



## Doctoral Thesis

# Research on static and pulse noise immunity of integrated digital circuits

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**RESEARCH ON STATIC AND PULSE NOISE  
IMMUNITY OF INTEGRATED DIGITAL CIRCUITS**

DISSERTATION

submitted to the

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ZURICH

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presented by

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## S U M M A R Y

In high-speed digital systems of integrated logic gates having propagation-delay-times ( $t_{pd}$ ) of 10n.sec. or less, static and pulse noise immunity of the circuit must be well known to insure correct operation of the system.

In this thesis, the "Worst case" and "Worst-Worst case" static noise margin is defined, measured and discussed as a function of power-supply voltage, temperature and fan-out. High noise margin (about 7 volt) can be achieved using "High Threshold Logic" gates. This is achieved at the expense of the gate's speed and efficiency.

Pulse noise immunity in digital integrated logic gates depends not only on the power-supply, but also on  $t_{pd}$  of the gate.  $t_{pd}$  has been measured for integrated logic gates and for J-K flip-flops as a function of capacitive load, temperature and fan-out.

The relationship between  $t_{pd}$  and pulse noise immunity is analysed theoretically and is measured exactly using two equal gates together with the gate under test, connected in a cross-configuration. The higher the speed of the gate, the less is its immunity to pulse noise. Theory and measurements show good agreement.

Trouble due to pulse-shape variations caused by reflections on a long line connecting two or more high-speed digital integrated circuits, has been determined graphically applying Bergeron's theory. These disturbances have been eliminated using the so called "Integrated Matching gates", without affecting the logic system's fan-out capacity.

Crosstalk on lines connecting integrated logic gates has been recorded, if the pick-up line is at logic (0) or logic (1) level or if it connects gates having the same or opposite directions. Crosstalk noise and its effect on the correct operation of a digital system has been analysed theoretically. Theory and experiments show good agreement. Crosstalk noise has been eliminated and correspondingly the reliability of the system has been improved by proper matching of the connecting lines (using integrated matching gates), and by increasing the capacity of lines to ground. This has been achieved either by using proper lumped condensers or by using shielded cables. Shielded cables of low characteristic impedances show the best results.

Reduction in the digital system noise margin due to transient currents on the common power-supply rail and in the ground plane have been eliminated by reducing the lengths and characteristic impedances  $Z_0$  of these common lines.  $Z_0$  has been artificially reduced using a proper lumped condenser at the power-supply voltage input point of the I.C. package. Such a condenser has also been integrated and allows the use of long power-supply lines, feeding a large number of high-speed gates, without affecting their correct operation.

### ZUSAMMENFASSUNG

In der vorliegenden Promotionsarbeit werden die statische und dynamische Störsicherheit von sehr schnellen integrierten Schaltkreisen theoretisch und experimentell behandelt.

Die Einflüsse der Speisespannung, der Temperatur und der Eingangs- und Ausgangsfächerung (Fan-in und Fan-out) auf die statische Störsicherheit wurden gemessen und diskutiert.

Die Einflüsse der kapazitiven Last, der Temperatur und der Ausgangsfächerung auf die Verzögerungszeiten der integrierten Schaltkreise werden mathematisch und experimentell erörtert.

Die dynamische Störempfindlichkeit von sehr schnellen logischen integrierten Schaltkreisen wird berechnet und gemessen für verschiedene Tore, bei verschiedenen Temperaturen, beim logischen (1) sowie beim logischen (0). Ihre Abhängigkeit von der Verzögerungszeit wird untersucht. Langsame Tore sind weniger empfindlich gegen Störungen.

Die Reflexionen und das Übersprechen bei zu langen Verbindungsleitungen zwischen schnellen integrierten Schaltkreisen und der davon herrührende Einfluss auf die dynamische Störsicherheit des logischen Systems wurden ebenfalls untersucht. Verfahren und Vorrichtung zur Vermeidung von Reflexionseffekten werden theoretisch und experimentell untersucht.

Die Störungen infolge der Stromversorgungs- und Erdungsleitungen werden auch gemessen und diskutiert. Massnahmen, um die statische und dynamische Störsicherheit zu verbessern, werden vorgeschlagen und die damit erreichten Verbesserungen werden gemessen und dargestellt. Der Erfolg dieser Massnahmen kann als sehr günstig bezeichnet werden.