Function Analysis for Electronic Products

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Abstract

This paper is based on the function analysis, as it is known from Invention Machine® Software [1, 2] and other different sources [3, 4]. It is based on an object model, which presents functionality in a subject – action – object layout (SAO).

Function analysis is well known for its use for mechanical products. Within mechanical products it is easier to identify the different components that a function model should consist of. One has only to focus on parts and assemblies of a similar hierarchical level. These components are normally already grouped together in a parts list.

With electronic products it is unclear how to formulate a functional model. We normally have the housing and within the housing one or more circuit boards with different ASICs, BGAs and hundreds of other smaller electronic components such as resistors and capacitors.

This paper will show different ways of how such products can be effectively structured using pareto analysis (also known as ABC analysis). It will also elaborate on how to define “components” for a function analysis as functional groups consisting of different electrical parts or sections of these parts. Based on the way the electrical product was pre-structured for the analysis, it is shown how this will impact the way the functions (actions) are defined. After the definition of the function, the simple value analysis that can be done with such a structure will be shown.

All suggestions, hints and insights are derived from practical work with function analysis in an electronics company. The aim of the work is not to show a novel way of function modelling but to combine two well known methods in a tricky way to get a workable and useful tool for the expert in the field.

Keywords

Function analysis, electrical product, electronic product, value analysis

1 INTRODUCTION

Different function modeling techniques are used to build models of technical systems. A specific function modeling technique will be discussed in this article that is very well known from the implementation in the Invention Machine® Software [1, 2] TechOptimizer^{TM} or Goldfire Innovator^{TM}.

This technique is based on the value analysis approach by Lawrence Miles [6] which dates back to 1961. In Germany, the value analysis is used broadly by the VDI (Association of German Engineers) [7, 8, 9, 10] and is well established in German industry. The VDI is using the term function to describe what a technical system does. Within this function model, the so called black box approach is used, which points in a completely different direction than the function model that was developed by TRIZ specialists using the work done by Lawrence Miles [3, 4, 5] as basis. A comparison of the both approaches was done in [11] and [15].

This function analysis is a symbiosis between the function model of Lawrence Miles and the SuField modeling of technical systems. It is somewhat more than the SuField model on the basis of the components that are brought into interaction with one another - and it is somewhat less than a thorough SuField analysis, as there is no exact differentiation between substances and fields.

The practical usage of the function analysis that will be discussed here was described in an actual project in

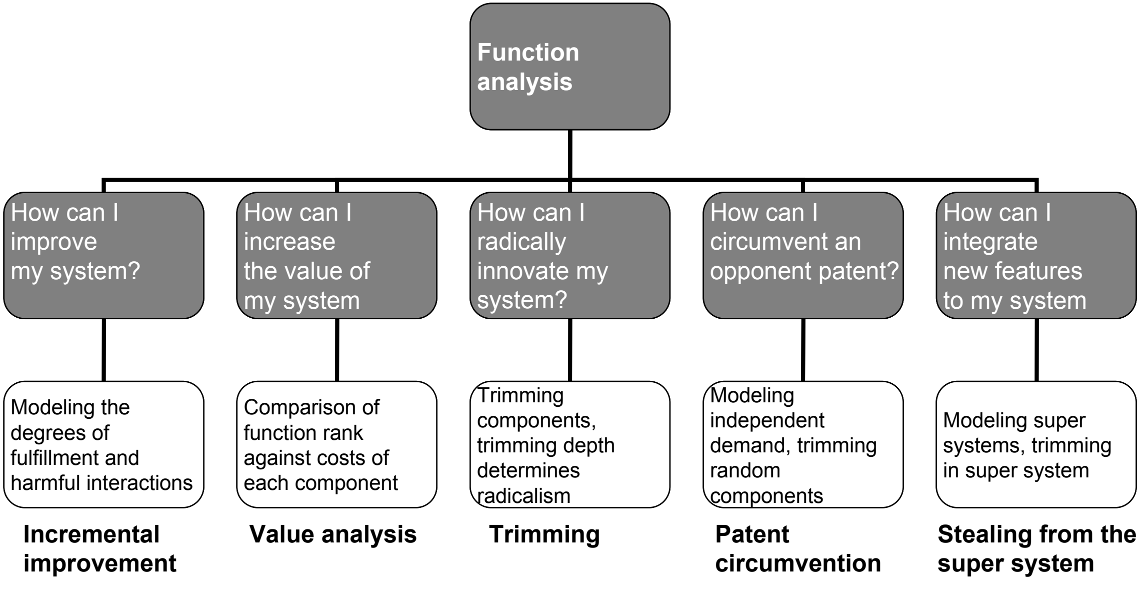

Figure 1: Branches of the function analysis.

Siemens Mobility for an arm rest for a trolley car [12, 13] and a key lock system [14].

To understand the usage of this functional analysis within electronic products, the state-of-the-art function analysis for mechanical systems will be described here first.

2 FUNCTION ANALYSIS BASICS

Within the function analysis, components of a technical system are linked together via actions that they execute with respect to one another.

A function analysis can be used for different problems (see Fig. 1). Therefore, different branches of a function analysis exist. The usage of the function analysis for a value analysis approach was already mentioned. The merging of the function analysis with the SuField modeling technique of TRIZ leads to a model, where an engineer can easily describe the functions that he wants to eliminate or improve. Linking the model to the idea behind the ideal machine led to the trimming technique, which in turn can be used for radical improvement of the system. Innovation and product managers are trying to pack more features into their products. A function analysis of the different super system components can help to identify new attractive features. This branch is also called “stealing from the super system”. And finally, this kind of function analysis is also used not only for describing technical systems but also to model the independent claims of a patent for a patent busting session. This method was recently introduced by Sergei Ikovenko.

All of these branches have a common base, which is the basic function analysis. This function analysis consists of three major steps:

- Component analysis
- Interaction analysis
- Function modeling

The component analysis itself has different steps. It is used to identify the components of the technical systems that are under consideration and the components of the super system that interact with the system.

In [4], the term “material object” is used to describe components that are permitted for a function analysis. A material object is an object consisting of substances and/or fields, whereas a substance is an object with resting mass (i.e. screw, nail) and a field is an object without resting mass that transfers an interaction between substances (i.e. magnetic field). In [3, 5], the term “material object” was eliminated again, as it only describes components that are permitted in a function analysis. Components that are not permitted are parameters and software. Parameters are linked to the components themselves and software is normally modeled as actions between the components.

When performing a component analysis, one should also be aware of the hierarchical level of the technical system that is being investigated. If the model is too abstract, it may provide insufficient information. If the model is hierarchically too low, the analytical effort will increase dramatically. With some practice in function modeling, the right level is normally selected. For beginners, a good way to deal with the problem is to begin on a highly abstract level and dig deeper into parts of the system if the need arises.

The first step of the component analysis is to identify the technical system. The system to be considered should be named. This is an important step as it sets the boundaries for subsequent steps.

Next, one would identify which super system is around the system. The question that has to be answered here is as follows – “In which environment is the technical system a component?”

Then the main function of the technical system has to be formulated. The main function is the function that the technical system was designed for. It also has to follow the guidelines of the formulation of functions in the function analysis step. The main requirement for a true function is to change or maintain a parameter of the object that it is pointing to. This could sometimes lead to some confusion, as people tend to formulate functions differently. With this rule, for instance, it is not allowed to say that a helmet protects the head, because the head just stays the same with or without the helmet. Here, it would be better to say “the helmet deflects a bullet”.

Once the main function has been described, the components of the system are then listed and finally the relevant components within the super system that interact with the given system are identified.

As an example for the different steps of the function analysis, the key lock system described in [14] is used. The electro-mechanical system is shown in Fig. 2. In this system, when a key is inserted into the key lock, a small switch is actuated, which then gives its signal to contacts that could be read by other equipment that interacts with the key lock.

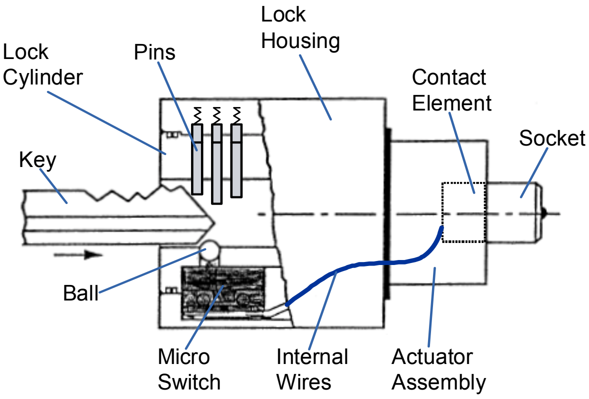

Figure 2: Cross section through the key lock.

For this key lock, the component analysis looks like that shown in Fig. 3. As this is a function model derived from an actual workshop that was held, the main function was formulated as “key lock emits signal”. With this signal, a field is already being used. Most of the time, it is better to try to formulate it with a component with resting mass. In this case, one would have to say that the “key lock closes an auxiliary circuit path”. Both main functions are permitted and possible.

Doing such a component analysis with mechanical assemblies is relatively easy as mechanical assemblies have different subassemblies that can act as components. Within electronic products there are most often no subassemblies. There is a circuit board and on this circuit board are a hughe number of small components. It wouldn’t make sense to model all this components for a function analysis.

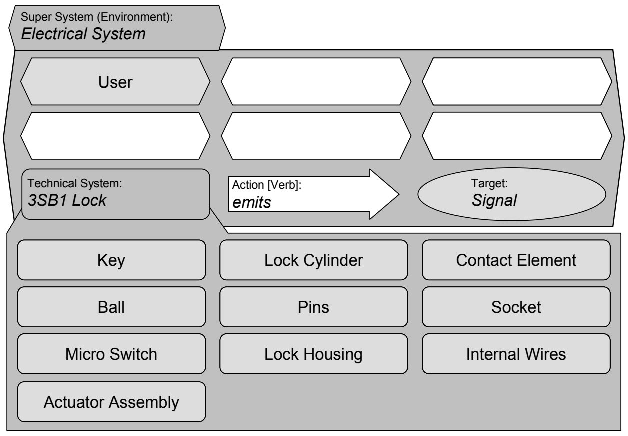

Figure 3: Component analysis for the key lock.

In the second step of the function analysis - the interaction analysis - an analysis is made to determine which components interact with one another. Normally, this is close to a physical basis.

To build up an interaction matrix, one has to enter all components of the system, the targets and the relevant components of the super system into a table with identical order in a header row and header column.

Then each cell of the table is inspected and in case of an interaction of the component of the row and the column of the cell, then a "+" sign is entered into the cell. If there is no interaction, a "-" is entered.

After the whole interaction matrix has been filled out, it is checked for diagonal symmetry. If there are cells that are not symmetrical it has to be decided which cell is correct. Then the same sign is set in the corresponding cell.

The interaction matrix is then checked to see if there are any rows or columns that only have "-" in their cells. That would mean that the component doesn't interact with the others - and could therefore be removed. This is sometimes the case with super system components.

The interaction matrix of the key lock is shown in Fig. 4. This matrix shows that there are also cells that are filled in the diagonal row. This was added in [3, 5], as a component could interact with itself if the relevant field is not modeled. This means that if there is a fluid, which flows into place, one can model it as "fluid moves itself" or as "gravity moves fluid". But this is very seldom the case.

	Key	Ball	Socket	Micro Switch	Internal Wires	…	Signal	User
Key	-	+	-	-	-		-	+
Ball	+	-	-	+	-		-	-
Socket	-	-	-	-	+		+	-
Micro Switch	-	+	-	-	+		-	-
Internal Wires	-	-	+	+	-		-	-
…						-		
Signal	-	-	+	-	-		-	-
User	+	-	-	-	-		-	-

Figure 4: Interaction analysis for the key lock.

Electronic products have also here some difficulties to face. As the different components on the circuit board are just in physical contact with the circuit board itself, all the functions would be directed to the circuit board and to field components such as "current". This would give cuircuit board and current immense weight when calculating function rank.

Function modeling is the third step. There are three requirements that must be fulfilled so that a function can be modeled between two components.

1. Both components must be valid components (material objects)
2. The components interact with each other (there is a "+" in the interaction matrix)
3. Parameters of the recipient of the function are changed or maintained as a result of the interaction

The sender of the function is called function carrier. It is the component that does something. The recipient of the function is the object of the function. Something is done to this component.

With these rules it should be already clear that it is not permitted to use double sided arrows or passive verbs to describe the action between two components.

A function model of the key lock is shown in Fig. 5. It is also shown that in a graphical representation, the three kinds of components are differentiated by their shape. Components of the engineering system are shown as rectangular, supersystem components as hexagonal shapes and target components as oval shapes.

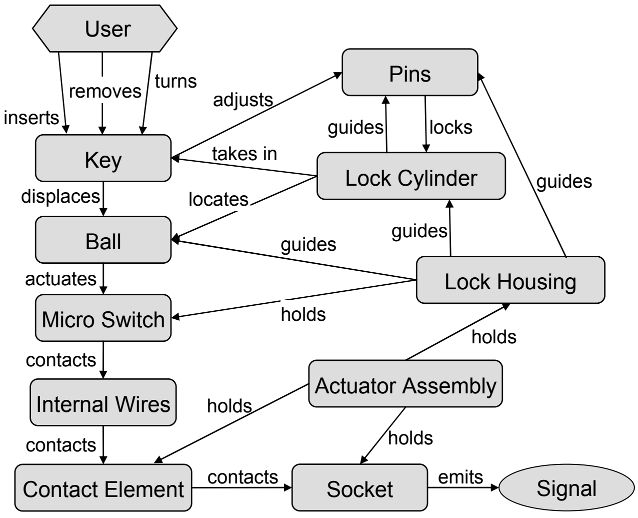

Figure 5: Function model for the key lock.

Having modeled a technical system with this function analysis, one can head into different directions with this model as already discussed above (see Fig. 1).

If the direction should be towards incremental improvement, then in the next step, a decision has to be made whether the actions are desired or not desired.

When radically improving the system, parts of the system are to be trimmed out of the model and their useful functions redistributed. This leads to new would-be function models, the so called trimming models. There can be a number of trimming models based on one function analysis of an existing system. Each of them leads to a different future and poses different problems for us to solve.

If the value of the system is to be determined, a value analysis can be performed with the model by calculating the functional rank and costs of each component within the model.

This represents a very comprehensive technique to model a technical system. But it was developed with mechanical devices and mechanical engineering systems. Within those systems you can clearly understand the different assemblies within the system, what the various parts are and how they interact with each other. When this technique is applied to electrical devices, we encounter a completely different problem. Electrical devices normally consist of a few housing parts, a circuit board and a lot of electric components mounted on this circuit board. As a consequence, there are a large number of capacitors, resistors, ASICs and plugs mounted on a circuit board, which make up most of the costs of the product.

3 COMPONENT ANALYSIS FOR ELECTRONIC PRODUCTS

Having to formulate the main function of an electrical device leads to the first problem.

A mechanical system does something to another physical component. A motor turns a shaft, a car moves a passenger, a bending machine bends parts, and a drilling machine turns a drill. So within those systems, something is turned, moved or deformed. It is still easy with devices like water heaters or microwave ovens. They heat water or food. But when it comes to electrical devices like a power converting device or a computer they don't do anything to physical objects. If these devices are not wireless devices, then they still establish some form of contact; however, "contacts wire" couldn't be a main function of the system. Within the function analysis a component can be a physical object or also a field. The main function of a power converting device can therefore be formulated as "converts power" or "converts current". For the computer it would be something like "produce signal".

The next step within the component analysis is to define the components of the systems. Here the gap between the contradiction of a meaningful function analysis and wasting too much time on producing that function model has to be closed. This requirement for electrical products is even more stringent than for mechanical or electro-mechanical products. With mechanical or electro-mechanical devices, like the lock example, there are normally predefined assemblies that can be used as components for a component analysis. In electrical products often there is only one circuit board with many smaller parts like transistors or resistors on it. As in a mechanical product, groups of these components make up a functional group, which can be seen as an "assembly" of an electronic product. As there are hundreds of these components on the circuit board, it would take hours just to identify which component belongs to which functional group.

A good approach to cut down the time that is needed to determine the function groups is to use the pareto analysis. To perform such an analysis, one has to follow these steps:

1. List all of the components in a tabular form
2. Rank the components by their price in descending order
3. Note the costs as cumulative costs and calculate the percentage
4. Divide into the three groups (A, B and C)

The A parts are normally 5% of all parts and represent 75% of the costs of a product. The next 20% of the parts represent about 20% of the costs. Finally the last 75% of parts only represent 5% of the costs.

The A and B parts are now taken to create functional groups. If a part is dealing with digital inputs, then a group "digital input" is created. The A and B parts that deal with digital input are placed in that functional group.

Large parts - like the housing - are considered as components in their own right or can be grouped in one group that is called "housing".

Those parts that are used within different functional groups get special treatment. If there are ten capacitors of one kind on a board, and four capacitors belong to the digital input group and six belong to the digital output group, then these capacitors have to be split according to the groups that they belong to. This means that instead of having one row of these capacitors in the table there should be two rows: One row with a group of four capacitors and one row with a group of six capacitors. The first row can then be grouped in the digital input group and the second row can go to the digital output group. The costs are then according to the percentage of the different

Name	Amount	Production costs	Percentage	Percentage added up	Functional group	
Transistor	4	32.93	16.0%	16.0%	Safety circuit	A-Parts
Housing part 1	1	16.19	8.1%	24.1%	Housing	
Transformer	1	15.97	8.0%	32.0%	Potential separation	
Housing part 2	1	15.59	7.8%	39.8%	Housing	
Circuit board	1	13.62	6.8%	46.7%	Circuit board	
Special component	1	7.19	3.6%	50.2%	Housing	
Adapter assembly	1	6.40	3.2%	53.4%	BUS	
Socket board adapter 10 pole	1	3.98	2.0%	55.4%	Connection circuit board	
Plug	1	3.77	1.9%	57.3%	Connection circuit board	
Cutout	2	3.64	1.8%	59.1%	Intrinsic safety	
Plug	1	3.63	1.8%	61.0%	Connection circuit board	
Thyristor	2	3.59	1.8%	62.8%	Intrinsic safety	
IC-Element	5	3.12	1.6%	64.3%	Intrinsic safety	
Plug	1	2.93	1.5%	65.8%	Connection circuit board	
Plug	1	2.89	1.4%	67.2%	Connection circuit board	
Socket board adapter 6 pole	1	2.54	1.3%	68.5%	Connection circuit board	
IC-Element	3	2.20	1.1%	69.6%	Intrinsic safety	
Throttle	1	2.04	1.0%	70.6%	Converter	
Capacitor	6	1.87	0.9%	71.6%	Filter	
Cutout	1	1.82	0.9%	72.5%	Intrinsic safety	
Transistor	2	1.66	0.8%	73.3%	Converter	
Capacitor	10	1.55	0.8%	74.1%	Converter	
IC-Element	4	1.48	0.7%	74.8%	Intrinsic safety	
Diode	3	1.42	0.7%	75.5%	Intrinsic safety	B
Transistor	2	1.37	0.7%	76.2%	Intrinsic safety	

Figure 6: Pareto analysis for electronic product.

groups. 40% of the costs of these capacitors are allocated to “input” and 60% to “output”.

With a circuit board, it is a little more difficult because there are different functional groups sitting on one circuit board. A good way to deal with this issue is to estimate how much space the functional group takes up on the circuit board. The functional group will get a share of the circuit board that is equivalent to the percentage share of the space that this group uses up on the board.

If one tries to have the circuit board as a separate component within the function analysis, it sometimes can destroy the meaning of the analysis if a value analysis is performed with it. The functional rank of the circuit board as component would be very high as it is connected with each of the electrical components - and physically retains and electrically connects them. As the circuit board is a main component that connects everything together, this is quite true. However, generally we want to see how the functional groups interact with each other and with this as focus, the circuit board as one part will have a major impact on the function over cost diagram of the value analysis of such a function analysis.

If one wants to understand the various interactions and the importance of the circuit board - or is not going in the value analysis direction - it can make sense to consider the circuit board as a separate part. This is shown in the pareto analysis in Fig. 6. Please note that to confidental considerations the shown part of the pareto analysis does not correspond with the next figures. The pareto analysis is derived from an other function analysis workshop then the following figures. Also the costs are changed slightly due to confidality reasons. Nevertheless figure 6 can show how this step should be performed.

If only A and B parts of the system are to be investigated, then one only has to deal with 25% of the parts that make up the system. However, 95% of the costs of a product are taken into consideration. Most of the time, this approach is completely sufficient. The ABC approach dramatically cuts down the time needed for performing the analysis and also provides a very good basis to create the functional model.

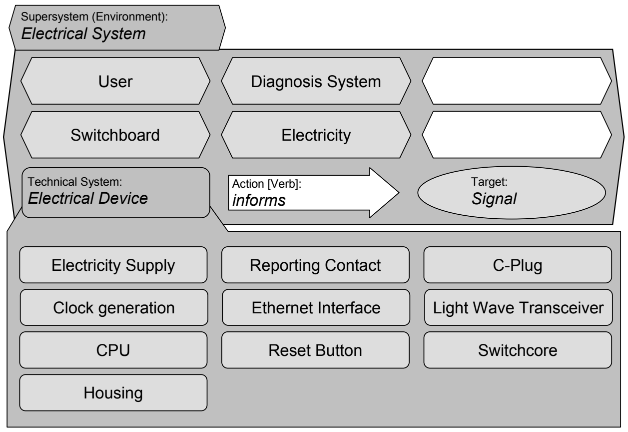

Figure 7: Component model for an electrical device.

If even less time is available, one only deals with the parts that represent up to 80% of the costs of the product. This is a more approximate approach but can also be a good way of dealing with products with a large number of components. This is also a good approach, if one is not intending to do a value analysis and just wants to come up with the functional groups. With 20% of the most costly components, it is quite certain that the important function groups will be identified.

These functional groups are then the components of the technical system. They are listed in the component model as seen in Fig. 7.

If a value analysis should be done with the system, then the different components that make up a functional group can be added up to obtain the costs of the functional group.

4 INTERACTION ANALYSIS FOR ELECTRONIC PRODUCTS

In a mechanical system, an interaction is easily determined as the various parts of the system are in physical contact with one another. In an electronic product, all the components interact on a physical level via the circuit board.

Therefore, it is not an interaction matrix on the physical level but an interaction matrix on the logical level. It has to be determined which functional group deals logically with another functional group. Does the digital input group deal with the main core group or not? Do they exchange something with each other? If there is a logical interaction of the functional groups in consideration, a “+” is entered in the box connecting these components. If there is no interaction, a “-“ is entered in the box.

	Electricity Supply	Clock generation	CPU	Ethernet Interface	Reset Button	…	Signal	User	…
Electricity Supply	-	+	+	+	-		-	-	
Clock generation	+	-	+	-	-		-	-	
CPU	+	+	-	-	+		-	-	
Ethernet Interface	+	-	-	-	-		+	-	
Reset Button	-	-	+	-	-		-	+	
…						-			
Signal	-	-	-	+	-		-	-	
User	-	-	-	-	+		-	-	
…									-

Figure 8: Interaction matrix for an electrical device.

5 FUNCTIONAL MODELING FOR ELECTRONIC PRODUCTS

Bidirectional arrows are not permitted, which sometimes poses a problem for people performing a function analysis with electronic devices. Normally, the wording that is used is: “Those functional groups communicate with each other”. But “to communicate” as an action within the function analysis is not allowed, as it is a bidirectional action. One has to split it up into two arrows. A good way to do this is to use the action “inform”. The Ethernet group informs the core group and the core group informs the Ethernet group, for instance. In this way, the bidirectional arrow is split into two arrows and therefore the functional rank can be calculated.

With the action “inform” one depicts - on an abstract level - the software running on that functional group. A function model of an electrical device is shown in Fig. 9.

From such a model, it is easy to calculate the function rank of each of the components involved. As the costs of the functional groups have already been calculated, one can draw a function over cost diagram for a value analysis as shown in Fig. 10.

It is also possible to enhance the function model in another direction and show the category (useful or harmful) of the function as well as the performance

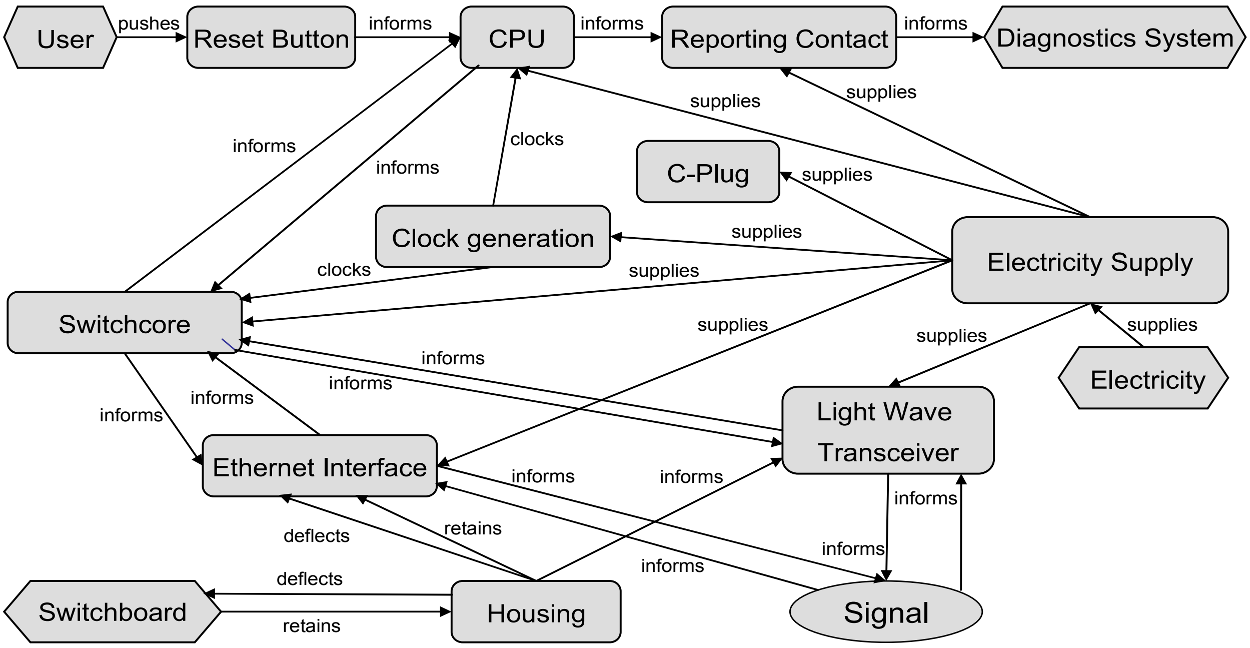

Figure 9: Function model of a electronic product.

(insufficient, normal or excessive). Such a model could then be used for incremental or even radical improvement of the system.

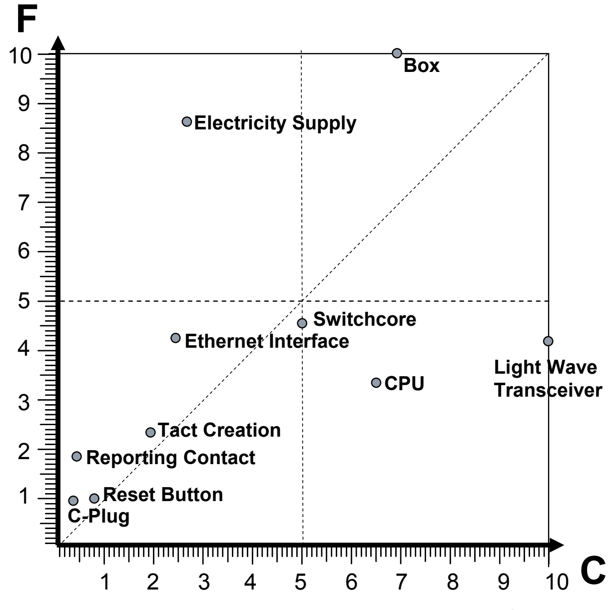

Figure 10: Function over cost diagram for an electrical device.

6 SUMMARY

An overview of the different steps of a function analysis was provided in this article. As an electronic product has a structure that is completely different from mechanical or electro-mechanical devices, the way in which a function analysis is performed for these products must be appropriately adapted.

Therefore, this paper has shown how to select components for a function analysis using the pareto analysis approach. This paper also explains how main functions are determined for such products. The interaction matrix is created based on the conclusions drawn in the component analysis step. Here, the adaptation required is not in the tools used in this step, but in the thought process on which the interaction matrix is based. Finally, a few hints are given on how to do the function modeling of electronic products.

This then leads up to a complete function model that in turn can be used for different sectors if the model is enhanced in those directions. Of these, the value analysis approach was shown in a little more detail.

This paper has shown the special requirements of an electronic device when it comes to a function analysis. These different viewpoints should help anybody having to create good function models for electronic products.

Therefore, this paper

1. helps to simplify function modeling for electronic devices for the practical usage
2. introduces a stepwise logic that structures the function modeling for electronic products
3. proposes a standard for function modeling of electronic devices
4. uses pareto analysis for simplification and preparation of the value analysis of electronic devices

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