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ICEM MODELING OF MICROCONTROLLER CURRENT ACTIVITY

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Abstract
The ICEM draft proposal deals with an extension of the IBIS [1] standard, aimed at predicting conducted-mode as well as radiated-mode emission [2]. This proposal provides a modeling methodology for the power supply network and the current activity of an integrated circuit. Thanks to these models, predicting conducted-mode emission levels on the chip as well as on the application board becomes possible by the means of SPICE-based analog simulations. This allows the chipmaker to better choose the chip package as well as the number of power supply pairs, and the integrator to fine tune the number of power supply networks and decoupling capacitors. Ils peuvent-être élaborés soit pendant la phase de conception ou soit par mesure une fois que le silicium est disponible. The corresponding models may be elaborated either in the design phase or from measurements performed as soon as the silicon becomes available.
This article briefly summarizes the ICEM model, then introduces the proposed methodology aimed at obtaining the current activity model from the measurements performed on the current consumed on the power supply pins of an IC.

1. Introduction

Predicting conducted-mode emission relies on the knowledge of the current flowing on the power supply networks of an IC and its PCB. In order to obtain this current, the behavior of the power supply network impedance and the profile of the instantaneous current consumed by the chip core both have to be identified. Each building block of the IC architecture (core, memories, buffers, analog functions) can be modelled this way. Figure 1 depicts the main principles of ICEM [3] modeling in the case of a microcontroller, including core and buffers.
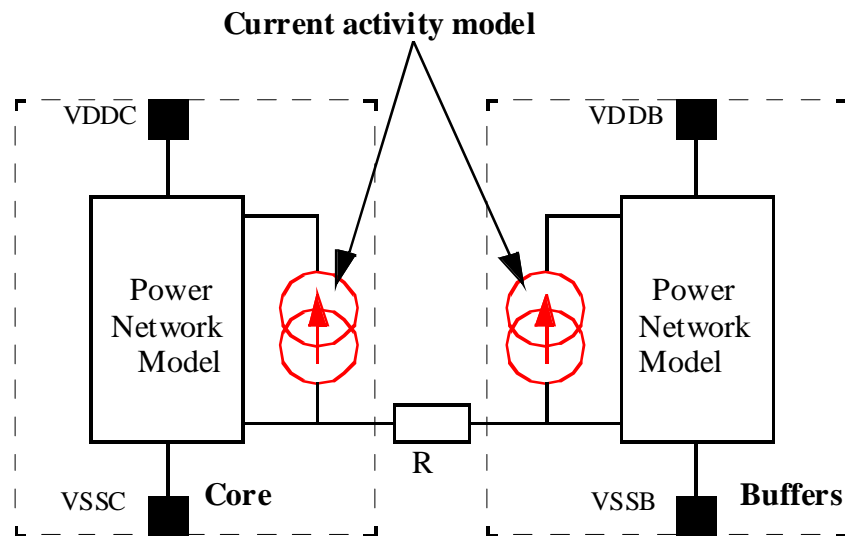

Figure 1 : ICEM modeling principles

The core and buffer models include the power supply impedance as well as a specific current activity. An isolation resistance between both grounds represents the substrate leakage resistance and is supplied by the model as well. Of course, depending of the IC, including additional models for each entity is made possible.
In order to model current activity, good knowledge of the power supply impedance model is compulsory. Afterwards, computing the profile of the current flowing on the chip is made possible by measuring the current consumed on power supply pins . An 8-bit microcontroller from the 80C51 family [4] was chosen for introducing the modeling methodology.

2. Model of the microcontroller power supply network

The kind of model used to represent the power supply network depends on the frequency band used by the IC. This band depends on the sharpness of the edges and of the amplitude of the instantaneous current, as well as on the physical dimensions of the power supply connectors. The band used by the current peaks of the 8-bit microcontroller is 300 MHz-wide. In this case, a plain RLC model is accurate enough to represent the power supply network of the core and the buffers. Model elements are extracted thanks to measurements performed on a test board with a network analyzer, as shown in figure 2.
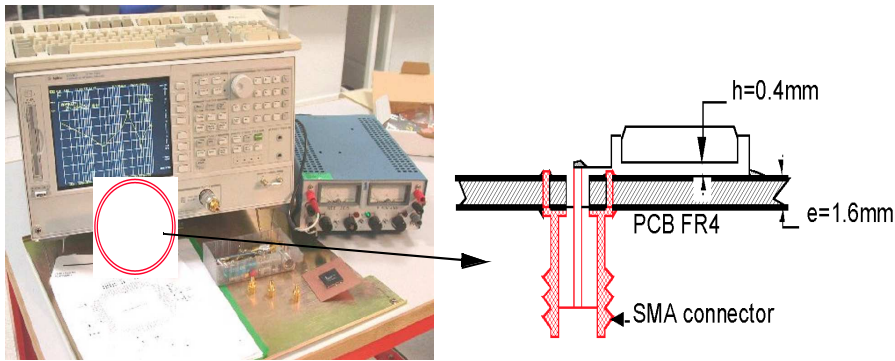

Figure2. Test setup for power supply network model extraction

Figure 3 displays an example for a power supply pair. The µC ground is connected with the test board ground, and the VDDC1 pin is connected with the inner conductor of the SMA connector. The frequency response of the impedance shows three kinds of impedance up to 300 MHz.
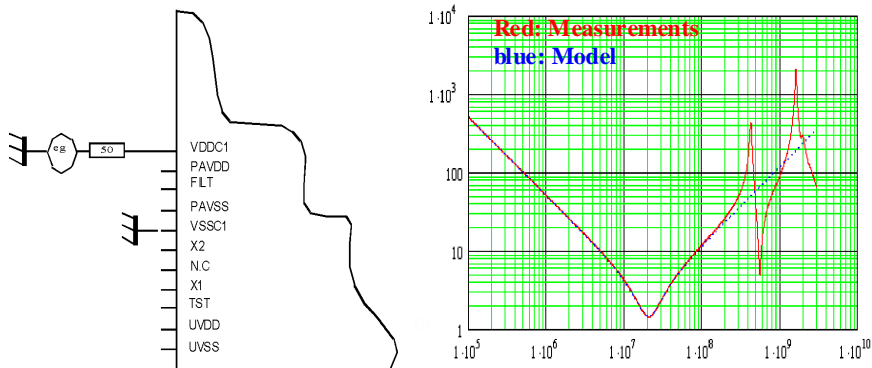

Figure3. Measurement setup example and frequency response of a power supply pair.

At frequencies lower than 10 MHz, the impedance is capacitive, and its value can be computed at a given frequency. At 15 MHz, the impedance is resistive, and its value can be extracted from the curve. Above 20 MHz and up to 300 MHz, the impedance is inductive and can be computed as in the first case. Figure 4 displays the partial model of the network for this supply pair.
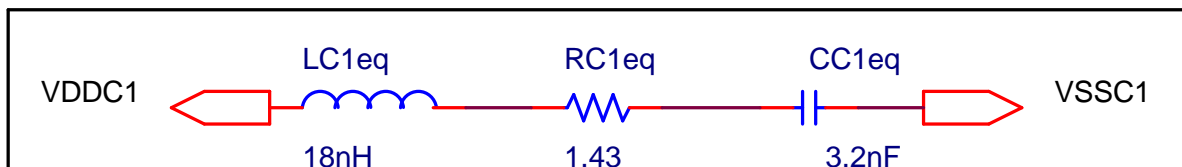

Figure 4. Network impedance model example for a power supply pair.

The same method can be used to model each power supply pair of the core as well as of the buffers.

3. IC current activity modeling

In order to obtain the current model, it is compulsory to define a given activity. In this example, the RESET mode of the microcontroller was chosen. The principles rely on the knowledge of the power supply network and on the measurement of the current consumed in this network. This measurement is performed by inserting a Rm resistor, low enough to avoid generating too high a voltage drop on the power supply (< 100 mV), and uses a differential current probe.
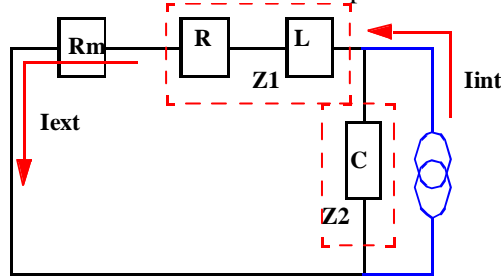

Figure 4: How to extract the current consumed by the chip

The Iint equivalent current generator flows into two parallel impedances. The measurement of the Iext external current allows us to deduce Iint by using the formula below :

$$I_{int} = I_{ext} \times \left(\frac{Rm + Z1 + Z2}{Z2} \right) K_z(f)$$

For that purpose, it is compulsory to convert the measured current from time domain into frequency domain by using a FFT in order to obtain Iext(f), and then in the opposite way by an inverse FFT in order to retrieve Iint(t) . Figure 5 summarizes the proposed method.
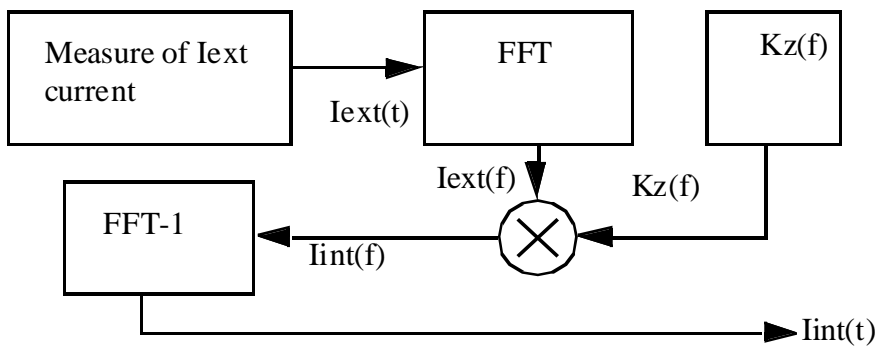

Figure 5. The methodology for IC current activity modeling.

Of course, it is important to define the FFT resolutions in both domains in order to obtain enough accuracy on the model. The transition times of the internal currents may be around 1 ns, thus making it compulsory to record signals for several ms. These criteria allow us to define the electrical characteristics of the scope used for acquisition. In this example, observation time is 4µs, time resolution is 100ps, and thus trace depth reaches 40 Kbytes. The whole acquisition setup passband is 1.5 GHz, and the sampling frequency of the scope is 10 GHz.
Figure 6 displays the internal current Iint(t) (in red) extracted by the means of this method, and the measured current Iext(t) (in green). The amplitudes of the internal current peaks are far higher than for the external one (150 mA vs. 7 mA).
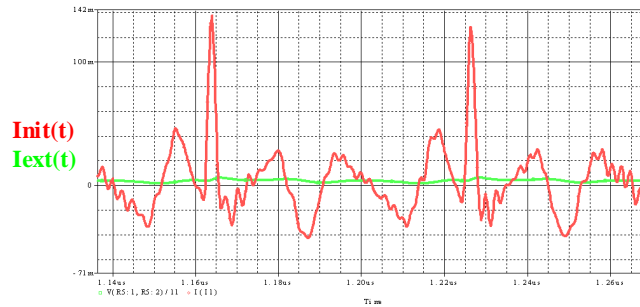
Figure 6. Current profile extracted by this method.

Figure 7 shows the external current Iext(t) extracted by modeling (in red) and compared with the corresponding measured current (in green).
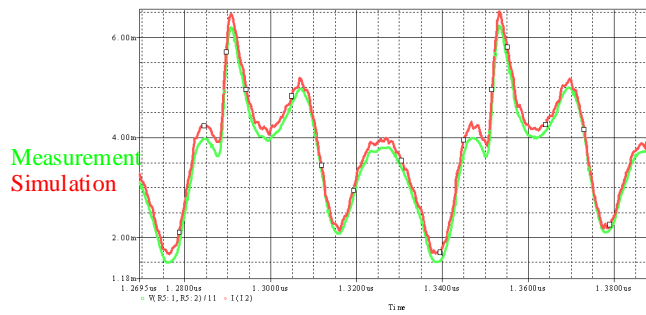

Figure7. Comparison between simulation and measurements.

4. Conclusion

The current extraction method based on supply current measurements provides a model for internal currents, in order to be included in the ICEM model. Although off-the-shelf simulators do not presently allow the designer to predict the current consumed by the chip, introductory VHDL-AMS based simulations showed quite a good correlation between simulations and measurements. Current research uses ICEM in order to demonstrate the prediction of noise levels on internal and external supply networks. In particular, ICEM is used to evaluate the noise level generated by the digital core and injected in the analog blocks. Furthermore, other research is conducted on the use of ICEM to optimize areas of ground and supply copper planes. This method provides a model which is accurate enough to predict conducted-mode emission.

5. REFERENCES

[1] "EIA 656: IBIS version 3.2" ANSI standards, www.eia.org/ibis

[2] International Electro-technical Commission "IEC 61967: Integrated Circuits, Measurements of Conducted and Radiated Electromagnetic Emission", IEC standard, 1999

[3] International Electro-technical Commission " IEC 62014-3: EMC for Component – Part 3: Integrated circuits Electrical Model (ICEM), ", IEC standard proposal, 2002

[4] www.atmel.com