CircuitHawk™

Automated Schematic Review Driven by Electrical Stress Analysis

Thermal Analysis and
MTBF Predictions Included

White Paper v6

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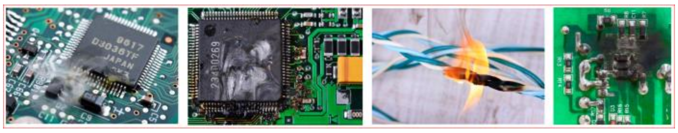
Introduction

Many engineers spend most of their time working on electronic board development, including functional specifications, design, simulations and testing of the product. How sure are you that your product is robust and reliable?

Have you done everything to ensure that all the design errors are detected and your customer will not experience failures?

Of course, you believe that you took all measures, yet the reality may be different.

Are you familiar with the following pictures?



Due to market pressure and the lack of tools, hidden design errors remain undetected. Sometimes, it does not take a long time until the customer uncovers some errors. That seriously affects the company's reputation and incurs financial losses.

In the best case scenario, the design flaws are detected during the prototype approval test of the final product. In this case, an in-depth investigation is required in order to locate the root-cause of the error. This can take at least a few days or at worst a few weeks or months. At this time the development team is busy finding the root-cause of the design error and the manufacturing line is on hold. This causes a delay in the final product launch, creating cost losses, which are critical for the success of the project.

The Need for a Robustness Verification Test

The main problem in the present method of detecting design errors is the lack of a "Specification for Reliability / Robustness Design verification". We are familiar with the term "Qualification Test" derived from the "Quality Verification" Specification that tests the final product.

There is no Specification for the "Relification Test" derived from "Reliability Verification Test" that tests the design robustness.

In order to prepare the spec for the "Qualification Test", many documents are prepared describing the product, its functionality, the signals at the connectors, etc. For the "Reliability Verification Test" case, there is no methodology, and most of the companies intend to test only the products Service Life. There is no Good Engineering Practice specification, there are no robustness test documents and of course, no test methodology. In most cases, only Design Rule Check (DRC) error messages are examined, manual checks and design reviews are performed, but it takes much time and effort. Sometimes there are so many DRC errors that the designers ignore them.

The New Reliability/Robustness Verification Methodology

The proposed solution is firstly to define a standard, which includes suitable Good Design Practice rules for the company products, according to the component technologies used in the circuits. At the beginning, the user may check all the rules manually, but the final idea is to use a new generation of simulation and analysis tools that includes hundreds of rules, which check the designs in minutes.

Examples of Good Design Practice Rules

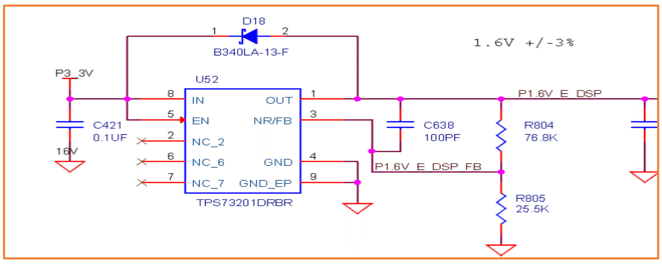
- When using a crystal, capacitors should be added on both sides within a range of values according to the frequency.
- Each DC/DC Converter Output should be sampled by an ADC using an appropriate voltage divider, while the ADC should share the DC/DC Output Ground.
- Each IC power pin should have one or more decoupling capacitors according to the manufacturer recommendations. If there are many such pins, the engineer may specify a different rule accordingly.

There are hundreds of additional rules that, if not carefully used will incur costs in repairing the faulty products at the customer's end. From our experience, the product becomes less robust due to such errors. In such situations, the manufacturer releases the product to the market with a high failure rate without knowing that he can detect the errors and amend the product.

What is a design error?

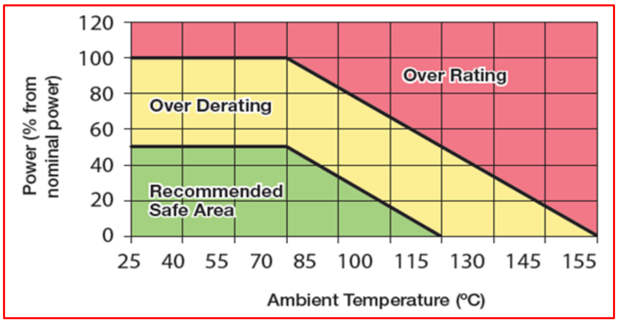
The component manufacturers define electrical properties (parameters) in datasheets with nominal, minimum and maximum values and the required connectivity to other components. The engineers are required to take into consideration the above properties and follow the manufacturer recommendations in their design. A wrong use of the component is caused by disregarding the manufacturer recommendations and causes a design error.

The diagram below shows a DC-DC converter that generates 1.6V from a 3.3V Source. The engineer correctly calculated the voltage divider that feeds the feedback input, but switched the two resistors R804 and R805, causing a 4.8V output instead of 1.6V. The components connected to the 1.6V rail will be damaged. BQR's CircuitHawk software can easily detect such an error.



Other examples of Design Errors

- ✓ Unused IC Inputs should not be left floating, unless the manufacturer expressly allows it
- ✓ Digital Inputs should be at correct Levels (V_{IL}, V_{IH}) according to the Datasheet
- ✓ Component stresses should be below 50% between 25°C and 80°C Ambient Temperature and between 80°C and 120°C should derate linearly to zero, as shown in the diagram:



The Solutions – CircuitHawk and fiXtress: the EDA Verification Software

fiXtress is a software originally developed to perform Component-Derating calculations at the development stage where the flexibility to modify the design is significantly higher and cheaper than the design correction after First Article tests. The purpose of the Component-Derating analysis is to ensure that the components are electrically stressed according to the Derating guidelines and that the physical size of the component or the thermal model matches the requirements. Meeting these requirements ensures a robust and reliable product.

In retrospect it turned out that in many designs analyzed by the fiXtress software there were hidden design errors that caused high stress. At first it seemed that the solution was to increase the rating of the component, but after an in-depth analysis it was discovered that the high stress was caused by a design error, and once fixed could bring the following benefits:

- ✓ The power of the board could be lower
- ✓ Component size will decrease
- ✓ The design robustness will improve

In this case, the First Article approval test will also pass successfully.

This led to the development of BQR's CircuitHawk software that checks component connectivity together with the results of the stress analysis and not just on the connectivity alone as done by the DRC.

The software is divided into two packages:

- ✓ The Plug-In package within the designer CAD (Mentor, OrCAD or Altium)
- ✓ The CircuitHawk Verification software that interfaces with the Plug-In.

This creates convenience at work and allows concurrent team work on different parts of the design.

The CircuitHawk Verification software includes several modules:

- ✓ ASR module is used to find design errors in the circuitry, which can cause high stress malfunctions.
- ✓ Rapid module is designed only for DC calculations and can work on a partial circuit. At the end, the ASR module is re-activated as a second stage for re-testing using the results of the stress analysis calculations.
- ✓ Precise module for the most comprehensive testing includes AC, DC and BUS simulations. At the end, the ASR module is re-activated as a second stage for re-testing using the results of the stress analysis calculations.

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✓ Re-analysis of all boards together as a Multi-Board system (integration).

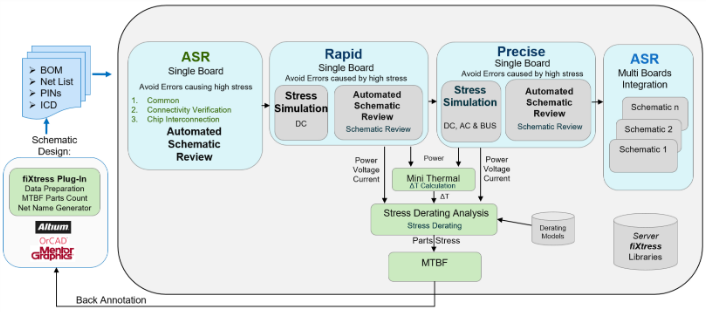
CircuitHawk integrates with fiXtress to provide also:

✓ Preliminary Thermal Analysis, which calculates the self-heating of the board as a function of the real power dissipation of the components.

✓ component Derating analysis.

✓ Reliability analysis.

The complete solution is shown below:



Plug-In:

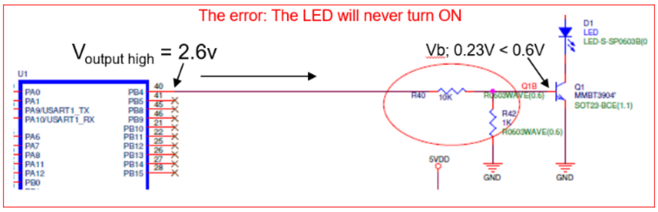
Creating the design data: The data needed for CircuitHawk and fiXtress is automatically retrieved by a plug-in that connects to the schematic capture CAD program. The plug-in is suitable for the three popular CAD manufacturers: Altium, OrCAD and Mentor. This module generates all the necessary data, and back annotates the results of the electrical stress and the failure rate directly to each component in the CAD database.

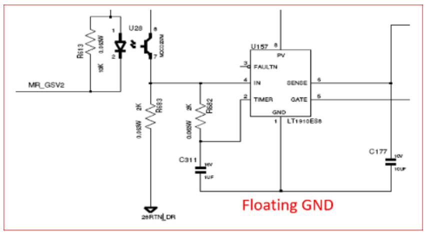
CircuitHawk Verification:

Automated Schematic Review Module - Errors detection related to the connectivity between pins of different components, connectivity between a group of Pins or Signals, or any group of discrete signals. The module includes 5 groups of Checks:

1. Common Rules – a fixed set of 16 Groups while each Group includes 20 Sub-Groups.
2. Connectivity Rules – Specific Rules configurable by the User using a Wizard
3. Chip Interconnection – Hierarchical sequential connectivity checks between several components Busses according to a Reference Design (such as the connection of an ASIC to its DDR4 and Flash Memories, Peripherals etc.).
4. Rules based on the Electrical Levels and Stresses Analysis – an important layer that checks that the input voltage levels are within the Component Manufacturer Specifications.
5. Multi-Boards - In addition to the tests carried out for each board separately, integration testing can be performed and reveal another layer of errors caused by a mismatch in the definition of electrical interfaces between the components.

Additional errors that CircuitHawk detects:





Rapid module – a Components stress calculation based on the voltage propagation estimation on each node. The calculation includes tens of parameters according to the component type. The calculations may be performed on a non-finished design and helps the designer to correct on-going errors.

Precise module – Electrical stress calculation on all the design components using Kirchhoff loops and Fourier Analysis. The calculation includes tens of parameters according to the component type. The calculation will be performed only on the finished product design and will check the components stress against their maximum and derated ratings at the operating temperature and also adds thermal considerations to the layout phase.

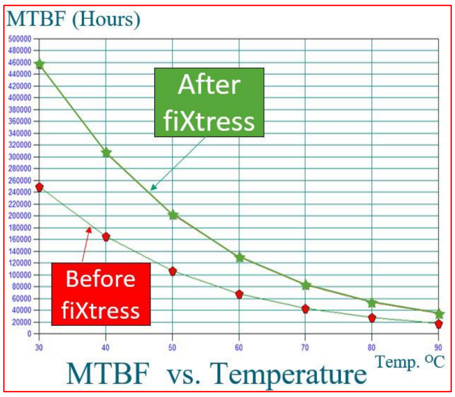
fiXtress Modules:

Mini Thermal Analysis module – As this analysis is performed before PCB layout is done and real thermal data are known, this module estimates the board temperature increase due to self-heating and takes this information to the Stress Derating Analysis.

Electrical Stress Derating module – Checks if the operating point for each components is within acceptable electrical and temperature stress limits.

MTBF module- finally, we can calculate the MTBF (according to various standards) more accurately by using the accurate components stress data. By using fiXtress, MTBF increases at least twice.

Advantages of using CircuitHawk & fiXtress:



- ✓ A more reliable and robust final product
- ✓ Shortens the design cycle and Integration Testing
- ✓ Generates a product documentation at the development stage and thus design updates can be easily performed in the future.

CircuitHawk generates data for the Thermal Analysis

One of the most important parameters for thermal analysis is the actual power dissipated in each component. This power is calculated automatically by fiXtress and can be provided to the thermal analysis tool. Usually, this parameter is unavailable to the thermal engineer and that is why he uses the maximum value of the components power from the datasheet. In this case, these results are the worst case and if we use them we will create over-design such as over-cooling or taking components with higher rating values (which may be desirable), but sometimes it increases the cost and the physical size of the product unnecessarily.

CircuitHawk generates data for Reliability Calculations

The product Reliability is measured by the MTBF according to different standards or by the Failure Rate distribution in time using the Physics of Failures method. These calculations are strongly influenced by the stress of each component. In this case, CircuitHawk provides the exact stress and consequently the reliability calculation is more accurate.

Differences between CircuitHawk, DRC and Spice

The use of CircuitHawk does not preclude the use of DRC or Spice but may rather be used as a supplement to tests and analysis that they cannot encompass or provide.

DRC may be used to discover and fix simple errors such as floating inputs, shorted outputs, missing drivers to the net, etc. and then let CircuitHawk discover the errors that DRC cannot detect.

The purpose of the Spice is to display the waveform for each signal including noise in relatively small analog circuits and adjust the component values so that the signal is as expected and clear of noise. Spice cannot be used in digital circuits with large components. The purpose of CircuitHawk is to check errors in the design and analysis of stresses. fiXtress is less suitable for switching power supplies than Spice. Yet, for DC/DC converters, fiXtress handles very well many types found in present PCBs.

Conclusions

CircuitHawk is a new software which helps the designer to detect hidden errors early in the design process. CircuitHawk is using an Automated Schematic Review method which is empowered by electrical circuits stress analysis and a database of rules. A Rule Wizard Editor is available to add new rules. The Tool uses C++ rather than scripts and runs very fast on very large boards. Furthermore, the CircuitHawk uses the power signals and the loads (ICD: Interface Control Document) from the connectors to perform real simulation as it is powered in real use, in comparison to other tools that do not use the ICD.

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