Designing Compliant PCBs Using Virtual Prototyping Software

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Virtual prototyping tools can assist both the design engineer and the board designer in meeting compliance requirements.

INTRODUCTION

Governments around the world have created regulations that attempt to control the level of radiated emissions from electronic devices. These devices, utilizing advances in modern technology, generate higher levels of emissions. Now, more than ever, it is becoming crucial to optimize designs at an early stage to minimize potential emissions problems. By using the appropriate tools as part of the overall design process, products can be developed faster and more cost-effectively.

Differential mode radiation is generated by current traveling around loops on a circuit board. A signal generated at the driver causes a current to travel from the driver to the receiver (or vice versa). The return path for this current is through the ground path connecting the receiver to the driver. The complete path forms a loop antenna which radiates electromagnetic energy directly from the board. Switching currents also cause voltage drops in the ground path. Noise in the ground system is a mechanism by which common mode radiation is generated.

Analysis tools can be used to simulate the radiated emissions produced by these loops and to simulate the emissions level on a net-by-net basis. This strategy helps to isolate and pinpoint problem areas. In order to prevent these problems, "virtual prototyping" tools can be used. These tools help to optimize placement strategies, select appropriate technologies, determine routing strategies and analyze the ground structure to reduce emissions from the PCB.

A VIRTUAL PROTOTYPING MODEL FOR EMC

The most effective way to use emissions analysis software is during the early stages of design, before the layout is specified (Figure 1). In order to be effective in optimizing the design, the capability to perform a "fast" analysis on all signals using preliminary design information or estimates is required. Utilizing default parameters such as the characteristic impedance of a track, assuming Manhattan distance for the routed track, assuming track configuration (stripline or microstrip), estimating ground grids and using default model parameters allows a designer to create a virtual prototype of the circuit and to consider system design issues (for example, image planes and enclosures) very early in the design of the PCB. As more design detail becomes available, the information can be updated to produce more detailed and accurate results.

Once all of the design information has been defined, a "detailed" analysis can be run on critical signals. "Detailed" analysis is more compute-intensive than the "fast" analysis but the increase in CPU time results in increased accuracy. "Detailed" analysis takes the geometrical and technology information and produces transmission line models for each of the selected nets. Information such as the true ground return path, routing patterns, track impedance and ground plane position can be taken into account in the analysis. "Detailed" analysis also makes use of models such as the Input/Output Buffer Information Specification (IBIS) behavioral model or full transistor level models for a high level of precision.

Creating device models is a common concern for users of back-end verification tools. In the virtual prototyping model, this problem is not as difficult as it may seem. In the early stages of the design very little exact information is available and complex models are not necessary. In fact, they may hinder the design process. Utilizing a simplified electrical model enables design optimization without the pain of modeling every device in the design to a high level of detail.

Identifying critical signals early in the design process allows the engineer to drive the physical design of the PCB. Using constraint-driven placement and routing tools enables this process to be automated. Constraints such as allowable routing layers for a track, track spacing, track widths, track impedance, termination strategies and other design parameters can be entered to eliminate many of the problems before they occur. In order to use the tools effectively, the effort of both the design engineer and the board designer is required in the physical design of the PCB.

USING VIRTUAL PROTOTYPING TOOLS IN THE PHYSICAL DESIGN PROCESS

Virtual prototyping tools are effective only if a design process is adapted to take advantage of these tools. The

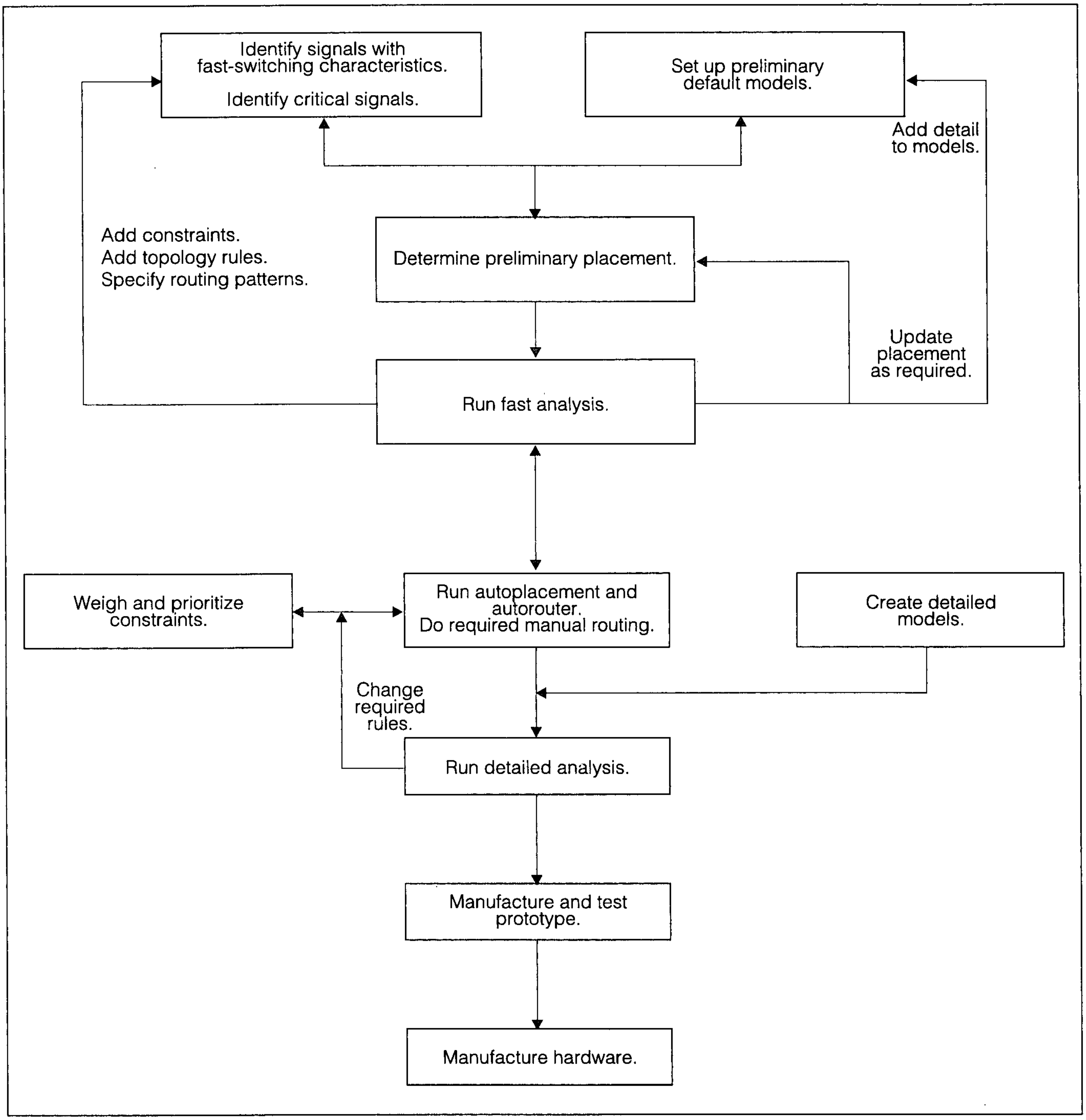

Figure 1. *Design Process.*

suggested process is one that makes efficient use of EMI analysis throughout the physical design process. However, physical design of the PCB is only part of an overall process that must be put in place to ensure system level compliance.

Initially, the design engineer should work with fast analysis tools. The tools can be used to identify and determine suitable design alternatives that ensure the electrical integrity of the product being designed. "What-if" design alternatives that best suit the requirements can be created. When designing for EMI compliance, signals with fast switching characteristics and other special requirements should be identified.

Critical signals are usually the clock signals used to synchronize circuitry or the signals connected to devices having very fast transition times. Default models or conservative approximations for the device models can be used initially. It is not necessary to have precise models early in the design process since most of the design information is unavailable. As the design progresses, the models can be refined and detail added as required. When identifying critical signals, all applicable constraints should be determined. Constraints are used when performing the analysis, and if an autoplacement and autorouting tool is being used, the constraints can be applied immediately. For example, constraints for high speed buses and shielded nets can be used to increase the accuracy of the simulation. These constraints can be applied automatically by the autorouter when the critical nets are routed.

Other design disciplines (thermal, signal integrity and manufacturability, for example) should also be considered when determining the constraints. A certain design decision to reduce emissions can often impact another discipline. For example, putting certain devices close together can cause a thermal problem due to the increase in power density. Ideally, the software can analyze and constrain all of these disciplines simultaneously. These tools are often referred to as concurrent engineering tools. All of the constraints for the design should be captured and weighed relative to each other.

Alternative placement strategies should be studied. Rotating a device or placing it in one location rather than another can significantly reduce the loop area of a track, which in turn reduces the emissions from that signal. Appropriate devices should be grouped together so that rules can be applied to the group as well as enabling the entire group of devices to be moved together. Floor planning capability allows the user to specify "rooms" to place groups of devices.

Once the placement of critical devices has been determined, the routing patterns (for example, starburst, Vs or daisy chain) for critical signals can then be specified. By determining and specifying the pin order in which a track is routed, emissions levels can be reduced. Once the required routing for a track is determined, the constraint can be captured as a topology rule.

EMI shielding that will be available in the system should be used to prevent the analysis from being too conservative. By taking into account the shielding provided by the enclosure, image planes and EMI boxes, the analysis tool can indicate if the system has the necessary shielding to pass regulatory testing. This can also reduce the complexity of the chosen design alternatives and reduce the cost of the circuitry (for example, determining that fewer layers are required on the PCB).

Once the placement has been finished and the design is ready to be routed, an interactive or automatic router can be used to route the critical nets. Autorouters capable of utilizing assigned priorities can help to achieve design requirements. Once circuitry having the required electrical integrity has been placed and routed, that portion of the design can be locked to ensure that no further changes are made to that circuitry.

Depending on the required accuracy and where in the design process analysis is being applied, more detailed models can be created (IBIS models are typically used for detailed analysis). During the design process more detailed information about the devices being used may become available (particularly in designs which utilize ASICs). Device modelers are available to help the user enter the required information to create behavioral models. Utilities to create the IBIS models from SPICE net lists are also available.

Once the models have all of the required information, a detailed analysis can be performed on the critical signals. If the detailed analysis shows a potential emissions problem, the layout should be modified to correct the problem. If all of the design constraints have been achieved and the detailed verification of the critical nets does not show any potential problems, the design can then proceed to the manufacturing phase.

SUMMARY

Government regulatory requirements set limits on allowable levels of radiated emissions from electronic devices. Advances in technology have made the task of meeting these compliance limits more difficult than ever.

The mechanisms that drive both differential and common mode radiation originate at the circuit board level. By minimizing potential noise sources at the board level, the task of controlling emissions at the system level is made easier. Virtual prototyping tools available today can assist both the design engineer and the board designer to minimize the number of prototypes and visits to the test chamber needed to meet compliance requirements.

Virtual prototyping tools themselves do not ensure that a manufactured design will meet regulatory requirements at the system level. However, the proper tools used in conjunction with a process that tackles the overall EMI problem will help to reduce both product development costs and time to market.

Other design disciplines, such as thermal, signal integrity and manufacturability, for example, should be considered when determining the constraints for high speed buses and shielded nets.

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