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36

CHAOTYCZNY INWERTER MOS
CHAOTIC MOS INVERTER

In the integrated circuits XCMOS two crowbar circuits protecting the input circuit (gate) against the influence of electrostatic discharge (ESD) are used [1]. In the series HC/AC-MOS being produced the protecting elements are the ESD-SCR (SILICON-CONTROLLED RECTIFIER) networks in which the basic functional role is played by a semiconductor structure, in literature known as LATCHUP [2]. A non-linear, two-terminal resistant R_N of the S-type current-voltage characteristic (i,v), with the extreme points of operation (i_s, v_s), (i_h, v_h) [SWITCHING, HOLDING CURRENT/VOLTAGE], provides the model of this structure. In this paper the model of the ESD circuit at the MOS gate input, within the connection LR∞C-LATCHUP/SCR (Fig.1) [5], has been proposed for mathematical analysis.

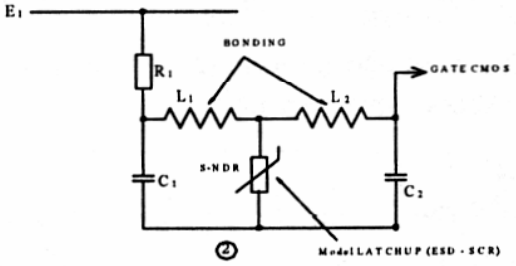

Fig. 1. Schematic diagram of the ESD block of the CMOS

The curve describing the SCR has been approximated by means of the polynomial:

$$R_N : V(i) = ai^3 + bi^2 + ci, \quad a > 0,\ b < 0,\ c > 0,\ b^2 - 4ac < 0, \tag{1}$$

where the coefficients a, b, c have been made dependent on the co-ordinates (i_s, v_s), (i_h, v_h). Subsequently the methods of analysis described in [3] have been used and the equation of state has been derived as follows:

$$C_1 \cdot \frac{dV_{C1}}{dt} = -\frac{1}{R} V_{C1} - i_{L1} + \frac{E_0}{R}, \tag{2}$$

$$C_2 \frac{dV_{C2}}{dt} = i_{L2}, \tag{3}$$

$$L_1 \frac{di_{L1}}{dt} = Vc_1 - V_{RN}(i_{L1} - i_{L2}), \tag{4}$$

$$L_2 \frac{di_{L2}}{dt} = -Vc_2 + V_{RN}(i_{L1} - i_{L2}), \tag{5}$$

where: C_i, L_i (i=1,2) denote the capacities and inductances, respectively, i_{L1}, i_{L2}, V_{C1}, V_{C2} denote the variables of state corresponding to capacities/ inductances, E_0 denotes the

supply voltage of the circuit, R denotes the resistor of high-resistance (in the order of $10^8\ \Omega$).

After introducing the so-called relaxation-oscillation parameters (τ,ω) the dynamics of the system will be characterised by the equation:

$$\Lambda^4 + \Lambda^3\left[\frac{1}{\tau_1} - \gamma\tau_1\omega_1^2 - \gamma\tau_2\omega_2^2\right] + \Lambda^2\left[\omega_1^2(1-\gamma) + \omega_2^2\left(1-\gamma\frac{\tau_2}{\tau_1}\right)\right] + \Lambda\left[\frac{1}{\tau_1} - \gamma\tau_1\omega_1^2 - \gamma\tau_2\omega_1^2\right]\cdot\omega_2^2 + \omega_1^2\omega_2^2(1-\gamma) = 0, \quad (6)$$

where: $\tau_1 = RC_1$, $\tau_2 = RC_2$, $\omega_1^2 = \frac{1}{L_1C_1}$, $\omega_2^2 = \frac{1}{L_2C_2}$, and γ is the coefficient dependent on the position of the constant point. Based on this equation the formulae for Lyapunov exponents have been derived and the concept of exponents signs spectrum [4] has been used in order to show the chaotic behaviour of the systems designated as (- ,0,0,+) and (-,-,0,+).

The set of material constants of the circuit (L,C,R) for which the response of the system that had been tested is chaotic has been determined. It has been shown that in order to satisfy the chaos criterion (-,0,0,+), the coils (L), capacitors (C) and resistance (R) have to satisfy the following relations:

$$C_2 > C_1, \quad (7)$$

$$L_1 = R^2(C_1 + C_2), \quad (8)$$

$$L_2 > L_2^{MIN} = R^2\cdot\frac{C_1}{C_2}(C_1 + C_2). \quad (9)$$

Some numerical examples have been presented in the paper. Also the algebraic equation describing the LATCHUP/SCR characteristics has been given as follows:

$$R_N : V(i) = 0{,}8\cdot10^{24}\cdot\frac{V}{A^3}i^3 - 3{,}6\cdot10^{16}\frac{V}{A^2}i^2 + 4{,}8\cdot10^8\frac{V}{A}\cdot i, \quad (10)$$

The constant points and the non-dimensional Lyapunov exponents, corresponding to these points, have been determined as well.

Finally, the explanation of the unstable (chaotic) behaviour (occurring immediately after the switching of the supply voltage V_{DD}) of the CMOS inverter, equipped with the unused inlet/outlet (I/O), has been proposed.

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