Graphical Analysis Applications in an Electrical Engineering Technology Laboratory

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Abstract

Troubleshooting frequently focuses on the process of developing a systematic logical approach to the identification and solution of a problem. Identifying the problem, devising a hypothesis for its cause, postulating a test strategy that will identify the source of the fault, implementing tests to confirm the fault, and correcting the fault are some of the steps in this process. This paper describes the use of graphical analysis techniques that take the student beyond the point of *fixing* the immediate problem on a single unit to asking questions about the underlying causes for failures when several units are involved and proposing solutions that will prevent their recurrence.

Introduction

A learning tool called ALFRED (Amplitude Linear Frequency Related Educational Device) was developed in the mid 1980's by the faculty and staff of the Electrical Engineering Technology Department of Purdue University to provide students in a sophomore-level course "with hands-on experience in electronic troubleshooting from the system level to the component level."[1-3] It is essentially a one octave music synthesizer that has served as a useful tool to teach troubleshooting for more than a decade. A supplementary board that monitors "six inputs—two thermometer calibration voltages, three single ended DC voltages, and one temperature dependent differential voltage—and displays them one at a time on a three and one-half digit display" was introduced by Aubrey and Brelage in 1995.[4] It functions as a temperature and voltage monitor for the rest of ALFRED. Hundreds of students have developed their troubleshooting skills to the point where they are able to locate and repair multiple faults at the component level in a complex electronic system.

In an effort to address problems associated with the manufacturing environment, lectures on graphical analysis techniques, such as flowcharts, check sheets, run charts, Pareto charts, cause & effect (fishbone) diagrams, histograms, etc.[5], were added to the troubleshooting course (EET 276) in 1997. They provide methods of data analysis that relate to the solution of production problems where issues of reliability and quality control are concerned.

Student Involvement

A homework assignment is given in which the student uses a check sheet to tabulate the results of various test procedures conducted at different locations on several units of a fictitious electronic system. One is required to enter the data in a spreadsheet, construct histograms that show the frequency of each of the tests for several locations, analyze the results, determine what faults are present, and decide how significant they are. During a laboratory session, students analyze several ALFRED fault sheets to identify types of faults, how often they occur, on which board(s) they occur, and draw conclusions about possible causes for the failures.

Homework Problem Stated

The homework assignment is stated as if it is a preliminary report from tests conducted on several faulty units:

During one 8-hour shift, 60 units were removed from the assembly line of a product due to failures. Each unit was placed on a bed-of-nails tester and several measurements were taken at 5 different test points (**a-e**). The 5 test points do not necessarily indicate a progression of signal through the unit! The assessments of the data from these measurements on each unit are listed in Table 1 below in the form of 5-digit numbers. For each of the digits the numeral interpretations are as follows:

- Numeral **0** indicates acceptable AC and DC signals at the test point;
- Numeral **1** indicates no AC or DC signal at the test point.
- Numeral **2** indicates a DC quiescent current that exceeds the maximum specification at the test point;
- Numeral **3** indicates a DC quiescent current that falls below the minimum specification at the test point;
- Numeral **4** indicates a frequency that exceeds the maximum frequency specification at the test point;
- Numeral **5** indicates a frequency that is less than the minimum frequency specification at the test point;
- Numeral **6** indicates the presence of the +V supply at the test point;
- Numeral **7** indicates the presence of the -V supply at the test point;
- Numeral **8** indicates an AC voltage greater than the maximum specification at the test point;
- Numeral **9** indicates an AC voltage less than the minimum specification at the test point;

This assignment requires the student to analyze the data using various graphical techniques discussed in lecture. It focuses on the most-significant digit, the middle digit, and the least-significant digit in each number, and on all of the digits collectively in all of the numbers. In order to provide variation each semester, the 5-digit numbers are derived from the student identification numbers of the students enrolled in the course.

Table 1. Test Measurement Results

abcde	**abcde**	**abcde**	**abcde**	**abcde**	**abcde**
69640	69983	71373	71681	80333	81045
22912	25082	25801	27346	27418	27908
49823	49927	61567	62751	63196	64294
64359	64525	65989	66899	66990	69051
81353	83188	83869	84414	85477	86455
43832	45251	45805	46678	46910	48402
87208	87416	87732	88836	88891	88970
29491	35369	40227	41609	42004	43577
89072	89158	89243	89877	91359	94120
00640	04804	07356	07716	13760	21918

The student determines how many times each numeral **0-9** occurs in column **a** of Table 1 and records the results in the top row of Table 2. The same procedure is repeated for columns **c** and **e**. Finally, the total number of times each numeral appears, regardless of the column, is recorded in the bottom row of Table 2. A histogram for each of the 4 rows is constructed that indicates how often each of the numerals (fault assessments) occurred.

Table 2. Frequency of Each Numeral Check Sheet

Digit/Problem	0	1	2	3	4	5	6	7	8	9	Total
Most Significant											
Middle Digit											
Least-Significant											
Entire Group											

As an alternative approach, the student is encouraged to use a spreadsheet to parse the 5-digit numbers into 5 columns and construct a histogram for each of the conditions represented by the 4 rows in Table 2. The histograms of the data in Table 2 are illustrated in Figure 1.

The student is required to make several observations about the information displayed in each histogram. For example, a few of the details the histogram for test procedures conducted at test point **a** indicates are:

1. None of the units tested failed the minimum frequency specification for this test point (there are no numeral **5** responses).
2. The amount of failures associated with odd numerals occurred less frequently that those corresponding to even numerals.
3. The amount of failures associated with even numerals increased as the numeral increased.
4. The greatest number of units (18) indicated that the maximum specification for the AC voltage at this test point was exceeded.

Additional observations are possible for this test point, as well as for the other histograms in Figure 1, but will not be discussed at this time. The objective of the exercise is to encourage the student to make as many observations as possible.

Laboratory Activity

Technicians introduce specific types of faults in the ALFRED units and have documented them for several semesters in order to establish enough data to make this laboratory activity possible. Open or shorted passive components, missing or bent pins on active devices or ICs, bad sockets, cold solder connections, solder bridges between traces or pins of an IC, open jumpers, etc., illustrate the types of faults placed in the units.

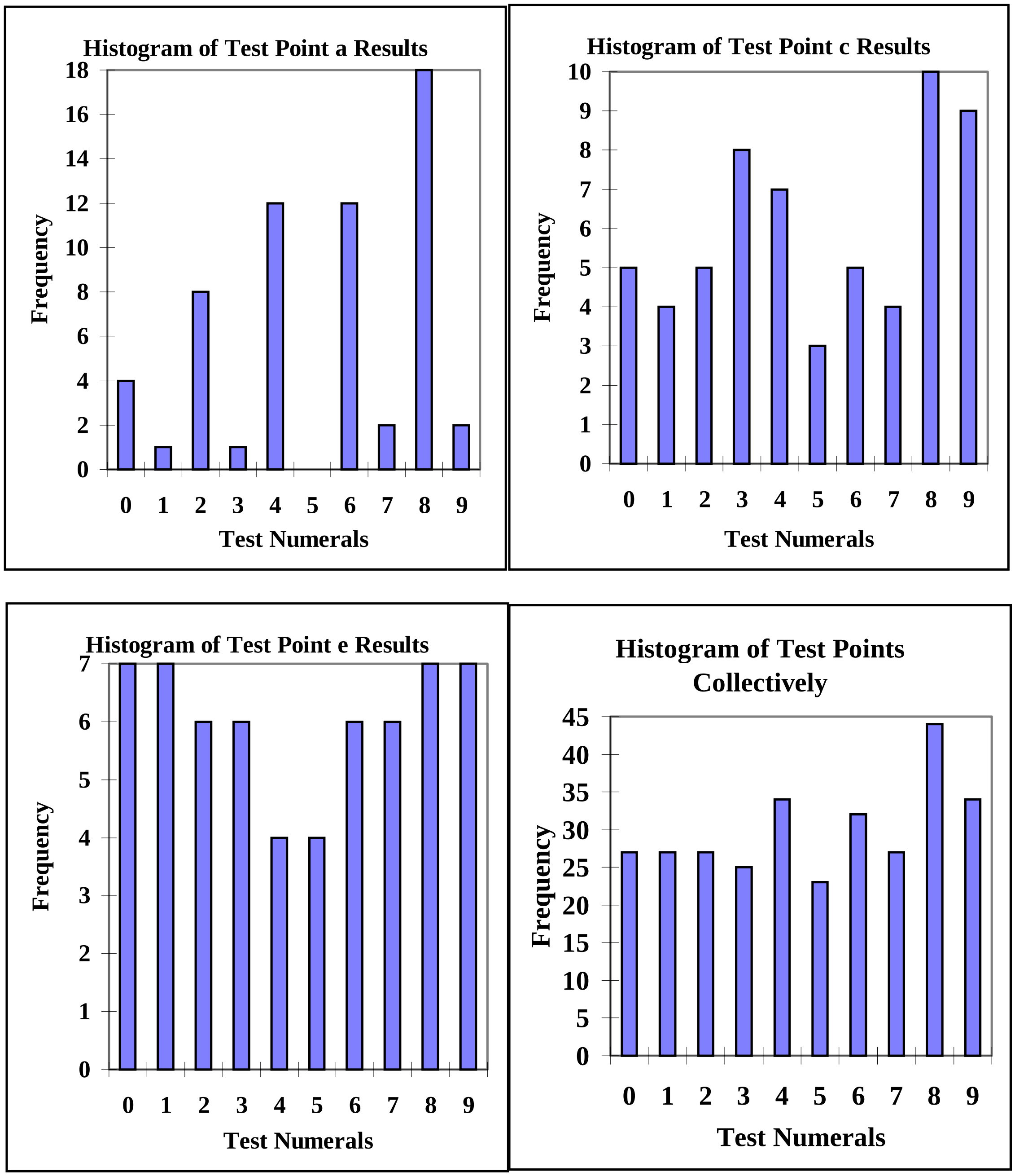

Figure 1. Histograms of Test Measurement Results.

During one laboratory session, each pair of students receives a different assortment of fault forms, previously compiled by technicians, that indicate faulty boards and the component-level faults put in several ALFRED units. The reports are distributed as if they are repair forms from the previous day's production run. The task before students is to identify the major problems and make recommendations that will prevent their recurrence. But, before recommendations can be made several questions must be answered.

Each group generates a fault check sheet that indicates the types of faults reported on their repair forms, how often the faults occurred, and on which board(s) they occurred. The lab instructor polls the groups and tabulates the results from all of the repair forms on an overhead transparency. Table 3 illustrates a typical summary. Are these results typical of a daily run or do they signal that serious problems have arisen?

The most prevalent fault reported in Table 3, is open jumpers or traces. Why are there so many? Are the traces too narrow or too thin? Are there problems with the reliability of the printed circuit boards? Did those printed circuit boards come from the usual source or are they from a different vendor? Is the machine that inserts the jumpers nicking some of them or cutting some of them short?

Resistors rarely ever fail! But, Table 3 shows that an unusually large number of 10-kΩ resistors did fail (only in this course!). A lesser, but significant number of 1-kΩ resistors also failed. They occurred on several different boards in the ALFRED units. However, the 1-kΩ resistor failures seem to be concentrated on Board 2, while the 10-kΩ resistor failures occurred on Boards 3, 4, and 5. Did we get a bad batch of resistors? Are they from our usual sources? Are we using resistors with too low a wattage rating? Is the automatic insertion equipment damaging them?

Boards 2 and 3 are more heavily populated than the other boards in ALFRED. Consequently, their component layouts are more complex and require a greater number of jumpers. One should not be surprised to find that more failures occurred on the more heavily populated and more complicated boards. Should the circuits on those boards be redesigned or some of them moved to a less populated board?

These questions merely illustrate the kind of questions that could be raised. The answers to them will likely raise additional ones, but eventually enough answers will be found that one or more solutions can be implemented and the problems corrected.

During this segment of the lab session, students actively participate in the dialog and demonstrate their brainstorming skills. It is not unusual for those who have had industrial experience to provide anecdotes that enhance the learning activity.

Conclusion

Troubleshooting is a learned skill that is a vitally important tool for any engineering technologist or engineer who is able to *fix* things. Greater success seems likely for those who are able to extend their problem solving skills and discover the reasons for the failures encountered. Comedian Steve Allen, the original host of the *Tonight Show* on NBC, would occasionally report the nightly ball scores, “5 to 2, 3 to 1, 3 to 2, etc.” Obviously, the information was of little value because the teams were not identified. If students learn to reach beyond *fixing* the immediate problem, to ask questions and formulate solutions that will prevent recurrence of those problems, then they will become successful troubleshooters, not merely someone who is *reporting the nightly ball scores*.

Table 3. ALFRED Fault Check Sheet							
Fault	Board 1	Board 2	Board 3	Board 4	Board 5	Board 6	Total
Short, Solder Bridge	0	8	18	12	4	4	46
Open Jumper, Trace	3	16	13	12	17	39	100
Part in Backwards	0	0	3	0	0	0	3
Bent, Missing Pins	0	2	5	0	10	0	17
Wrong Device	2	12	0	0	0	0	14
Defective Switch	0	0	0	0	4	0	4
Defective Socket	2	15	0	0	0	0	17
Bad Device:	0	0	0	0	0	0	0
LM741	2	0	0	0	0	0	2
TIP31	2	0	0	0	0	0	2
7404	0	11	0	0	0	0	11
7408	0	17	0	0	0	0	17
7805	0	0	0	0	0	0	0
7915	1	0	0	0	0	0	1
74154	0	12	0	0	0	0	12
74C922	0	15	0	0	0	0	15
CD4066	0	1	0	0	0	0	1
TL072/82	0	7	0	4	16	10	37
TL084	0	0	18	0	0	0	18
XR2206	0	0	8	0	0	0	8
3915	0	0	0	0	0	9	9
3046	0	0	1	0	0	0	1
2N2222	0	0	2	0	0	0	2
H11F1	0	0	5	0	0	0	5
2044	0	0	0	9	0	0	9
MPF102	0	0	0	0	1	0	1
LM339	0	0	0	0	3	0	3
2N4036	0	0	0	0	0	2	2
2N2102	0	0	0	0	0	1	1
2N3904	5	0	0	0	0	0	5
LED	6	0	0	0	0	1	7
Shorted Capacitor	0	0	2	0	4	3	9
Open Capacitor	3	1	5	8	1	3	21
Bad Resistor:	0	0	0	0	0	0	0
1 or 1.2	7	2	0	0	0	0	9
10	0	1	0	0	2	2	5
620 or 680	0	0	0	0	0	4	4
1k	1	13	3	2	0	0	19
3.3k, 3.6k, or 4.7k	0	0	1	0	2	0	3
10k	0	1	18	17	12	0	48
13k, 15k, or 18k	0	0	0	0	0	1	1
22k, 47k, or 68k	0	0	10	2	0	0	12
100k, 150k, or 680k	0	0	1	2	0	0	3
Totals	34	134	113	68	76	79	504

References

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Biographical Information

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Mr. William Frank Reeve is currently an Associate Professor in the Electrical Engineering Technology Department of Purdue University. He has had a varied career in industry, the military, and in education. He received the Bachelor of Science and Master of Science degrees in physics from the University of Louisville. He has conducted research on ionic vacuum pumps and quadrupole mass spectrometers, investigated physical properties of salt-ice, snow, and single-crystal ice, and taught chemistry and physics in high school for three years prior to joining the faculty of Purdue University. In addition to his duties at Purdue, he has conducted numerous workshops on electrical safety in hospitals, coordinated and taught week-long courses for Landis & Gyr, Inc., and Otis Elevator Company, served as an IEEE evaluator for TAC of ABET, and served on the editorial board of the **Journal of Engineering Technology**.