Instruction Dependent Upset of a Microcontroller

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***Abstract*— Direct injection experiments have been carried out on a microcontroller in order to determine upset dependencies of digital electronic systems. The microcontroller provides a platform to examine the effects of direct injection timing, frequency, and pulse duration on a digital system with known programming and a known operational state. Results indicate that in addition to a dependence on frequency and pulse width of the direct injection signal, different programming instructions demonstrate different upset thresholds.**

Keywords-IEMI, Upset, Digital Electronics, HPM

I. INTRODUCTION

There has been significant research into the effects of RF signals at the device level [1] as well as at the circuit and chip level [2], while more recently the RF Effects MURI [3] provided significant advances in understanding and predicting RF effects. A microcontroller, being a simple but complete computer on a single chip and thus representing an intermediate level of complexity between an individual CMOS device and a complete digital system, is an ideal device to use as a test-bed in attempting to understand and predict RF effects on digital electronic systems [4]. In addition, earlier research on quantifying the susceptibility of microcontrollers to RF pulses [5] suggested that carefully timed RF pulses relative to clock signals could yield useful information about the underlying mechanisms of RF interference.

II. EXPERIMENTAL SYSTEM

A. Experimental method

Our experimental approach was to mount the microcontroller on an evaluation board, both for ease of programming and to provide convenient connections for RF injection. A function generator provides an external clock signal to the microcontroller. By providing the clock and knowing specifics of the programing the instruction being carried out at each clock cycle is known. A delay generator is used to gate a direct injection RF signal with a user-specified amplitude at a predetermined time into microcontroller XTAL1 signal line, along with the external clock signal from the function generator.

For the majority of experiments, the microcontroller is programmed to execute a counter, and we monitored the outputs to determine the state of the microcontroller. For each suite of experiments, we performed the RF injection and recorded the response of the microcontroller. Specifically, we monitored the output of the counter, and documented whether or not the RF pulse resulted in an upset. At each voltage we repeated the experiment a specified number of times, and made use of a Bayesian approach to convert the binary data (effect/no effect) into a continuous probability of effect curve. We then summarized the curve for each location by the voltage associated with a 50% probability of upset (which we refer as the threshold voltage), together with a 95% confidence interval (strictly a Bayesian credible interval). The model we have developed suggests a number of experimental investigations.

B. Experimental Results

Data have been taken to examine the upset threshold dependence on frequency, pulse duration, and instruction state. The most interesting of these is the dependence on the instruction being carried out by the microcontroller at the time of injection.

Data taken to date indicates that the upset threshold varies with the software being executed. Further work is being conducted on a variety of assembly instructions including bitwise operations, data exchange, and branching instructions. Significant progress has been made in programming the MCU, allowing injection of RF while it is responding to interrupts and adhering to the watchdog timer.

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