BIRD 74 - recap

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Introduction

This document is a recap of progress and discussions on BIRD74 "EMI Parameters". It outlines the reasoning behind the BIRD, what was proposed, and comments and changes that were made.

History

The first presentation was given at the IBIS Summit Meeting at DAC on June 21, 2001.

A second presentation was given at DesignCon on January 28, 2002.

The BIRD was submitted in November 2001.

Current version, 74.6, was accepted on 8 August 2003.

Why the BIRD was introduced

EMI is becoming increasingly important in PCB design. All electronic equipment has to pass an FCC emission test. More and more manufacturers are looking towards some kind of simulation/analysis that will help them solve EMI problems before finding them in testing. As clock frequencies go higher and higher EMI becomes more of a problem.

However EMI simulation is not an exact science. The problem is too complicated for today's computers. You will probably have to simulate for 10 years to get and accurate answer. Obviously unacceptable. So simulation is out, but some kind of analysis that is able to identify which signals radiate more than others (relatively), and show where the energy flows in a system, can help in identifying potential EMI problems.

No longer requiring absolute accuracy makes the analysis considerably easier, and, more importantly, possible. With that in mind there is more freedom in choosing the parameters needed for the analysis. So the parameters that have been chosen are ones that are readily available in data books. This makes it very easy to create models.

There is also a choice, too, in how to use these parameters. The Reference section at the end of this document provides the technical documents behind these parameters and their usage.

EMI Mechanisms

The EMI mechanisms considered are:

Differential Mode
Direct radiation from signal loops.

Current-Driven Common Mode
Signal return currents create noise voltages across finite return planes that drive attached cables.

Voltage-Driven Common Mode
Signal voltages and noise voltages due to crosstalk drive attached cables.

Power Bus
Digital switching creates power bus noise.

Heatsinks
Act as antennas driven by potential differences on the return plane.

Crosstalk
Coupling among nearby traces.

Immunity
Electro-Static Discharge (ESD), Magnetic (differential model) and Electric (common mode) Field Susceptibility.

The Parameters

Here are some of the topics that were discussed, but not necessarily resolved, at the teleconference meetings and by email:

The parameters cannot be expressed using the multi-lingual extensions. The proposed parameters are of the form “name = value” rather than an expression.
The parameters should occupy their own chapter.
The parameters are to be bounded by [Begin EMI ...] and [End EMI ...] statements.
Store SI and EMI parameters in the same place, i.e. in an IBIS model, as the SI part of the IBIS model already contains information that can be used in EMI analysis (e.g. rise/fall time, max. current).
There is no specific version of IBIS that this BIRD is targeted for.

Here are the proposed parameters in BIRD74.2:

The following parameters are valid in a [Component] statement:

Type
This parameter indicates whether the component is a connector. It identifies the I/O signals which act as monopole antennas.

Domain
Defines whether the component is Analog, Digital or both. Analog circuits operate a very low signal levels (mV or uV) and can contain high gain amplifiers. Digital circuits, in contrast, operate at relatively large signal levels (compared to Analog circuits). See page 276 of reference [5].

Family
Describes the logic family. This can be one of UNDEF, TTL, CMOS or ECL. This parameter allows you to make reasonable assumptions regarding missing information (e.g. source impedance, input impedance, max. transient switching current). E.g. an unused, floating, CMOS input is likely to pick up noise because of its high input impedance. This is true for all logic families with high input impedance. This noise could cause unintentional switching. In CMOS, however, an unused gate whose inputs are floating may bias itself into the linear region. This will increase the dc current drawn by the circuit. See page 295 of reference [5].
With this parameter you can make reasonable assumptions for all the other parameters.

Cpd
Power Dissipation Capacitance.
Cpd includes both internal parasitic capacitance (e.g., gate-to-source and gate-to-drain capacitance) and *through currents* present while a device is switching and both n-channel and p-channel transistors are momentarily conducting.
Simultaneous switching of outputs is one of the main causes of transient noise voltages on the Power Bus resulting in common mode radiation. From the EMI point of view we need to know the high frequency noise on each DC Power Bus due to the switching of digital circuits. Fourier transform the transient current drawn from the power bus. Now knowing the current spectrum, the magnitude of each harmonic of the power bus noise voltage can be calculated. (See references [6] and [7].)
National Semiconductor, Texas Instruments, and Fairchild have datasheets and application notes on Cpd.
Some catalogs give the value of “Dynamic Power Supply Current Iccd”. Where Iccd = Vcc * Cpd
As a side note, Cpd is also used for Thermal calculations.

The following parameters are valid in a [Pin] statement:

CSPEC name
Describes a user definable name that corresponds to a model listed in the [Model] keyword. It is used to define connector pin impedances.

Clock Domain
Specifies the % of power used by each clock domain. A clock domain is a group of pins on a component.

The following parameters are valid in a [Model] statement:

Ferrite
Indicates that the model for this pin is a ferrite. Ferrite beads are very effective when used to dampen high frequency oscillations (caused by switching transients). They prevent high frequency noise from leaving or entering a circuit.

CSPEC
Assigns parameters to the pin CSPEC name. Possibilities are: the pin is Unshielded, Shielded (ground pins provide the shield), Shielded_pwr (power pins provide the shield), or Con_to_shield (pin connected to connector shell). In addition the pin can have an explicit filter capacitance**.** This is used to calculate an antenna impedance for the pin.

Using the Parameters

There are many ways in which these EMI parameters can be used. Reference [8] explains one way of using all of these parameters. Like all technical papers this reference explains the algorithm from a 10,000 foot (~3,048m) height. So it is up to the reader to develop their own algorithms based on this data. Reference [5] gives a number of equations (e.g. page 301) that are useful in the estimation of EMI. Some of the other references discuss a particular EMI mechanism. E.g. references [6] and [7] discuss power bus noise.

Some topics to discuss

Family keyword

- The list should really be unlimited. If this list is fixed what do you do about new or missing technologies?
- What's the intended use?

Additional parameters (not limited to):

- Clock frequency of the **Clock Domain** keyword.
  Suggested by Zuken. This data would be helpful in improving the accuracy for those ICs with a high pin count.
- Heatsink capacitance
  They act as antennas. They can be a significant EMI source.
- Voltage Range
  This parameter describes the voltage range of a driver (or bi-directional output) so that the radiation is not overestimated.
  Note that these voltages are not necessarily the same as the power rails. E.g. for ECL the power rails are 0V and 3.3V, but the voltage range is 1.625V to 2.375V.

Connector related parameters

- Zuken suggests that these become part of a more general IBIS connector specification. The bad side to this is that the parameters are no longer in one file.

The BIRD

- Perhaps write an EMI cookbook to go along with the BIRD.
- Add additional references as they are published or come to my attention.
- Solicit input from interested parties. Already IBM, Siemens and Zuken have made suggestions. Cadence and Intel have also provided valuable input.

Reference Documents

[1] J.L. Drewniak, T.H. Hubing, and T.P. Van Doren, "Investigation of Fundamental Mechanisms of Common-Mode Radiation from Printed Circuit Boards with Attached Cables," *Proceedings of the 1994 IEEE International Symposium on Electromagnetic Compatibility*, Chicago, IL, August 1994, pp. 110-115.

[2] C.R. Paul, *Introduction to Electromagnetic Compatibility*, John Wiley Interscience, New York (1992).

[3] D.M. Hockanson, J.L. Drewniak, T.H. Hubing, T.P. Van Doren, F. Sha, C.-W. Lam, and L. Rubin, "Quantifying EMI Noise Sources Resulting from Finite-Impedance Reference Planes," *IEEE Transactions on Electromagnetic Compatibility*, vol. EMC-39, no. 4, November 1997, pp. 286-297.

[4] C.R. Paul, "Printed Circuit Board EMC." *6th Symposium on EMC,* Zurich, March 1985.

[5] H.W. Ott, *Noise Reduction Techniques in Electronic Systems, 2nd Edition,* John Wiley Interscience, New York (1988).

[6] S. Radu, R.E. DuBroff, T.H. Hubing, and T.P. Van Doren, "Designing Power Bus Decoupling for CMOS Devices," *Proceedings of the 1998 IEEE International Symposium on Electromagnetic Compatibility*, Denver, CO, August 1998, pp. 375-380.

[7] J. Mao, B. Archambeault, J.L. Drewniak, and T.P. Van Doren, "Estimating DC Power Bus Noise," *IEEE EMC Symposium*, Minneapolis, MN, August 2002, pp. 1032-1036.

[8] UMR web page (http://emclab.mst.edu/consortium.html)
Click relevant selection under *Public Domain Documentation*.

[9] An http://www.google.com search for "Power Dissipation Capacitance" shows articles by Texas Instruments, National Semiconductor and Fairchild.

[10] Katja Koller, Gerald Bannert, "Crossbar Current out of CMOS IBIS Models", IBIS meeting at DATE2002.