain-computer interface. His current research interests include digital integrated circuit, EDA and brain-computer interface.