How to use Knowledge in an Analysis Process

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Abstract

An efficient design and analysis process is based on an enormous amount of knowledge and information. Therefore, tools and techniques for knowledge acquisition, representation, and visualisation have to be integrated into the overall design process but they don't have to be treated as separate components. The variety of knowledge sources and its dependency on the environment lead to a complex integration task. This paper presents a knowledge enriched approach to support a signal integrity analysis process.

1. Introduction

To improve the performance as well as the quality of electronic systems development engineers require the right information at the right time. The complexity of design and analysis processes lead to an increasing amount of necessary information to support the engineer in his analysis task. Therefore, effective and efficient procedures to retrieve, display, and re-use knowledge in critical design situations are necessary.

This paper presents how a *propose-and-improve* or a *propose-and-exchange* design approach [8] can be improved by using additional information and knowledge. The evaluation is performed exemplarily for the signal integrity analysis process of printed circuit boards (PCBs) and multi chip modules (MCMs).

In this problem area standard tools are used to solve specific problems. In general there input and result formats are in a universal form. The presented improvements illustrate how a more qualified result determination and presentation supports engineers in there decision processes. Furthermore, the improvement of problem and measure description by combining formal and informal forms of knowledge within a unique package is investigated. Based on the informal description a navigation and retrieval of additional information in an unstructured data space (e.g. news groups) is presented.

2. Data, Information, and Knowledge

Within any design and analysis process new information is extracted by the interpretation of available and well known data. The knowledge to use this information for the subsequent treatment of the process can be formulated explicitly or is present however in form of abilities and skills of experts, also called tacit knowledge.

To integrate information and knowledge into an analysis process, the following questions have to be answered:

- *What are the aims of knowledge support?*
- *What information and knowledge is available at any point of time within process?*
- *Can we produce new information from the existing data?*
- *When and where is this information useful?*
- *How can knowledge be integrated into a design process?*
- *How should information be presented?*

These questions are answered in the following by way of example.

2.1. The Problem: Signal Integrity

In order to understand the situation of signal integrity analysis some basic principles of signal propagation have to be described first. When a signal is propagating across a transmission line, a frequency dependent fraction $A(j\omega) = \frac{Z_0(j\omega)}{Z_S(j\omega)+Z_0(j\omega)}$ of the signal travels down the line. At its far end, a fraction $T(j\omega) = \frac{2 \cdot Z_L(j\omega)}{Z_L(j\omega)+Z_0(j\omega)}$ is reflected, the rest will be absorbed by the connected circuit.[1] The reflected signal travels back towards the driving gate. Due to the complexity of transmission line structures, the real behaviour can be determined by the aid of simulation and by measurement.

[1] $Z_0(j\omega)$ is the characteristic line impedance, $Z_S(j\omega)$ the load of the driving gate, and $Z_L(j\omega)$ the load of the receiving gate. A good overview on this problem of signal integrity effects can be found in Johnson and Graham [5].

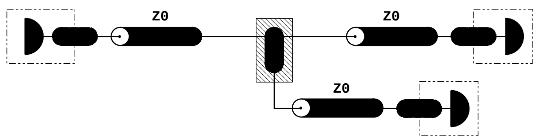


Figure 1. Bifurecated Line

Transmission lines are called *unmatched* when neither the source $Z_S(j\omega)$ nor the load impedance $Z_L(j\omega)$ matches the characteristic impedance $Z_0(j\omega)$ of the line, which is the reason for parasitic reflection effects. In such a situation so called termination measures are used to adjust load and characteristic impedance in order to avoid or reduce these reflection effects. Unfortunately this can only be achieved for very simple transmission line structures. Due to discontinuities, the most structures cannot be matched properly. All the same where termination measures are placed, a complete avoidance of reflection is not possible.

2.2. Information

The tacit knowledge for design and analysis processes consists of design parameters, rules, methods and plans, analogical associations, pre- and postconditions, types of failures and conflicts, heuristics for failure recovery and conflict resolutions. Explicitly formulated textual information is electronically accessible in a structured and unstructured way, like hypertext books and articles, news groups, mailing lists, interactive environments for computer based training and help systems. This kind of information comprises detailed theoretical background knowledge, which could be very useful in a design situation. Regrettably it is not directly accessible. In the design process it should be presented context related. Knowledge-based systems presents problem dependent rules and concepts including measure descriptions, conditions and impacts. The lack of an overall theory seems to be the reason, why knowledge-based systems are unfortunately rare and not integrated into the signal integrity analysis process.

An up to now unused source of potential information is the data produced during the analysis task. Additional evaluation or extraction of more relevant information from this data can be used to disclose unexpected data dependencies. The improvement of the analysis process by exploiting this kind of information requires a further identification of the way engineers use and utilize information and knowledge.

2.3. Using Information

Solving a signal integrity problem firstly the engineer has to decide '*whether a measure is necessary*' and secondly '*which measure would be adequate*'. In the first step he has to analyse the behaviour of the transmission line by simulation. In order to guarantee the functionality of the participating integrated circuits, conditions defined by the manufacturers have to be fulfilled. A first improvement of the analysis process can be reached by automatic evaluation of this conditional parameters (*decision support*).

In order to avoid or reduce parasitic effects the engineer has to handle the second problem. Therefore, he has to choose an appropriate *source* or *end terminator*, *clamping diodes*, or the *adjustment of the geometrical or electrical transmission line parameters* and he has to parameterise this measure. This situation illustrates some major problems:

- *Does an engineer know all possible termination measures?*
- *Is the impact, the functionality, or the relation obvious with other measures?*
- *Are all pre- and postconditions well known?*

These questions lead to the request that the analysis environment must offer the possibility to describe and store such rules in an appropriate way. During the analysis process the engineer has to be able to have access to these and other available information (*advanced information search mechanism*). Furthermore, the analysis itself should use this rules by a more or less automatic examination of the pre-conditions (*information enriched measure*). Each ter-

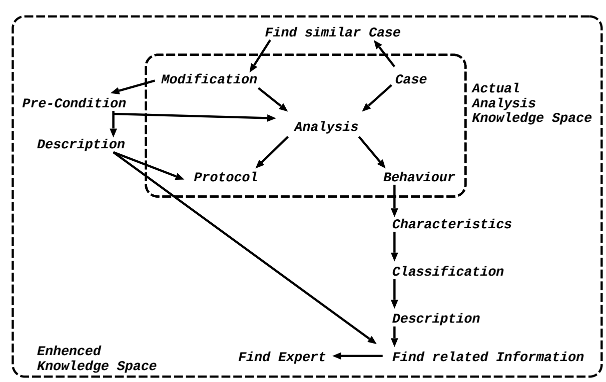


Figure 2. Knowledge enriched Analysis

mination measure has advantages as well as disadvantages. For complex situations an engineer has to analyse the application of several measures stand alone as well as in combination. For each of these, he has to choose an appropriate set of parameters. This is generally done by help of parameter variation, which simply means an optimisation process. For this optimisation the rules and constraints can be used in order to reduce the number of simulations (*constrained optimisation*). Figure 2 illustrates in the inner frame the current situation of information use and data generation. The only used external information source is the tacit knowledge of the engineer. The outer frame shows an enriched knowledge space for the signal integrity analysis to aid engineers in there decision process.

2.4. Availability of Information

Another problem is the lack of intuitive data representation. The observation of failure and differences between expected and real values triggers the understanding of dependencies (*learning by doing*). To support the engineer a direct visualisation of *action* and *re-action* would be very helpful. This visualisation should fulfill the principles[2] of adequacy, self description, control, conformable expectations, error tolerance, individualisation, and should support learning.

3. Knowledge enriched SI Analysis

The presented investigations were realised and implemented by HTML/XML, C++, and Java applications. Necessary technical enhancements for the signal integrity analysis were exemplarily performed within a transmission line simulator[3].

3.1. Decision Support

In general transmission line simulation is done by the aid of specialised analogue circuit simulators[4]. As a result of a time domain simulation the engineer can get access to voltage waveforms of arbitrary nodes of the netlist. The first modification of the analysis is to determine the range of the characteristic signal quantities[5] for which manufactures guarantee the functionality of the participating integrated circuits [3]. The direct access (see figure 3) to this characteristic signal quantities support the engineer in his decision process whether the application of a measure is necessary or not.

3.2. Information enriched Measures

The description of an arbitrary measure can be done by exact formal notification, by equations, etc. To use this in a simulation, it has to be presented in a specialised simulator dependent language. In general this representation is supported by textual and pictorial descriptions, which comprise information about application, conditions, and consequences. The following example illustrates this for a simple pull-down termination.

[2]European Standard EN ISO 9241:1996, Ergonomic requirements for office work with visual display terminals (VDTs) – Part 10: Dialogue principles.

[3]FREACS - FAST REFLECTION AND CROSSTALK SIMULATOR, INCASES Engineering GmbH, Germany

[4]Transmission line simulators are analogue circuit simulators, which support specialised transmission line and component models (e.g. IBIS, I/O Buffer Information Specification, ANSI/EIA-656) which provides the non-linear behavioural description of IC devices.

[5]Signal characteristics comprise timing (e.g. rise time) and magnitude (e.g. over and undershot) quantities.

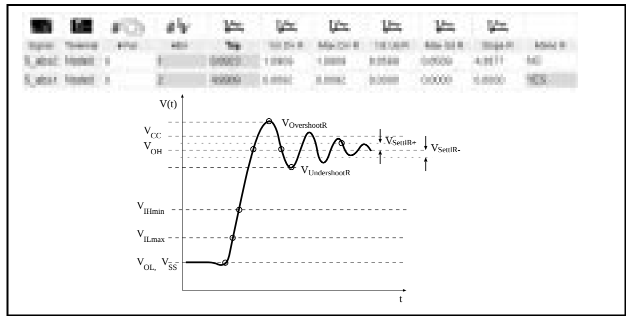
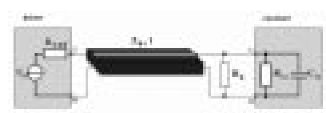


Figure 3. Characteristic Signal Quantities

PULL-DOWN TERMINATION ← *name*

controls the impedance mismatch at the receiving gate by a resistance $R_d \approx Z_0(j\omega)$ parallel to GND. *The application of such a measure pays respects to control, which exist for bipolar and* CMOS *components.* ← *position, value, application, intention*



← *illustration*

Pull-down terminations produce no additional signal delay e.g. by influence on the rising and falling edge. A disadvantage is the high power consumption. The application of such a measure is proposed in networks with a low duty cycle, which means a slight pulse-pauses relationship. ← *impact, restrictions, preferences*

```
SUBCIRC ($CONNECTED_TO, $VALUE)
{ TERM pull_down
  { RES Rd (NODEA=$CONNECTED_TO; NODEB=GND;
            VALUE=$VALUE;); }
  CONDITION
  { IF(    $VALUE == UNDEF
        && CONNECTED_TO_AREA(pull_down.$CONNECTED_TO,
                             &AREA))
    {
      pull_down.Rd.VALUE = $AREA.Z0;
    }}}
```

← *simulation model*

As an ideal solution all this explicit and tacit knowledge should be combined together to a unique package, a termination can be represented using the *Extensible Markup Language* (XML). Storage and retrieval of this documented measure models are realised within a standard hypertext environment. The engineer can access new measures simply by addressing the hypertext URL. The simulator is enabled to read and execute this additional information. Measure parameterization is supported by *initial conditions* or explicit parameterization in the simulation input.

Based on this, several model dependent constraints are evaluated during simulation time. The evaluated result protocol is also stored as a hypertext document.

3.3. Accessing additional Information

In some situations the expert may need additional information or he might ask some external expert for advice in order to get more information on measures to overcome his actual problem. To find related information he can know uses the available textual measure or problem description. Typically, textual retrieval is done by literally matching query terms with those in documents. Since there are usually many ways to express a given concept (synonyms), a literal term may not match those of a relevant document. In addition, most words have multiple meanings (polysemy), so terms will literally match in irrelevant documents. A better approach would allow to retrieve information on the basis of context or meanings (semantic).

In our interconnected world semantic text retrieval becomes a growing matter of public concern. The intention of semantic text retrieval is based on the fact that the content of any text document is limited to a certain, often closely outlined topic, which is directly reflected in the selection of words in this document. Rijsbergen [7] formulated the cluster hypothesis "*Closely associated documents tend to be relevant to the same request.*" Luhn [6] proposed in the late 50^{th} *that the frequency of a word occurrence in an article furnishes a useful measure of word significance.* For every Document d_i is $a_{i,k}$ a measure of importance of the word w_k in d_i. Every document can now be described by a feature vector $\vec{a_i} = (a_{i,1}, ...a_{i,n}) \in \mathbb{R}^n$. A similarity function $f : \mathbb{R}^n \times \mathbb{R}^n \to \mathbb{R}$ defines a similarity of two documents. One often used similarity measure in this vector space model is the cosine measure[6]. If $\vec{a_i}$ is a document and $\vec{q}$ a query vector, the cosine is defined by $cos(\vec{a_i}, \vec{q}) = \frac{<\vec{a_i}, \vec{q}>}{||\vec{a_i}||_2 \cdot ||\vec{q}\,||_2}$. In order to reduce the queuing effort Berry et al. [1] proposed the use of an approximated term by documents matrix $\underline{A} := [a_{i,k}]$. Such an approximation can be obtained by a truncated singular value decomposition[7]. The queuing effort on the original matrix is $\mathcal{O}(mn)$ and on the reduced matrix $\mathcal{O}(l(m+n+1))$ with $l \ll n, m$.

Based on this a semantic text browser was developed to create a semantic map of arbitrary hypertext structures. This semantic map allows a contextual navigation through structured as well as unstructured textual data spaces.

Figure 4 illustrates a semantic map (depth level 2) of an electronic hypertext. A node of the semantic map represents a document address (URL) within a hypertext. The similarity of a document to others is represented by node colouring. Another application of this browser is the visualisation of potential communities in accordance with the users common interest. To estimate these interest, the users have to provide textual information on there interests. This can be seen as an aspect of *community-ware* which supports the formation of groups in a distributed environment [4].

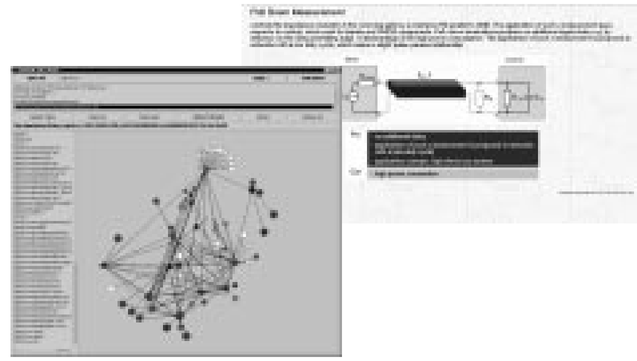


Figure 4. Semantic Map of Hypertext Data

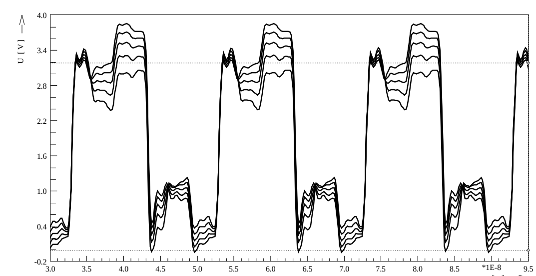


Figure 5. Waveforms of a Parameter Variation

3.4. Visualisation of Action and Re-action

In order to determine an optimal measure the investigation of the influence of several measure combinations by parameter variation is a common methodology. The use of rules and constraints can reduce the number of variations significantly (*constrains optimisation*). A result of a conventional parameter variation is a huge number of waveforms, which have to be analysed. Using an automatic evaluation of the characteristic signal quantities, a base for appropriate decisions seems to be available. But unfortunately the relation of action and re-action, in this case the relation of measure type & value to the resulting characteristic signal quantities is lost. A visualisation of this relation supports the understanding (*learning by doing*), and offers a powerful task to find an optimal measure. One way is to highlight the relations between the modified transmission line structure as well as the resulting behaviour. The result of each simulation is a set $\mathbb{B}$ of k characteristic signal

[6] Other common similarity measures are form *Jaccard 1912, Dice 1945, Sorensen 1948, Ochial 1957, Hamman 1961, Sokal/Sneath 1963*, or *Dale 1965*.

[7] The singular value decomposition [2] form a given matrix $\underline{A} \in \mathbb{R}^{n\times m}$, $n \leq m$, $rank(\underline{A}) = r$ is denoted as $\underline{A} = \underline{U}\ \underline{\Sigma}\ \underline{V}^T$, with $\underline{U}^T\underline{U} = \underline{V}^T\underline{V} = \underline{I}_n$, $\underline{\Sigma} = diag(\sigma_1 ... \sigma_n)$ with $\forall_{i=1}^{r} : \sigma_i > 0$ and $\forall_{j\geq r+1} : \sigma_j = 0$.

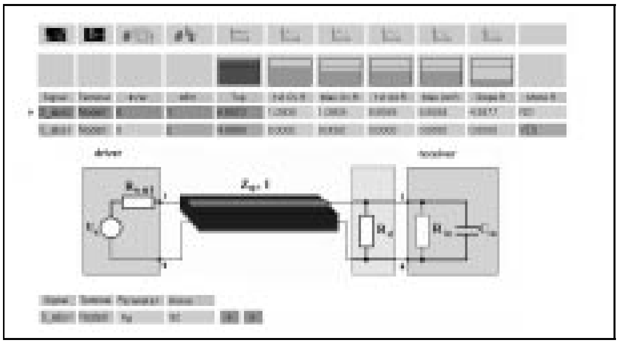


Figure 6. Action and Reaction

quantities $\{b_i | b_i \in \mathbb{P}_i, 1 \leq i \leq k\}$, which represent the behaviour of the case C. $\mathbb{P}_i$ is the set of possible values of the parameter p_i. Without loss of generality we assume the value of a parameter $p_i \in \mathbb{R}$ within a limited positive range $0 \leq p_i \leq p_{i_{max}}$. A visualisation can be realised by bar diagrams of the normalised parameter settings $\frac{p_i}{p_{i_{max}}}$. To emphasise the position of the parameter within the total range or the exceeding of the threshold value the bar is additionally coloured.

With regard to visualise the relationship of *action* and *re-action* we have to take a look into the relation of a modification M_i and its influence to the behaviour $\mathbb{B}$ of a transmission line structure C. Let us now assume an optimisation process of n measure values M_i, $1 \leq i \leq n$ in C. Each measure value is modified m times M_i^j with $1 \leq j \leq m$. The simulation can be interpreted as an injective mapping $f : C_M \mapsto \mathbb{B}$. Due to the fact that f is not bijective, the characteristic signal quantities can only be achieved through a simulation of a modified case C_M. The determination of an appropriate set of measures M_j based on given characteristic signal quantities B_α is in general impossible $\nexists\, g : \mathbb{B}_\alpha \mapsto M_j$.

4. Conclusions

Skills and knowledge are a necessary basis for a good design! What can trigger the improvement of such skills? The realisation of failure, success, and differences between expected and real values. The presented approach has shown at the example of signal integrity analysis how information support and context related information access at the right time helps to improve a complex design and analysis process. Furthermore, the use of knowledge can speed up the overall design circle. An aim oriented data representation can improve the understanding of failures and conflicting elements.

References

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