Design of device for quality control of PCB based on TRIZ

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ABSTRACT

The purpose of this paper was to present the problem of electronic devices quality control. An object under examination has been a printed circuit board (PCB) intended to control solar collectors. Having equipped the board, the system ought to be subjected to assembly and operational quality assurance process. Up until now, quality control was conducted manually and lasted 290 seconds. Therefore, it was necessary to develop a tool - a chuck that would be used to accelerate the quality check. The problem has been solved with the use of the TRIZ methodology, namely, the ARIZ 64 algorithm. A device has been designed that shortens the duration of quality control to 30 seconds. Consequently, 250 seconds were reduced (approx. 4 minutes).

KEYWORDS

TRIZ, ARIZ, algorithm, quality control, PCB, printed circuit board

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Introduction

The small company produces instrumentation for control of solar collectors. For this purpose, the company must carry out checks on the electronic part used as the controller microprocessor controller solar collector. Control is carried out manually by an employee and it takes 280 seconds (over 4 minutes).

The company wants to eliminate manual controls and develop a device that will speed up the process. It is necessary to shorten the duration of the operation.

The TRIZ method was used to solve the problem.

TRIZ (Theory of Inventive Problem Solving) is used in case of the emergence of a deadlock in the process of pre-design analysis, caused by conflicting requirements in relation to the product and its components. TRIZ divides inventive problems into five categories. The first category includes problems of an essentially engineering nature, i.e. problems that do not require any special creativity. It is generally believed that TRIZ is not sufficiently effective in solving the tasks of the first and second category; they are very basic and lie entirely within the competence of the engineer. Nevertheless, sometimes, it turns out that TRIZ can be applied also in jobs included in the first category, disciplining the design process and ensuring its solution at the lowest cost with the use of simple and cheap methods [1][2][3].

At the outset, there are three stages in the process of solving technical problems using TRIZ methodology:

- neutral description of the situation,
- definition of “Undesirable effect” leading to the formulation of "innovative situation",
- an “innovation task” resulting from the combination of neutral description, adverse side effects and the goal to be achieved. [4][5][6]

The goal to be achieved is often formulated as an "Ideal Final Result" (IFR), which is being built assuming the absence of any restrictions related with material, cost and time. The IFR is not always achievable in 100%, but it is always a kind of signpost for the designer and a guide in finding answers to the questions: what are the obstacles to achieving the IFR? under what conditions these obstacles will disappear? do we need to solve the fundamental task, or maybe it will be enough to solve the "bypass” task and this "bypass” task will show us the proper course of the analysis?

Problem solving by TRIZ methodology

1. Neutral description of the situation

In a plant of industrial electronics, a printed circuit board has been developed. Its task is to operate in a controller (Fig. 01) provided for the control of solar collectors. As usual, after completion of the PCB design and assembly, it is necessary to check the quality of both installation and operation.[7]

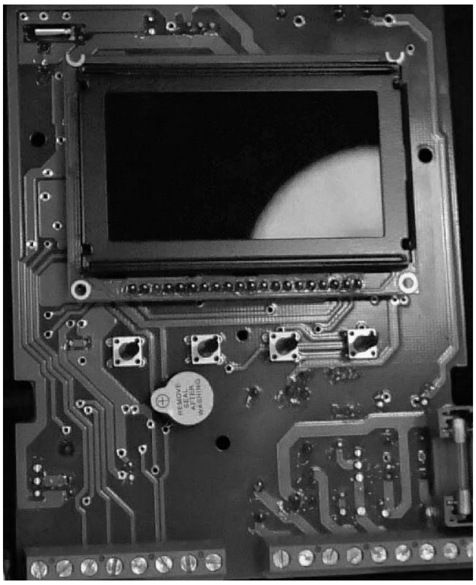

Fig. 01 A printed circuit board

The task was to find a solution that would streamline the complicated process of inspection and provide instrumentation capable of performing this function. The object of the test was the electronic circuit assembled on the printed circuit board.

The system is provided with a keyboard, display, power supply transformer, microprocessor, clock chip, measurement circuits, power phase synchronization circuits, relays for control of output circuits (motor, pump, fan), temperature measurement circuits, temperature - resistance transducers and assembly elements.

Correctness of the assembly of most of these elements is checked electronically. The system is via USB connected to a programmer and computer. First, the system is programmed. This involves attaching the programmer to a proper connector in the system and running the pre-written software. Validation is done by presenting different intermediate temperatures (-10, 30, 60°C) and checking whether the values obtained are within the tolerance limits. Based on this data, the computer determines if the measurement circuit is operating in a correct mode. If the circuit is not functioning properly or the results obtained do not meet the criteria set previously (do not fall within the tolerance limits), the microprocessor discovers an error, which means incorrect connection of soldered elements. The software then performs verification and tests the high voltage outputs. Positive outcomes of this study indicate that all components have been properly installed and provided with conductivity. For confirmation that all these operations have been performed correctly, a final report is made..

Additionally, the device is subjected to optical control and checking of the buttons. To enable the application of numerical control algorithm, it is necessary to connect the tested system to the test software. This operation is done entirely by hand. The first stage consists in visual checking if all elements are in the right places and none is missing, and if there is no visible damage. The next stage involves programming of the microprocessor. To do this, it is necessary to connect the power cord to the system, hold the board in position with the display turned down, and then insert and hold the programmer connector composed of six pins. Next the programming process lasting approximately one and a half minutes starts, and during this process all components must be manually kept together to prevent their uncontrolled disconnection. When this operation is completed, the programmer seat has to be removed, the power turned off and the board returned to its starting display-up position. The next step involves fastening with screws the tester cables to the connectors on the board. To each of the 17 pins (controller outputs), the corresponding cables must be screwed in sequence. Then the device is placed on an insulating base, to protect the product from damage and the operator from electric shock. A test program is actuated and it calibrates the input and output status via a numerical control algorithm, as described above. The task of the operator is to check whether the process is running correctly, and this is done by optical control of the diodes lighted at a predetermined time instant. Then all the buttons and displays are tested. When the button is pressed, the circuit closes. The result of normal operation is the response shown on the display. This also answers the question whether the screen is functioning properly. With the inspection process completed, the power supply is switched off and all connections are detached.

2. **Undesirable effect**

Under these circumstances, the " undesirable effect" will include all those activities that generate waste of time or require special attention.

In the context of the tasks described in this study, time-consuming is handling of the pins: 6 pins at first, and 17 pins in the next stage. The adopted technology which consists in fastening the cables with screws and holding tightly the assembled device to protect it from getting spontaneously disconnected is obviously only a temporary solution, generating loss of time and leading to errors and mistakes.

3. **Innovation task**

The initial and at the same time principal innovation task will be the elimination of excessive workload associated with connecting the board to cooperating objects. This means eliminating the operation of fastening with screws 17 cables to 17 pins and also eliminating the operation of holding the device and maintaining manually contact between the six pins to enable the processor programming.

4. Problem solving tools based on technical indicators and matrix of associations

The tool preferred by TRIZ and often used independently is a method of technical system indicators (the improvement of one indicator can result in the deterioration of another), elementary principles of invention extracted from the hundreds of thousands made inventions, and matrix with selection rules. Table I lists the aforementioned indicators.[8]

Table 1. The list of technical system indicators which tend to deteriorate with the continuous system evolution [9]

1. Weight of moving object	21.Power
2. Weight of stationary object	22. Loss of Energy
3.Length of moving object	23. Loss of substance
4. Length of stationary object	24. Loss of Information
5. Area of moving object	25. Loss of Time
6. Area of stationary object	26. Quantity of substance/the matter
7. Volume of moving object	27. Reliability
8. Volume of stationary object	28. Measurement accuracy
9. Speed	29. Manufacturing precision
10. Force (Intensity)	30. Object-affected harmful factors

11. Stress or pressure	31. Object-generated harmful factors
12. Shape	32. Ease of manufacture
13. Stability of the object's composition	33. Ease of operation
14. Strength	34. Ease of repair
15. Duration of action of moving object	35. Adaptability or versatility
16. Duration of action by stationary object	36. Device complexity
17. Temperature	37. Difficulty of detecting and measuring
18. Illumination intensity	38. Extent of automation
19. Use of energy by moving object	39. Productivity
20. Use of energy by stationary object	

The first step is to express conflicts which occur in the system using the above mentioned indicators. In Table 2 are given times necessary to perform each step.

Operation	Time
Connecting the device to the programmer	20s
Programming	180s
Connecting the device to the computer	120s
Starting the program	10s
Calibration of settings	120s
Testing correct operation of the program	120s
Testing correct operation of the buttons and display	10s
Disconnecting the device	120s
Total duration of the process	**700s**
Total duration of the operator work	**280s**

Table 2. Time necessary to perform each step.

It is easy to notice that the main objective of the task imposed will be to shorten the time of connecting and disconnecting the board to and from the power supply source and testing system, performed so far by fastening with screws the connecting cables to 17 pins.

This will improve the technical indicator called:
25 - Loss of time, and will result in:
37 – Less complex control and measurement
33 - Easy operation
32 – Easy manufacture

As a result of the improvement of these indicators, the deterioration of other indicators mentioned below can be expected, including:
29. Manufacturing accuracy
27. Reliability
36. System complexity

The indicators were combined in conflicting pairs and with the help of the "matrix of associations", the numbers of "elementary principles", i.e. proposals for changes in the system, were found. It would be difficult to show the whole matrix, and therefore only a fragment is presented below.

Improving Feature ↓ / Worsening Feature →		1 Weight of moving object	2 Weight of stationary object	3 Length of moving object	4 Length of stationary object	5 Area of moving object	6 Area of stationary object	7 Volume of moving object	8 Volume of at[…]
1	Weight of moving object	+		15, 8, 29,34		29, 17, 38, 34		29, 2, 40, 28		2, 8, 15, 38
2	Weight of stationary object		+		10, 1, 29, 35		35, 30, 13, 2		5, 35, 14, 2	
3	Length of moving object	8, 15, 29, 34		+		15, 17, 4		7, 17, 4, 35		13, 4, 8
4	Length of stationary object		35, 28, 40, 29		+		17, 7, 10, 40		35, 8, 2,14	
5	Area of moving object	2, 17, 29, 4		14, 15, 18, 4		+		7, 14, 17, 4		29, 30, 4, 34
6	Area of stationary object		30, 2, 14, 18		26, 7, 9, 39		+			
7	Volume of moving object	2, 26, 29, 40		1, 7, 4, 35		1, 7, 4, 17		+		29, 4, 38, 34
8	Volume of stationary object		35, 10, 19, 14	19, 14	35, 8, 2, 14				+	
9	Speed	2, 28, 13, 38		13, 14, 8		29, 30, 34		7, 29, 34		+
10	Force (Intensity)	8, 1, 37, 18	18, 13, 1, 28	17, 19, 9, 36	28, 10	19, 10, 15	1, 18, 36, 37	15, 9, 12, 37	2, 36, 18, 37	13, 28, 15, 12
11	Stress or pressure	10, 36, 37, 40	13, 29, 10, 18	35, 10, 36	35, 1, 14, 16	10, 15, 36, 28	10, 15, 36, 37	6, 35, 10	35, 24	6, 35, 36
12	Shape	8, 10, 29, 40	15, 10, 26, 3	29, 34, 5, 4	13, 14, 10, 7	5, 34, 4, 10		14, 4, 15, 22	7, 2, 35	35, 15, 34, 18
13	Stability of the object's composition	21, 35, 2, 39	26, 39, 1, 40	13, 15, 1, 28	37	2, 11, 13	39	28, 10, 19, 39	34, 28, 35, 40	33, 15, 28, 18

Table 3. TRIZ Matrix [9] [10]

By combining selected indicators in conflicting pairs, for each pair, the numbers of the elementary principles that can help in task solving are read from the matrix:

25/29 - 24,26,28,18
25/33 - 04,28,10,34
25/36 - 06.29
37/29 – 0
37/27 - 27,40,28,08

37/36 - 15,10,37,28
33/29 - 01,32,35,23
33/27 - 17,27,08,40
33/36 - 32,26,12,17
32/29 – 0
32/27 – 0
32/36 - 27,26,01

The principles that re-appear more than two times are 28, 26, 27.
From Table 4, a fragment of which is presented below, the content of the proposal has been read.

The elementary principles applied to eliminate the technical contradictions

Table 4. 40 principles [9]

1.Segmentation	21. Skipping
2. Taking out	22. „Blessing in disguise”
3. Local Quality	23. Feedback
4. Asymmetry	24. „Intermediary”
5. Merging	25. Self-service
6. Universality	26. Copying
7. „Nested doll”	27. Cheap short-living
8. Anti-weight	28. mechanics substitution
9. Preliminary anti-action	29. Pneumatics and hydraulics
10. Preliminary action	30. Flexible shells and thin films
11. Beforehand cushioning	31. Porous materials
12. Equipotentiality	32. Colour changes
13. The other way around	33. Homogeneity
14. Spheroidality - Curvature	34. Discarding and recovering
15. Dynamics	35. Parameter changes
16. Partial or excessive action	36. Phase transitions
17. Another dimension	37. Thermal expansion
18. Mechanical vibration	38. Strong oxidants
19. Periodic action	39. Inert atmosphere
20. Continuity of useful action	40. Composite material films

26 - Coping
27 – Cheap short-living
28 - mechanics substitution

Besides the principles most likely to re-appear, other principles should also be considered, including:
10 - Preliminary action
24 – „Intermediary”

The principles disclosed here indicate one reasonable solution, namely the use of strips with male and female pins and exact positioning of board relative to the adjusting device. The mere method of indicators, elementary principles and the matrix of associations cannot provide us with a clear guidance in this particular case. The essence of the problem lies in the fact that it is a very "detailed" problem and as such is not fit for system analysis.

5. Task solving with the ARIZ - 64 algorithm [11] [12] [13][14][15][16]

The ARIZ - 64 algorithm is composed of the following step:

I. **Problem clarification and formulation**

Step 1. Determine the ultimate goal.
Maximum reduction of time necessary for the performance of supporting operations, in this particular case these will be the operations of temporary assembly and disassembly of a large number of cables with pins.

Step 2. Check if the goal can be reached applying a "bypass" method, which means solving a different task but ultimately leading to the same goal.
The goal can be achieved by making on the PCB respective tracks that will co-work with tracks made on the auxiliary strip permanently connected to the wiring.

Step 3. Examine which solution, i.e. fundamental or "bypass", can give better effect.
"Bypass" solution seems to be much more promising.

Step 4. Specify the required quantitative indicators: speed, technological susceptibility, accuracy, size, etc.
The aim should be to reduce to minimum the time taken for connecting and disconnecting the sets with tracks.

Step 5. Clarify requirements arising from the specific conditions under which the new solution will be implemented.
The system designed to connect boards to external devices should provide the performance of this operation in the shortest time technically feasible.

II. **Analytic stage**

Step 1. Formulate the Ideal Final Result (IFR) (answer the question: what can this result give us?)
Ideally the board should be inserted with one movement into the base device and connected at the same time to the external device.

Step 2. Find out what hampers the achievement of IFR (answer the question: where is the obstacle?)
A large number of conductors (17 and 6) which must be properly connected to as many as 17 pins.

Step 3. Find out why this obstacle is important (answer the question: which factor is directly responsible for the existence of the obstacle?)
The wires are loose, untied, and easily get “mixed”.

Step 4. Determine under what conditions the IFR would be achievable (answer the question: under what conditions the obstacle is likely to disappear?)
If wires were bound together in one monoblock, their connecting would be much easier.

III. Operating stage

Step 1. Check to what extent it might be possible to remove the technical contradictions by the method of replacement (machine, mechanism, process), using the table of typical inventive "tricks"
Checked with no result

Step 2. Check to what extent it might be possible to introduce changes to the environment of the investigated object and to other objects
Checked with no result

Step 3. Adapt solutions from other fields of technology (answer the question: how are similar problems solved in other technical fields of knowledge?)

The design of computer system uses "male" pins embedded in an insulation strip and a system of "female" pins with the same seat pitch.

Step 4. Try to use a "reverse" solution (answer the question: "how are the tasks reverse to this one solved by the technology and what are the chances of using a reverse solution with the “minus sign” in the case under investigation)?

No corresponding case has been found.

Step 5. Use "prototypes" created by nature (answer the question: how does nature solve similar problems)?

In nature there is the problem of correctly splicing the nerve fibres in the case of trauma suffered by the bundles of fibres (e.g. in the spinal cord). Recent studies suggest that in some circumstances the fibres gain identification markers which indicate appropriate fibres for interconnection. Of course, markers might be implemented in the technology, but this solution would have a limited application only.

IV. Synthetic stage

Step 1. Examine how other parts of the object will change after changing its fundamental part.

Use a system of ready-made (available in the commercial network) contact strips, choose the right pitch to embed pins and adapt the board and cooperating equipment to the system of connections made with the use of strips.

Step 2. Examine how objects cooperating with the fundamental object will change.

Adjust the system of tracks to the use of contact strips.

Step 3. Examine the possibility of extending and varying the use of the object being changed.

Enter as a rule the use of ready-made strips with female and male pins embedded in them.

Step 4. Use the obtained new idea (or idea reverse to the obtained one) to solve other technical tasks.

It is possible to slightly modify the contact strips with "contact pads" placed on boards cooperating with other contact strips or with analogical boards provided also with contact pads. The method of "contact pads" can reduce the volume of the whole connection and may prove useful also in some other cases.

From the above it follows that ARIZ - 64 recommends the use of a system of contact strips. However, it should be remembered that the case we are dealing with is only a simple elementary task. There still remains one problem. To make the system of contact strips active, the following conditions must be satisfied:

- closing movement of all pins must be carried out in one plane and in one direction.
- to ensure that male pins are unerringly connected with female pins, proper referencing of the board must be provided following the rules of setting items in jigs.

Introducing the system of contact strips significantly reduces the time necessary for the quality control of PCB and its accessories (see Table 5).[17]

Table 5. Comparison of an average duration of processes with and without the use of a tool for quality control.

Operation	Time before	Time after
Connecting the device to the programmer	20s	5s
Programming	180s	180s
Connecting the device to the computer	120s	0s
Starting the program	10s	10 s
Calibration of settings	120s	120s
Testing correct operation of the program	120s	120s
Testing correct operation of the buttons and display	10s	10s
Disconnecting the device	120s	5s
Total duration of the process	**700s**	**450s**
Total duration of the operator work	**280s**	**30s**

Final product - device for quality control of printed circuit boards.

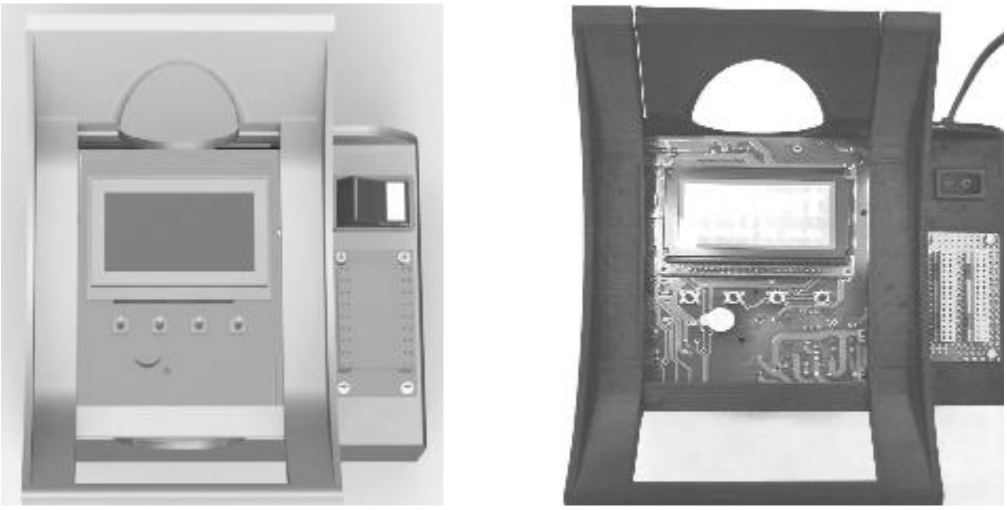

Fig. 02 Visualisation of a quality control device and its 3D printed version.

Conclusions

The problem has been solved with the use of the TRIZ methodology, namely, the ARIZ 64 algorithm. A device has been designed that shortens the duration of quality control to 30 seconds. Consequently, 250 seconds were reduced (approx. 4 minutes).
Small businesses knowing the TRIZ method can solve their own problems themselves.

This way companies reduce the cost of innovation because they do not have to pay the costs of turning to specialized companies involved in developing new concepts.

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