

# A Study of Thinking Process on Troubleshooting of Single-Chip Microcomputer System

Yen CHING-ZON

Oriental Institute Technology, yan@ee.oit.edu.tw

Ching-Fang LIN

De-Lin Institute of Technology, cflin112@yahoo.com.tw

Guo-Feng HUANG

Department of Industrial Education, National Taiwan Normal University, Taiwan, R.O.C., E-mail: eric.eric@msa.hinet.net

Chang YU-MIN

De-Lin Institute of Technology, cym@dlit.edu.tw

**KEYWORDS:** *single-chip microcomputer, troubleshooting, thinking aloud*

**ABSTRACT:** *There were three purpose of this study; (1) exploring successful factors of trouble shooting diagnoses in single-chip microprocessor; (2) analyzing the thinking processes of sampling group possessing successful achievement; (3) designing the diagnoses processes of trouble shooting in single-chip microprocessor circuits. 16 students of Electrical Engineering were sampled to participate the experiments in three types of diagnoses processes of trouble shooting in single-chip microprocessor circuits. Recording their experimental procedures, thinking aloud procedure and using protocol analysis were three main research methods in this study. The conclusion after data analyzing was as following: The successful factors of the diagnoses processes of trouble shooting in single-chip microprocessor circuits consists of professional knowledge, comprehension for circuits, fully taking advantage of strategies, wisely making use of electric meters, judging defining qualities of components, and using sensory assessment. The procedures for diagnoses processes of trouble shooting in single-chip microprocessor circuits are judging symptoms of trouble shooting, searching of trouble shooting points in circuit, firmly determining trouble shooting points, executing repair activities, accomplishing repairing process. The rank of indicated trouble shooting behaviors were that visual behavior was the most judging activity among all and sensory assessment was the most strategy among all while using electric meters ranked the second. The sampling group would mostly adopt open-loop method in taking advantage of strategy and indicated more trouble shooting behaviors of predicting, interrogation, description, and assessment. The sampling students could successfully and interactively make use of electric meters scaling and trouble shooting strategy. Students would refer circuit diagram and combine defining components features and circuit structures into thinking processes, and then assess the function of every component in circuit to firmly secure trouble-shooting points. The research result indicated that there were more successful diagnoses rate in trouble shooting in single-chip microprocessor while making use of such thinking process.*

## 1 BACKGROUND AND OBJECTIVE OF THE STUDY

Trouble shooting is a professional technical application to help students resolve problems. According to research, the diagnoses and repairing could be achieved by teaching design (Bedard & Fredreiksen, 1992; Foshay, 1989).

The diagnoses and trouble shooting are actually a series of cognitive processes (Chung, 1999). According to researches, trouble-shooting could be achieved by teaching design (Bedard & Fredreiksen, 1992; Foshay, 1989). The teaching of trouble-shooting is a course combining theory and practice, and is a mean to develop the ability of resolving problems (Yen Ching Jung, 2000).

The current teaching style in Colleges of Technology is to supplement the existing text with practical courses. However, due to the invariability of the text and teaching methods, it is difficult to foster good technicians in this teaching style (Hsieh Cheng Han, 1999). The assessment of technical skills in the traditional teaching style always put focus on conclusion rather than on process, so it is difficult for

teachers to inspire students to the ability of resolving problems, to know what problems students encounter, and to understand the effect of the teaching.

To improve the mentioned defects, the study would supplement thinking aloud with protocol analysis to strictly examine the behavior of the diagnoses and repairing. Thinking aloud can help figure out the complicated structure for resolving problems and identify the internal symbolic mechanisms. And, protocol analysis can explore the process of the trouble dealer's control, assessment, and achieving goals (Ericson & Simon, 1980).

Trouble-shooting is one of the best ways for the students to train the thinking process of resolving problems, so the courses about single-chip microprocessor have an important place in technical teaching. Teachers should try to help students foster their abilities of designing and repairing of hardware circuits. This study would collect the behavior models of diagnoses and repairing from students aiming at the subject of single-chip microprocessor to help teachers understand more about students, improve the teaching style, and finally improve the effect of teaching.

As mentioned above, the concrete goals of this research are: 1) exploring successful factors of trouble shooting diagnoses in single-chip microprocessor; 2) analyzing the successful thinking process of the sampling group; 3) designing the diagnoses processes of trouble shooting in single-chip microprocessor circuits.

## 2 RATIONALE

Two of the common strategies for problem resolving are the Heuristics and Algorithms. The Heuristics is the study of how people use their experience to find answers to questions or to improve performance. The users would remove the factors which are different with goals in the thinking process and finally resolve the problems in this way. It's like a shortcut for problem resolving.

The working backward is one of the Heuristics, which uses the means-ends analysis. It is used to find out the difference between the existing situations and goals (or the second goals) and then uses some ways to reduce the difference (Simon, 1980). There are four steps in the means-ends analysis:

1. To find out the difference between the goals and existing situations.
2. To find out an operation model that is similar to the difference.
3. To execute the operation and reduce the difference.
4. To repeat the steps 1-3, until the problem is resolved.

The means-ends analysis is to examine from the existing situations, so the repairers have to meet the requirements first and then to think that if the requirements could be got from the existing situations (Chung Sheng Hsiao, 1990; Mayer, 1992). The other way is the working forward. The repairer using the way should examine the existing situations and execute some kind of operation to change the situations. Any mistakes in the executing operation would lead to failure of problem resolving.

The Algorithms is used to describe the whole trouble situation exactly, which is a clear-cut procedure or a group of rules, and guarantee to get expected output from available input.

The main goal of the diagnoses and repairing is to examine the abnormally operating facilities and try to make them return to normal. Most experienced experts regard choosing suitable searching strategy as the most important factor of problem resolving (Macpherson, 1998). Perez (1991) thinks the factors which affect the ability of diagnoses and repairing include: 1) the ability of repairing and replacing components; 2) the ability of diagnosing tests; 3) the ability of searching problem resolving strategies. Both Morris and Rouse (1985) think the unsuccessful factors which affect the diagnoses and repairing include: 1) replacing components randomly because of the lack of basic acknowledge; 2) doing tests using inconsistent methods; 3) not using the strategies with right information.

The problem dealer should check the causes of problems and the whole situations at first before executing repairing (Rouse, 1991). To execute repairing needs the skill of problem resolving and the necessary acknowledge (Jereb, 1996; Rouse, 1991). When executing repairing, the problem dealer would identify the trouble using different strategies. The level of the dealer's ability, the type of the system, and the level of the trouble would decide what strategy is used. Johnson (1991) thinks the five most common strategies are: 1) trial and error; 2) exhaustive; 3) topographic; 4) half/split; 5) functional. Beginners show partiality for the strategy of trial and error. But experienced experts think the strategy lacks definite rules. Lesgold and the others (1986) called the strategy "swaptronics" instead. When some area or component

turns probably abnormal, the repairer would replace the abnormal component with normal one until the function returns to normal. The second strategy, the exhaustive, doesn't need professional skills, but is only suitable to be used for small scale circuits. The third strategy, the topographic, is used to examine and find out the normal points and trouble points on the circuit diagram (Rasmussen & Jensen, 1974). There are two important strategies on the basis of this study: 1) examining from the normal points to trouble points, and, on the other hand, 2) examining from the trouble points (the broken light, for example) to the input end (Johnson, 1992). The strategy of half/split is used to examine situations in the existing problem space and reduce the problem space. When the circuit becomes abnormal, the repairer would choose a reference point, and then try to find out in which half the trouble happens, and repeat the steps until the trouble point is found out. This repairer would use a tri-functional electric meter to find out where the trouble happens from the signs of the wave gage or the touching examination. The most difficult strategy is the last one, the functional, it is a strategy. The information about the system and the components is the major factor for choosing strategy (Johnson, 1991). This strategy includes a lot of types and its basic type is on the basis of the existing operation of the system and the expected results. The repairer could set up a model system of simulating the mental state to simulate the trouble situation (Dekleer & Brown, 1981).

Means (1988) puts forward five strategies of diagnoses and repairing aiming at electric facilities: 1) space splitting: this is used to examine the circuit from the middle point. Suppose there are six facilities. The better way to find out where the trouble happens is to examine from the middle of the circuit to save the examining time. For example, the circuit (see figure 1) is made up from six connecting facilities. One of the six becomes abnormal. The repairer using this strategy would examine the third or the fourth point first. This method would save much more time than examining them one by one; 2) reconfiguration: the repairer could re-connect the circuit bypassing the suspicious component and find out if the component is normal. For example, when the repairer doubt that there is something wrong with component A, he could re-connect the circuit bypassing the component A. If the circuit is normal after re-connecting, that means the component A is really going wrong; 3) historical analysis: this strategy is used to control the operation procedure of the system first before executing repairing. It is a available method to restrict the area which needs examining.

### 3 DISCUSSION AND CONCLUSIONS

Sixteen students majoring in electronic engineering at a College of Technology in Taiwan were sampled. The sample students were offered single-chip microcomputer circuits for thinking aloud trouble shooting experiment. Interviews and protocol analysis were also applied for further analyzing the trouble shooting process.(see figure 2,3,4) Five Conclusions were reached based on the literature reviews, research methodology, implementation and research results.

1. The factors of successful trouble-shooting single-chip microcomputer are described as the followings:
  - ( 1 ) Professional knowledge: Students should be equipped with the basic describing and processing knowledge.
  - ( 2 ) Circuits knowledge: Students should be aware of the golden rules of circuits.
  - ( 3 ) Strategy application: The proper application of strategies would lead to a higher possibility of success.
  - ( 4 ) Measurement skills: Students should be familiar with the measurement skills and procedures.
  - ( 5 ) Making full use of electric meters.
  - ( 6 ) Wisely assess all defining component features
  - ( 7 ) The multi-sensory assessment
2. The procedures of trouble-shooting single-chip microcomputer are described as the followings(see Figure 5)
  - ( 1 ) The judgment of drawback symptoms: eye-seeing, ear-hearing
  - ( 2 ) To search for the faults: circuits comprehension, data analysis, strategy application, meter measurement, sensory assessment

- ( 3 ) To locate the fault
  - ( 4 ) To execute the restoration: continue, restarted, components exchange
  - ( 5 ) To complete the restoration
  - ( 6 ) To polish the drawback up.
3. Successful trouble-shooting single-chip microcomputer lies mostly on eye-seeing the symptoms of the drawback. Both multi-sensory assessment and meter measurement are frequently used for successful locating the trouble-shooting point.
  4. Teachers should encourage students to apply strategies while conducting trouble-shooting because the research results showed that the sample students who have good command of strategy-using have higher potentiality of success than those who don't. Open-loop, components-exchange and comparative methods are frequently adopted by students; while predicting, interrogating, describing, and assessing behaviors are proved to be good thinking behaviors which lead to successful trouble-shooting.
  5. In general, students would first refer to circuit diagram and then combine both defining components features and circuit structures together, and finally assess the function of every component in circuit to firmly secure trouble-shooting points. The above constructs a successful thinking process of trouble-shooting single-chip microcomputer. The research result indicated that there was a higher possibility of successful trouble- shooting f single-chip microprocessor while making use of such thinking process.

#### 4 PROJECT ACHIEVEMENTS

1. Provide the teaching paradigm of troubleshooting single-chip microcomputer for Colleges of Technology in Taiwan.
2. Explore the factors of successful troubleshooting single-chip microcomputer for future classroom teaching.
3. Present the valuable troubleshooting strategies, process, and methods for both national and international academic fields.
4. Navigate the thinking aloud strategy on trouble-shooting process for engineering education field.
5. Pilot single-chip education research by conducting a qualitative study on trouble-shooting process.

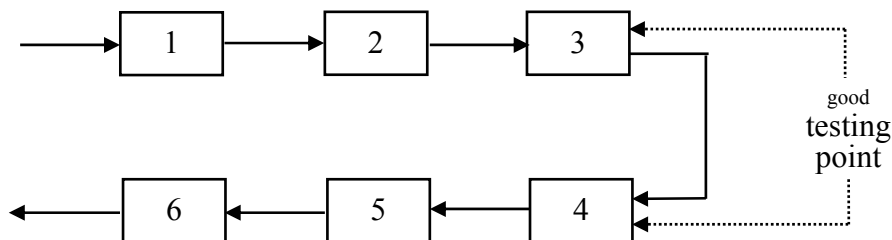


Figure 1 the circuit is made up from six connecting facilities

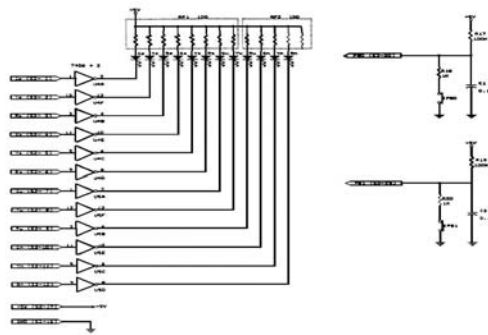


Figure 2 LED circuit

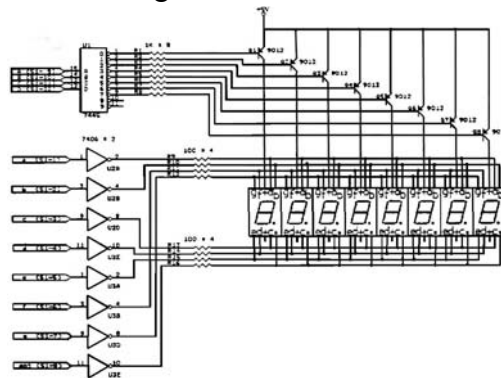


Figure 3 7-seg circuit

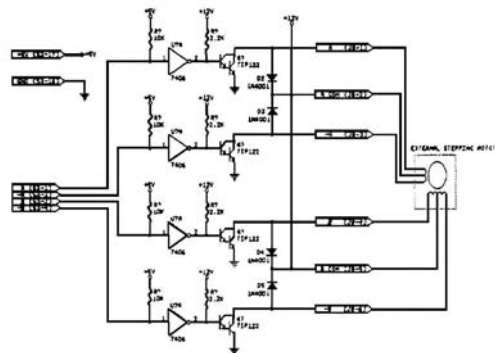


Figure4 stepping motor circuit



## REFERENCES

- 莊謙本,民 86, : 電子電路故障檢修評量模式研究。國立臺灣師範大學學報, 數理與科技類, 42 期, 7-24 頁。
- 謝澄漢,民 88, : 高工控制科機電整合控制實習教材發展與設備製作之研究。國科會研究報告 NSC-88-2516-S-003-002, 6-7 頁。
- 鍾聖校,民 79, : 認知心理學。臺北市:心理出版社。
- 顏晴榮,民 89, : 培養專科學生機電整合故障檢測之問題解決能力研究。國科會研究報告。NSC-89-2516-S-161-002。
- Bedard, D., & Frederiksen, C. H. ,1992,. *Comprehension and use of knowledge by students in learning complex technical skills*. Paper presented at the annual meeting of the American Educational Research Association, San Francisco.
- Chung, S.P.,1999,. *The effect of Thinking Aloud Pair Problem Solving ,TAPPS, on the Troubleshooting Ability of Aviation Technician Students*, Order No: AAC 9904415 ProQuest - Dissertation Abstracts. DAI-A 59/08, p. 2937.
- DeKleer, J.,& Brown, J. S. ,1981,. Mental models of physical mechanisms and their acquisition In J. R. Anderson ,Ed.,, *Cognitive skills and their acquisition*, ,pp. 285-309,. Hillsdale, NJ: Erlbaum.
- Ericsson, K.A., & Simon, H.A. ,1980,. Verbal reports as data. *Psychological Review*,87,215-252.
- Foshay, W. R. ,1989,. What we know ,and what we don't know, about training of cognitive strategies for technical problem-solving. *Journal of Structural Learning*, 10, 111-125.
- Ginsburg,H.P.et al., ,1983,. Protocol Methods in Research on Mathematical Thinking, in H.P. Ginsburg,,Ed.,, *The Development of Mathematical thinking* ,riando, Florida:Academic Press, Inc.,pp7-47.
- Johnson, S. D., Flesher, J. W., Jehng, J. C., & Ferej, A. ,1993,. Enhancing electrical troubleshooting skills in a computer-coached practice environment. *Interactive Learning Environments*, 3,3,, 199-214.
- Johnson, S. D.,& Satchwell, R.E. ,1993,. The effect of functional flow diagrams on apprentice aircraft mechanics' technical system understanding. *Performance Improvement Quarterly*, 6,4,. 73-91.
- Johnson, S. D., & Others.,1992,. *Application of Cognitive Theory to the Design, Development, and Implementation of a Computer-Based Troubleshooting Tutor*. National Center for Research in Vocational Education. Berkeley, CA.,ERIC Document Reproduction Service No. ED 351 602,.
- Lesgold, A., Lajoie, S., Eastman, R., Eggan, G., Gitomer, D., Glaser, R., Greenberg, L., Logan, D., Magone, M., Weiner, A., Wolf, R., & Yengo, L. ,1986,. *Cognitive task analysis to enhance technical skills training and assessment: Pittsburgh, PA: University of Pittsburgh*, Learning Research and Development Center.
- Macpherson,R.T. ,1989,. Factors affecting technological trouble- shooting skills. *Journal of Industrial Teachers Education*,35,4,,5-28.
- Mayer, R. E. ,1992,. *Thinking, problem solving, cognition*,2nd ed.,. New York: W. H. Freeman and Company.
- Means, B., & Roth, C.,1988,. *Some outcomes of a cognitive analysis of troubleshooting*. Paper presented at the American Psychological Association Convention, Atlanta, GA.
- Morris, N. M., &Rouse, W. B. ,1985,. *Review and evaluation of empirical research in troubleshooting* ,Interim Report NPRDC TR 86-20,: San Diego, CA: Navy Personnel Research and Development Center.
- Perez, R. S. ,1991,. A view from troubleshooting In M. U. Smith,Ed.,, *Toward a unified theory of problem solving*, pp.115-153. Hillsdale, New Jersey :Lawrence Erlbaum Associates.
- Rasmussen, J., & Jensen, A. ,1974,. Mental procedures in real-life task: A case study of electronic troubleshooting. *Ergonomics*, 17,3,, 293-307.
- Rouse, W. B. ,1991,. *Design for success : A human-centered approach to successful products and systems*. New York: John Wiley & Sons, Inc.
- Simon, H. A.,1980,. Problem solving and education. In D. T. Tuma, & F. Reif,Eds.,, *Problem solving and education: Issues in teaching and research*. Hillsdale, NJ: Erlbaum.