Applying the Law of Idealization to a Circuit Design Problem

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There are eight laws of technological system evolution in TRIZ system, which are the constitutions of TRIZ world:

1) **Law of Completeness:** Any engineering system evolves in order to have four basic parts - engine, transmission, working tool, and control system.
2) **Law of Energy Conductivity:** Any engineering system evolves in order to have easy end -to-end flow of energy through all components.
3) **Law of Harmonization:** Any engineering system evolves in order to have well coordinated rhythms (frequencies) of all components.
4) **Law of Idealization:** Any engineering system evolves in order to become more ideal.
5) **Law of Non-uniformity:** Parts of an engineering system evolve at different rate, the system's evolution rate depends on its lowest part evolution rate.
6) **Law of Transition to Super-system**: Any engineering system evolves in order to become a part of more complex super-system.
7) **Law of Transition to Micro-Level:** Any engineering system evolves in order to make working tools functioning on micro-level.
8) **Law of Substance-Field Evolution:** Any engineering system evolves in order to substitute:
   - Working fields in the sequence mechanical – acoustical – thermal – chemical – electronmagnetic;
   - Working subtances in the sequence from monolith to dispersed particles.

Compared with the above, the forty Inventive Principles describe only pieces of the Evolution Laws. As shown by the Fishbone Chart of Figure 1, the ultimate objective is the Ideal Final Result (IFR), the eight Laws compose the skeleton of system evolution, while the related inventive principles are minibones. Of course the eight laws may not function simultaneously, the technological system evolvs at diffirent rate for a specific law.

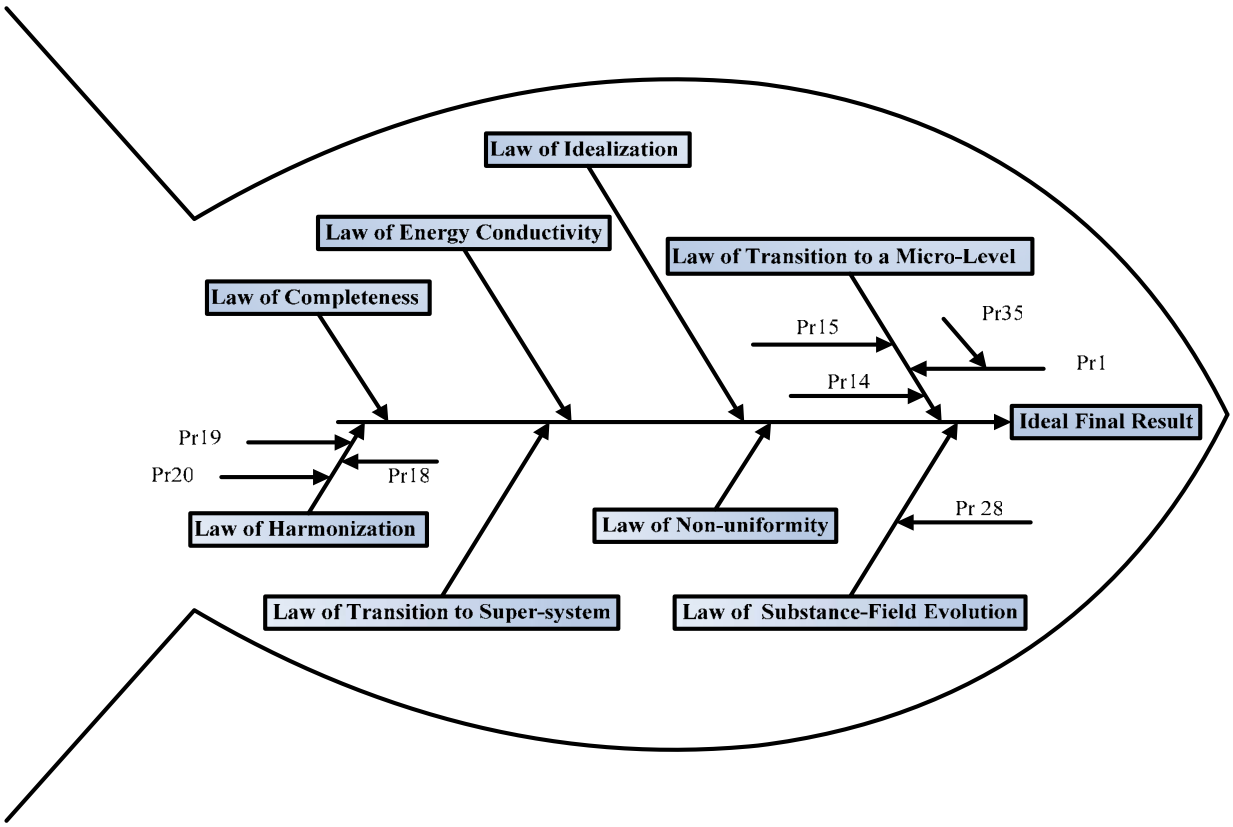

Figure 1 . Fishbone Chart of the Evolution of technological systems

Take the **Law of Transition to Micro-Level** as an example. When a system evolves to the micro-level, we can make it possess more dynamic characteristics to increase the controllability and efficiency of the system. The evolutionary trend is shown in Figure 2.

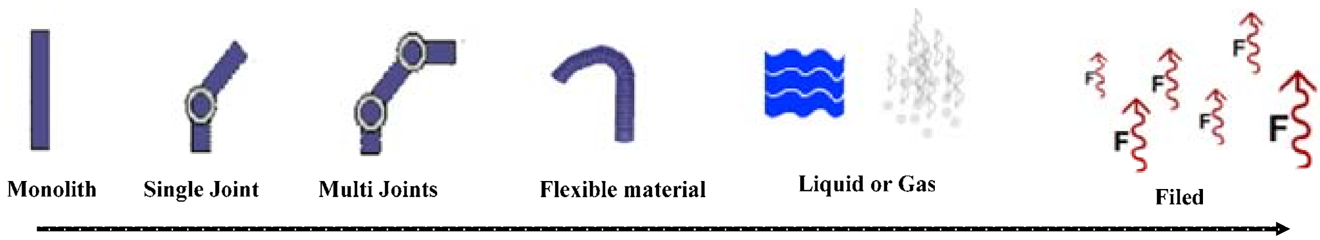

Figure 2 . Evolutionary trend of the **Law of Transition to a Micro-Level**

Moreover, the following inventive principles respectively describe one aspect of this evolutionary trend:

Principle 1. Segmentation

A. Divide an object into independent parts.

B. Make an object easy to disassemble.

C. Increase the degree of fragmentation or segmentation.

Principle 14. Spheroidality - Curvature

A. Instead of using rectilinear parts, surfaces, or forms, use curvilinear ones; move from flat surfaces to spherical ones; from parts shaped as a cube (parallelepiped) to ball-shaped structures.

B. Use rollers, balls, spirals, domes.

C. Go from linear to rotary motion, use centrifugal forces.

Principle 15. Dynamics

A. Divide an object into parts capable of movement relative to each other.

B. If an object (or process) is rigid or inflexible, make it movable or adaptive.

Principle 35. Parameter changes

A. Change an object's physical state (e.g. to a gas, liquid, or solid).

B. Change the concentration or consistency.

C. Change the degree of flexibility.

Indicated by the above, Evolutionary Laws are more abstracted than Inventive Principles so that they are called “the constitutions of TRIZ world”. In the real human society it is the functional laws(such as the Civil Law, the Criminal Law, the Marriage Law) who are applied in daily sentences。Similarly, the TRIZ Evolutionary Laws are rarely applied directly to guiding the innovations of technical systems because of their highly abstractness, however, the junior ones such as Inventive Principles, Separation Principles, Su-Field Model, Function Model Analysis, work more frequently.

Nevertheless, we happened to have a case in which the **Law of Idealization** was successfully applied to circuit design. The **Law of Idealization** can be called “King of the Laws” because it points out the ultimate objective of all evolutionary trends: the IFR. The objective of IFR is to accomplish all the useful functions without any cost or harmful function. Suited to that, the connotation of Ideality is defined by referring to the definition of “Value” in Value Engineer, shown by Equation 1.

$$Ideality = \frac{\sum Useful\ Functions}{\sum Cost + \sum Harmful\ Functions}$$

Equation 1 . Definition of Ideality

When analyzing a problem in technical systems, we often start from the problem itself and keep going forward for the solution without knowing the right direction. If we begin with the end, that is, specifying the IFR of the system at first, we always can find a more ideal solution by this way than the previous one; even if we cannot manage to accomplish the perfect IFR, we can get one near it.

This case is about a Printed Circuit Board (PCB) problem. The circuit might stop working because the fuse blew out of expectation, which resulted more related cards could not work normally, for it supplies the power to them. This situation bothered the clients deeply, so the R&D staff must work hard to solve it.

The principle chart of this part of circuit was shown in figure 3, in which the red ellipses marked the fuses.

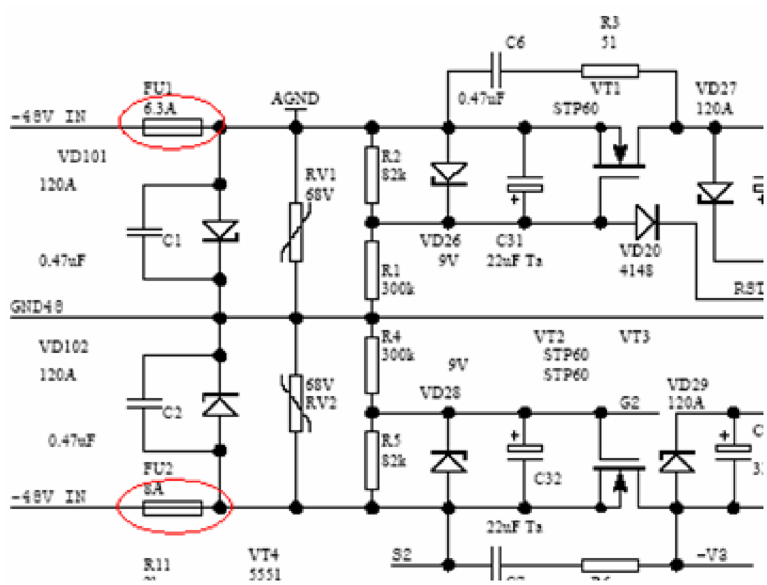

Figure 3 . Components chart of the PCB

Then we analyze this problem by applying the “Problem driven” method as follows.

1 ） What is the problem of this technical system?

The Fuse blew in time because of overloaded current to protect a component. However, after the fuse had blown, the PCB could not provide current any longer for other card so that the operation was interrupted. The current solution is that the operating staff replaced the blown fuse and reset the operation after detecting the interrupt alarm. But clients usually could not tolerate the unavoidable interrupt. The function relationship was shown by Figure 4.

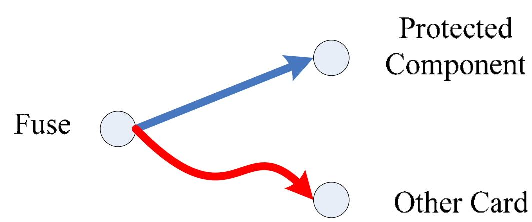

Figure 4 . Function relationship in the Fuse problem

2 ） Could the Fuse which made troubles be removed?

No. Because the protected component needed the fuse to cut off the current before the overload did harm to itself. If the fuse didn’t exist any longer, the protected component would be burned out, which not only costs much but also is hard to replace, so the interruption could last much longer. This function relationship was shown by Figure 5.

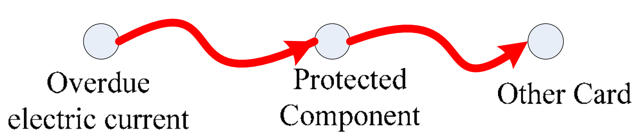

Figure 5 . Function relationship without Fuse

3） What is IFR?

It is to remain the useful functions and remove the harmful ones:

Level 0——the Protected Component has perfect self-protecting capability so that it can endure or reduce the overloaded current;

Level 1——the Protected Component is not able to self-protect but other components can provide distributing current to prevent it from burning, so the circuit can work without any interruption;

Level 2——the Protected Component has to stop working when current over loads, but it can recover promptly when the current resumes the normal level, so that the interruption can be as short as possible.

4）Which IFR's Ideality is higher?

Level 0: Because the Protected Component is purchased from outside, so the modifications last a long period and at a great cost. And it's risky in technology.

Level 1: Distributing current so as to let the appropriate amperage passes the Protected Component while the excessive amperage turns to the other part of the circuit which might be damaged. This kind of protecting method had been designed in this PCB for resisting lightning strikes. However, it's obvious that it doesn't work perfectly as expected. So risks still existed and this idea costs to some extent.

Level 2: The point is that the current can recover automatically after the interruption. The fuse does not need to be replaced by manual work. If the interrupting period reduces a great deal, the clients are likely to accept this status.

Referring to the definition of Ideality, we engaged engineers to mark the three levels with Level 2 as the standard. The result was shown in Table 1.

Table 1 . Marks of different Levels of IFR

	Level0 IFR	Level1 IFR	Level2 IFR
Useful function	3	2	1
Cost	10	5	1
Harmful Function	0	2	1
Ideality	0.30	0.29	0.50

It can be seen that Level 0 or Level 1 IFR's Ideality is lower than Level 2 although they are all able to provide protections. The reason lies in the difference of cost and technical risks. So we absolutely decided to look for solutions by applying Level 2 IFR.

5）What indications Level 2 IFR give us?

Being guided by Level 2 IFR, the engineers thought out two solutions shortly:

（1） Auto-recovering Fuse. It can automatically recover in a short period after the fuse interrupts and the cost of this kind of fuse is acceptable.

（2） Introduce the sampling circuit in front of the Protected Component. The sampling circuit can cut off the current instantly (say, within 100μS) when it is excessive. When the current comes back to the normal level, the circuit recovers automatically and the Protected Component can work well then. This kind of circuit is easy to design so costs little.

6）How about the feasibility of these solutions?

The project team was divided into two groups: one focused on the Auto-recovering Fuse, the other focused on the sampling circuit. The former discovered by marketing investigations that there is no suitable fuse with the specification as we need, so this solution was given up. The latter discovered that the capability of resisting lightning strikes was not enough and it's necessary to prevent the inner circuit from being into short circuit or overloaded status only utilizing the sampling circuit. Hence they adopted a "Fuse + Sampling circuit" solution to implement the protections. The principle chart was shown as Figure 6, in which the red oval marked the sampling resistance and the green one marks the fuse.

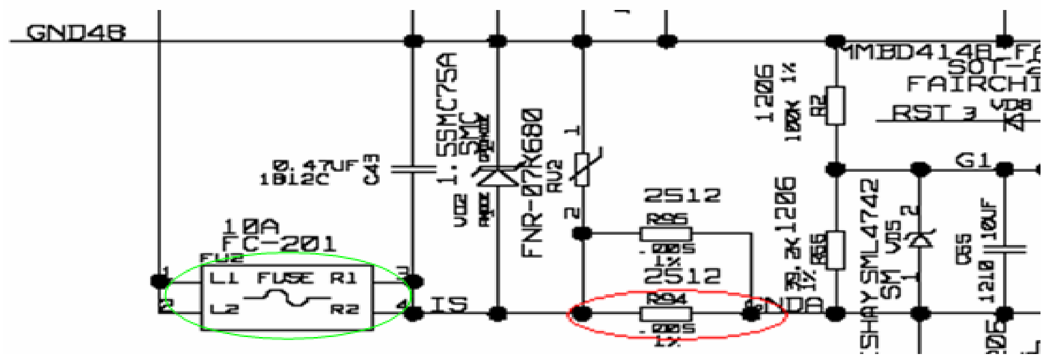

Figure 7． The newly designed circuits

After the newly designed PCB was put into application, the facts proved that this solution had lower cost and better effect. It improved the reliability of this PCB a great deal and was evaluated positively by the customer.

Review the process of solving this problem as the conclusion. The Law of Idealization and IFR changed our thinking way greatly indeed. The definition of Ideality could be able to evaluate the possible solutions. These concepts not only helped to solve the above problem but also deeply influenced the engineers who consequently realized the magic power of TRIZ. They must be able to benefit from this experience in the future.

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